Department of Defense
Fiscal Year (FY) 2021 Budget Estimates

February 2020

Defense Advanced Research Projects Agency

Defense-Wide Justification Book Volume 1 of 5

Research, Development, Test & Evaluation, Defense-Wide

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Department of Defense
FY 2021President's Budget
Exhibit R-1 FY 2021 President's Budget
Total Obligational Authority
(Dollars in Thousands)

16 Jan 2020

Appropriation	FY 2019 (Base + OCO)	FY 2020 Base Enacted	FY 2020 Emergency (Included in Base Enacted)	FY 2020 OCO Enacted	FY 2020 Total Enacted (Base + OCO)
Research, Development, Test & Eval, DW	3,425,549	3,458,321			3,458,321
Total Research, Development, Test & Evaluation	3,425,549	3,458,321			3,458,321

R-121PB: FY 2021 President's Budget (Published Version), as of January 16, 2020 at 10:52:34

Department of Defense
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(Dollars in Thousands)

16 Jan 2020

Appropriation	FY 2021 Base	FY 2021 OCO for Base Requirements	FY 2021 OCO for Direct War and Enduring Costs	FY 2021 Total OCO	FY 2021 Total (Base + OCO)
Research, Development, Test & Eval, DW	3,566,348				3,566,348
Total Research, Development, Test & Evaluation	3,566,348				3,566,348

Department of Defense
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Summary Recap of Budget Activities	FY 2019 (Base + OCO)	FY 2020 Base Enacted	FY 2020 Emergency (Included in Base Enacted)	FY 2020 OCO Enacted	FY 2020 Total Enacted (Base + OCO)
Basic Research	473,587	486,406			486,406
Applied Research	1,347,624	1,401,085			1,401,085
Advanced Technology Development	1,410,246	1,489,124			1,489,124
Management Support	194,092	81,706			81,706
Total Research, Development, Test & Evaluation	3,425,549	3,458,321			3,458,321
Summary Recap of FYDP Programs					
Research and Development	3,425,549	3,458,321			3,458,321
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Summary Recap of Budget Activities	FY 2021 Base	FY 2021 OCO for Base Requirements	FY 2021 OCO for Direct War and Enduring Costs	FY 2021 Total OCO	FY 2021 Total (Base + OCO)
Basic Research	533,688				533,688
Applied Research	1,376,509				1,376,509
Advanced Technology Development	1,568,383				1,568,383
Management Support	87,768				87,768
Total Research, Development, Test & Evaluation	3,566,348				3,566,348
Summary Recap of FYDP Programs					
Research and Development	3,566,348				3,566,348
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Total Research, Development, Test & Evaluation	3,425,549	3,458,321			3,458,321

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Total Research, Development, Test & Evaluation	3,566,348				3,566,348

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16 Jan 2020

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

Line No	Program Element Number	Item	Act	FY 2019 (Base + OCO)	FY 2020 Base Enacted	FY 2020 Emergency (Included in Base Enacted)	FY 2020 OCO Enacted	FY 2020 Total Enacted (Base + OCO)	Sec
2	0601101E	Defense Research Sciences	01	423,895	432,284			432,284	U
4	0601117E	Basic Operational Medical Research Science	01	49,692	54,122			54,122	U
	Basic Research			473,587	486,406			486,406	
9	0602115E	Biomedical Technology	02	94,423	92,771			92,771	U
14	0602303E	Information & Communications Technology	02	401,453	428,556			428,556	U
15	0602383E	Biological Warfare Defense	02	31,951	34,588			34,588	U
18	0602702E	Tactical Technology	02	295,118	313,002			313,002	U
19	0602715E	Materials and Biological Technology	02	192,774	214,976			214,976	U
20	0602716E	Electronics Technology	02	331,905	317,192			317,192	U
	Applied Research			1,347,624	1,401,085			1,401,085	
34	0603286E	Advanced Aerospace Systems	03	287,907	279,741			279,741	U
35	0603287E	Space Programs and Technology	03	256,181	190,306			190,306	U
56	0603739E	Advanced Electronics Technologies	03	100,042	123,616			123,616	U
57	0603760E	Command, Control and Communications Systems	03	178,074	229,134			229,134	U
58	0603766E	Network-Centric Warfare Technology	03	413,948	507,424			507,424	U
59	0603767E	Sensor Technology	03	174,094	158,903			158,903	U
	Advanced Technology Development			1,410,246	1,489,124			1,489,124	
150	0605001E	Mission Support	06	67,850	68,498			68,498	U
165	0605502E	Small Business Innovative Research	06	112,579					U

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2	0601101E	Defense Research Sciences	01	479,958				479,958	U
4	0601117E	Basic Operational Medical Research Science	01	53,730				53,730	U
	Basic Research			533,688				533,688	
9	0602115E	Biomedical Technology	02	107,568				107,568	U
14	0602303E	Information & Communications Technology	02	435,920				435,920	U
15	0602383E	Biological Warfare Defense	02	26,950				26,950	U
18	0602702E	Tactical Technology	02	233,271				233,271	U
19	0602715E	Materials and Biological Technology	02	250,107				250,107	U
20	0602716E	Electronics Technology	02	322,693				322,693	U
	Applied Research			1,376,509				1,376,509	
34	0603286E	Advanced Aerospace Systems	03	230,978				230,978	U
35	0603287E	Space Programs and Technology	03	158,439				158,439	U
56	0603739E	Advanced Electronics Technologies	03	95,864				95,864	U
57	0603760E	Command, Control and Communications Systems	03	221,724				221,724	U
58	0603766E	Network-Centric Warfare Technology	03	661,158				661,158	U
59	0603767E	Sensor Technology	03	200,220				200,220	U
	Advanced Technology Development			1,568,383				1,568,383	
150	0605001E	Mission Support	06	74,334				74,334	U
165	0605502E	Small Business Innovative Research	06						U

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173	0605898E	Management HQ - R&D	06	13,663	13,208			13,208	U
		Management Support		194,092	81,706			81,706	
Total Research, Development, Test & Eval, DW				3,425,549	3,458,321			3,458,321	

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173	0605898E	Management HQ - R&D	06	13,434				13,434	U
		Management Support		87,768				87,768	
Total Research, Development, Test & Eval, DW				3,566,348				3,566,348	

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Advanced Technology Development				1,410,246	1,489,124			1,489,124	
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57	0603760E	Command, Control and Communications Systems	03	221,724				221,724	U
58	0603766E	Network-Centric Warfare Technology	03	661,158				661,158	U
59	0603767E	Sensor Technology	03	200,220				200,220	U
Advanced Technology Development				1,568,383				1,568,383	
150	0605001E	Mission Support	06	74,334				74,334	U
165	0605502E	Small Business Innovative Research	06						U

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4	01	0601117E	BASIC OPERATIONAL MEDICAL SCIENCE	Volume 1 - 43

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Line #	Budget Activity	Program Element Number	Program Element Title	Page
9	02	0602115E	BIOMEDICAL TECHNOLOGY	Volume 1 - 49
14	02	0602303E	INFORMATION & COMMUNICATIONS TECHNOLOGY	Volume 1 - 57
15	02	0602383E	BIOLOGICAL WARFARE DEFENSE	Volume 1 - 91
18	02	0602702E	TACTICAL TECHNOLOGY	Volume 1 - 95
19	02	0602715E	MATERIALS AND BIOLOGICAL TECHNOLOGY	Volume 1 - 119
20	02	0602716E	ELECTRONICS TECHNOLOGY	Volume 1 - 137

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

Line #	Budget Activity	Program Element Number	Program Element Title	Page
34	03	0603286E	ADVANCED AEROSPACE SYSTEMS	Volume 1 - 161
35	03	0603287E	SPACE PROGRAMS AND TECHNOLOGY	Volume 1 - 171
56	03	0603739E	ADVANCED ELECTRONICS TECHNOLOGIES	Volume 1 - 179
57	03	0603760E	COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS	Volume 1 - 191
58	03	0603766E	NETWORK-CENTRIC WARFARE TECHNOLOGY	Volume 1 - 205
59	03	0603767E	SENSOR TECHNOLOGY	Volume 1 - 223

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

Line #	Budget Activity	Program Element Number	Program Element Title	Page
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165	06	0605502E	SMALL BUSINESS INNOVATION RESEARCH	Volume 1 - 239
173	06	0605898E	MANAGEMENT HQ - R&D	Volume 1 - 241

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Program Element Title	Program Element Number	Line #	BA	Page
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ADVANCED ELECTRONICS TECHNOLOGIES	0603739E	56	03	Volume 1 - 179
BASIC OPERATIONAL MEDICAL SCIENCE	0601117E	4	01	Volume 1 - 43
BIOLOGICAL WARFARE DEFENSE	0602383E	15	02	Volume 1 - 91
BIOMEDICAL TECHNOLOGY	0602115E	9	02	Volume 1 - 49
COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS	0603760E	57	03	Volume 1 - 191
DEFENSE RESEARCH SCIENCES	0601101E	2	01	Volume 1 - 1
ELECTRONICS TECHNOLOGY	0602716E	20	02	Volume 1 - 137
INFORMATION & COMMUNICATIONS TECHNOLOGY	0602303E	14	02	Volume 1 - 57
MANAGEMENT HQ - R&D	0605898E	173	06	Volume 1 - 241
MATERIALS AND BIOLOGICAL TECHNOLOGY	0602715E	19	02	Volume 1 - 119
MISSION SUPPORT	0605001E	150	06	Volume 1 - 237
NETWORK-CENTRIC WARFARE TECHNOLOGY	0603766E	58	03	Volume 1 - 205
SENSOR TECHNOLOGY	0603767E	59	03	Volume 1 - 223
SMALL BUSINESS INNOVATION RESEARCH	0605502E	165	06	Volume 1 - 239
SPACE PROGRAMS AND TECHNOLOGY	0603287E	35	03	Volume 1 - 171
TACTICAL TECHNOLOGY	0602702E	18	02	Volume 1 - 95

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Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	423.895	432.284	479.958	-	479.958	415.112	394.290	383.616	400.581	-	-
CCS-02: *MATH AND COMPUTER SCIENCES*	-	202.334	220.824	289.803	-	289.803	234.234	220.423	217.700	253.493	-	-
CYS-01: *CYBER SCIENCES*	-	12.946	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
ES-01: *ELECTRONIC SCIENCES*	-	38.156	43.333	35.801	-	35.801	42.583	43.204	47.383	35.858	-	-
ES-02: *BEYOND SCALING SCIENCES*	-	51.283	47.000	59.025	-	59.025	38.700	53.290	53.290	53.290	-	-
MS-01: *MATERIALS SCIENCES*	-	72.181	63.412	52.560	-	52.560	66.647	48.638	41.138	37.138	-	-
TRS-01: *TRANSFORMATIVE SCIENCES*	-	46.995	57.715	42.769	-	42.769	32.948	28.735	24.105	20.802	-	-

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.

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 Cyber Sciences project supported long-term national security requirements through scientific research and experimentation in cyber security. Information technologies enabled important new military capabilities and drove the productivity gains essential to U.S. economic competitiveness. Meanwhile, cyber threats grew in sophistication and number, and put sensitive data, classified computer programs, mission-critical information systems, and future economic gains at risk. The basic research conducted under the Cyber Sciences project produced breakthroughs necessary to enhance the resilience of DoD information systems to current and emerging cyber threats.

Exhibit R-2, **RDT&E Budget Item Justification:** PB 2021 Defense Advanced Research Projects Agency	**Date:** February 2020
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*

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, 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 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).

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	**Date:** February 2020
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*

B. Program Change Summary ($ in Millions)	**FY 2019**	**FY 2020**	**FY 2021 Base**	**FY 2021 OCO**	**FY 2021 Total**
Previous President's Budget	422.680	432.284	431.356	-	431.356
Current President's Budget	423.895	432.284	479.958	-	479.958
Total Adjustments	1.215	0.000	48.602	-	48.602
• 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	9.666	0.000			
• SBIR/STTR Transfer	-8.451	0.000			
• TotalOtherAdjustments	-	-	48.602	-	48.602

Congressional Add Details ($ in Millions, and Includes General Reductions)	**FY 2019**	**FY 2020**
Project: CCS-02: *MATH AND COMPUTER SCIENCES*		
Congressional Add: *DARPA Foundational and Applied Artificial Intelligence*	15.000	-
Congressional Add Subtotals for Project: CCS-02	15.000	-
Congressional Add Totals for all Projects	15.000	-

Change Summary Explanation

FY 2019: Increase reflects reprogrammings offset by the SBIR/STTR transfer.
FY 2020: N/A
FY 2021: Increase reflects expansion of Artificial Intelligence and Electronics Resurgence Initiative programs, offset by smaller program decreases.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
CCS-02: *MATH AND COMPUTER SCIENCES*	-	202.334	220.824	289.803	-	289.803	234.234	220.423	217.700	253.493	-	-

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 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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Human Social Systems	29.100	27.000	26.000

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, 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 2020 Plans:

- Develop and deploy highly complex social simulations with known causal ground truth as test bed challenges for social science research communities.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Quantify the diagnostic and predictive accuracy, robustness, and efficiency of social science representation and modeling tools by testing them against simulations. - Determine the capabilities and limitations of representation and modeling tools for understanding and predicting cause and effect in highly complex social systems. - Demonstrate efficiency and value of rapid, scalable replication capabilities for accelerating rigorous understanding of human social systems and behaviors. - Implement and test algorithms for automatically assigning quantitative confidence scores to social and behavioral science research. - Develop capabilities for adjusting algorithms based on user-specific needs and interests. - Develop framework for training and testing agents to represent community-level collective intelligence. - Design methodology for tracking and assessing aggregate indicators of socio-political behavior. - Explore novel artificial intelligence (AI) tools with potential to effectively elicit and impart acquired knowledge precisely when useful and applicable via user friendly interfaces. ***FY 2021 Plans:*** - Refine, implement, and test algorithms for automatically assigning quantitative confidence scores to social and behavioral science research. - Demonstrate expert and non-expert usability of algorithms for automatically assigning quantitative confidence scores. - Increase return rate efficiency of algorithms for automatically assigning quantitative confidence scores to social and behavioral science research. - Evaluate the efficacy of agents for representing community-level collective intelligence. - Begin testing methodology for tracking and assessing aggregate indicators of socio-political behavior for generalizability. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from design and development to testing and evaluation.			
Title: Machine Common Sense (MCS) ***Description:*** The Machine Common Sense (MCS) program is exploring approaches to enable commonsense reasoning by machines. Recent advances in machine learning have resulted in new artificial intelligence (AI) capabilities in areas such as image recognition, 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 commonsense 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	15.500	16.815	21.810

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
of grounded concept models; and commonsense knowledge repositories to support AI system development. AI systems that are capable of more human-like reasoning will be able to behave more appropriately in unforeseen situations. ***FY 2020 Plans:*** - Develop a suite of core cognitive models using a variety of AI approaches, to include deep learning, probabilistic simulation, and symbolic reasoning. - Devise techniques for evaluating core cognitive models against human cognitive development capabilities within a simulation environment. - Construct a baseline simulation environment to evaluate models and machine learning methods against human cognitive performance for prediction tasks. - Assess performance of developed common knowledge services against a benchmark commonsense challenge problem suite. ***FY 2021 Plans:*** - Enhance core cognitive models with additional capabilities and evaluate model performance against increased levels of human cognitive performance for prediction tasks. - Develop core cognitive models with initial experience learning capabilities, and evaluate model performance against experience learning tasks. - Modify simulation environment for evaluation of additional machine learning methods, cognitive capabilities, prediction tasks, and experience learning tasks. - Enhance common knowledge services to handle commonsense phenomena of increased complexity, and assess performance of services against a benchmark commonsense challenge problem suite. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects continued development of machine common sense technologies and simulation environment, and expanded efforts to assess performance against a benchmark commonsense challenge problem suite.			
Title: Guaranteeing AI Robustness against Deception (GARD) ***Description:*** The Guaranteeing AI Robustness against Deception (GARD) program is developing techniques to defend against deception 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	7.600	17.244	19.100

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
AI systems suitable for use in adversarial environments. GARD aims to develop new algorithms and theory for ML and AI that are robust to deception attacks. ***FY 2020 Plans:*** - Identify sources of vulnerability and develop robustness metrics for ML algorithms in adversarial environments. - Characterize the defensibility of ML under various sensor modalities, and design ML defense algorithms for single sensor modalities. - Establish an evaluation framework to quantify the performance and robustness of new ML techniques. - Develop ensembles of highly-diverse models having orthogonal features, and evaluate the robustness of the ensembles to black-box adversarial attacks. ***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 multi-sensor data sources to reduce vulnerability to adversarial inputs. - Extend evaluation framework for testing ML defenses for multi-sensor scenarios, and implement and test ML defenses for use against an AI-enabled adversary. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects continued development of robust ML techniques and an ML risk evaluation testbed, and expanded efforts to evaluate techniques for use against an AI-enabled adversary.			
Title: World Modelers ***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, disruption of natural resources, supply chains, and production systems can have widespread consequences. 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 2020 Plans:*** - Develop models for acute, high-impact phenomena such as natural disasters that disrupt civilian infrastructure. - Extend the integrated workflow to operate on compressed temporal scales, and optimize the extended workflow on food security, migration, and acute, high-impact use cases.	16.800	17.500	19.050

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Perform evaluations on realistic scenarios in collaboration with DoD, Intelligence Community (IC), Department of Homeland Security (DHS), and other potential transition partners. ***FY 2021 Plans:*** - Refine models of acute, high-impact phenomena such as natural disasters that disrupt civilian infrastructure to enable ensemble forecasting and estimation of uncertainty. - Introduce more complex perturbations, and apply technology to additional use cases such as disease outbreak. - Perform additional evaluations incorporating new data sources, models, and factors for a diverse set of transition partners. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects continued efforts to develop models for acute high-impact phenomena, and expanded efforts to evaluate techniques in collaboration with transition partners.			
Title: Synergistic Discovery and Design (SD2) ***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 2020 Plans:*** - Apply discovery algorithms to novel systems that have not been characterized by human experts, and extend algorithms that foster scientific understanding to accelerate novel design. - Integrate discovery algorithms with design protocols to automate the experimental process. - Improve experimental planning tools to reduce the experimental costs required to obtain a functional design. - Scale software and infrastructure to process experimental data, and evaluate tools by testing their ability to adapt protein and cellular circuit designs for use in biosensors. ***FY 2021 Plans:*** - Test design and discovery tools in supporting a design-test-build cycle to rapidly produce biosensors and stable solar materials. - 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.	20.500	21.000	19.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Develop methods for extracting generalized and compressed knowledge representations for more adaptable and model based artificial intelligence (AI). - 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects ramping down of development of computational techniques that extract scientific knowledge from data, and expanded efforts to demonstrate and test techniques on biosensor and protein design and solar material synthesis.			
Title: Learning with Less Labeling (LwLL)	7.750	14.500	17.650
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 can be costly. 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 and use in variable, unpredictable, real-world environments, especially where training data is costly or sparse. ***FY 2020 Plans:*** - Develop ML algorithms that are robust to distributional mismatch between the data on which the system is trained and the data on which the system operates post training. - Develop estimates for the rate at which an ML system will converge with increased training in terms of the hyperparameters of the system. - Construct challenge problems and associated labeled and unlabeled data sets, and demonstrate increased learning rates and distributional robustness of the new ML algorithms. ***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 far fewer labels, and to generalize to multiple tasks and domains on datasets relevant to DoD. ***FY 2020 to FY 2021 Increase/Decrease Statement:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The FY 2021 increase reflects continued development of ML techniques that require less labeled data for effective training, and increased efforts to demonstrate techniques on datasets relevant to DoD.			
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 2020 Plans:*** - Award new FY 2020 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 2019 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 2018 participants to refine technology further and align to 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.	17.000	17.000	17.000
Title: Safe Documents (SafeDocs) ***Description:*** The Safe Documents (SafeDocs) program is developing software technologies that reduce syntactic complexity of data formats, and improve the capability to reject invalid and maliciously crafted data in electronic documents and streaming data. The high complexity of electronic documents and streaming data greatly increases the computational attack surface. The	12.300	14.000	15.450

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
SafeDocs program is focused on simplifying existing data formats, with attention to compatibility, and advancing the state of the art in the security of document and data format parsers. Simplification is essential to enabling automated code verification and assuring that the conditions of data validity are enforced. SafeDocs technology aims to enable secure documents and streaming data. ***FY 2020 Plans:*** - Explore formal development approaches for reduced-complexity format variants for electronic documents and streaming data, and the associated processing software. - Design reduced-complexity format variants and parsers for electronic documents and streaming data, with attention to compatibility. - Initiate construction of verified functionally correct, efficient parsers for syntactically complex formats currently in use. ***FY 2021 Plans:*** - Create a safe subset for a widely used electronic data document format, and show that it supports the same 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects continued efforts to develop reduced-complexity formats for electronic documents and streaming data and verified functionally correct, efficient parsers, and increased efforts to demonstrate techniques in representative systems.			
Title: Advanced Tools for Modeling and Simulation ***Description:*** The Advanced Tools for Modeling and Simulation thrust will develop 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	14.900	15.400	8.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
systems. Another focus area of this thrust is multi-physics models for predicting behavior and non-intuitive failure pathways for complex, dynamic physical systems. ***FY 2020 Plans:*** - Incorporate uncertainty into multi-physics analysis and synthesis capabilities. - Develop techniques based on data analysis and machine learning tools to guide design exploration and find promising designs. - Identify mathematics and algorithms that allow for direct generation of multi-physics/multi-scale simulation codes. - Identify and select DoD relevant challenge problems on which to evaluate the performance and accuracy of a novel computable model enabled simulator. ***FY 2021 Plans:*** - Initiate development of a computable model framework to generate multi-physics simulators with improved accuracy and reduced level of effort over current approaches. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift in focus from testing and demonstration to development of new modeling.			
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 2020 Plans:*** - Demonstrate a collaborative agent for human-machine communication, extending and leveraging the human capacity to plan and execute diverse tasks across multiple domains. - Evaluate and optimize human-computer interaction technologies across multiple task domains and use cases. ***FY 2021 Plans:*** - Perform final human-computer interaction technology evaluations on multiple program use cases. ***FY 2020 to FY 2021 Increase/Decrease Statement:***	16.700	10.565	6.750

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The FY 2021 decrease reflects ramping down of development of human-computer interaction technologies, and final demonstrations and evaluation of developed capabilities.			
Title: Complex Hybrid Systems ***Description:*** The Complex Hybrid Systems program thrust 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 2020 Plans:*** - Demonstrate simultaneous design and integrated exploration of team structure, capabilities, and problem solving strategies in a dynamic experimental environment. - Conduct multiple demonstrations of the use of knowledge representation and design tools to predict team structure and problem solving strategy of high performing teams with machine elements. - Demonstrate the capability to build, maintain, and reason over rich models of complex systems in diverse application domains to include hypersonics, epidemiology, and synthetic biology. ***FY 2021 Plans:*** - Demonstrate predictive power and generalizability of approaches for designing team structure and problem solving strategies against a scenario not utilized in the development of the approach. - Predict and explain team structure and problem solving strategy of high performing teams with machine elements in an additional experimental environment. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects minor program repricing.	9.000	6.500	6.250
Title: Foundational Artificial Intelligence (AI) Science ***Description:*** The Foundational Artificial Intelligence (AI) Science thrust will develop 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,	-	16.500	35.900

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Design, test and evaluate physics-based machine learning systems to achieve increased prediction accuracy and control of complex dynamical systems by incorporating physical symmetries, conservation laws, and generated data for training into AI architectures. - Begin development of hardware and control software for autonomous experimental chemistry systems. - Develop automated approaches for extracting data from chemistry text and diagrams, and demonstrate semi-autonomous experimentation informed by models. - Demonstrate the discovery of scientific laws governing equations on real-world problems in one or more relevant DoD domains where the behaviors are not known in advance. - Leverage advancement in machine learning techniques to initiate the development of introspective AI systems that are capable of generating compact representations of experiences from learning data. - Initiate the development of AI tools capable of abstracting task behaviors into generalized rules and rule dependencies. - Initiate efforts to develop generators and novelty-robust AI techniques to rapidly identify and respond appropriately to new classes of entities and attributes. - Identify novel, non-Von Neumann computer architectures based on new and unexplored mathematical paradigms exploring the actual boundary between classical and quantum computing. - Initiate efforts to explore frontiers in Artificial Intelligence with a focus on third wave AI. - Formulate AI-based approaches such as autoencoders, evolutionary programming, and neural sketch learning for analysis of computing systems at design stage, to prevent cyber attackers from executing unintended, emergent computations on critical infrastructure and DoD systems. - Formulate practical approaches to enable multiple parties to cooperate in improving each other's machine learning (ML) models while providing guarantees that each party's datasets and models remain private. - Formulate approaches for identifying attack methods from the signals and information in the images, video, text, and other communication modalities transmitted to ML systems or humans. ***FY 2021 Plans:*** - Develop automated approaches to extract data from electronic lab notebooks, tables, and figures.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- 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. - 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. - Initiate development of capabilities for AI systems with competency-awareness to understand, support, and exploit the interdependence between teammates - Initiate development of capabilities for AI systems to collaborate autonomously in novel tasks. - Demonstrate, in modeling and simulation, non-Von Neumann devices and circuits that have significant benefits over classical computers. - Continue efforts to explore frontiers in Artificial Intelligence with a focus on third wave AI. - Develop representations of computing designs such as layered application programming interfaces and processor microarchitectures, and demonstrate effective anticipation of emergent execution. - Develop and implement computationally feasible cryptographic techniques for securing the information exchange transactions implicit to cooperative training of ML models, and demonstrate their ability to preserve privacy when attacked by a sophisticated adversary. - Develop and implement algorithms for fingerprinting deception attacks, and demonstrate advanced capabilities such as online detection of attacks and attribution of the attacker. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase is due to program expansion into additional technology solution spaces.			
Title: Alternative Computing ***Description:*** The Alternative Computing thrust will explore and develop 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	-	9.800	20.913

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Initiate efforts to determine instances where near term quantum processors can outperform classical computing in the optimization of complex systems. - Design and initiate development of a preliminary near term achievable quantum computer for the optimization of complex systems. ***FY 2021 Plans:*** - 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. - Demonstrate the use of a near term quantum computer for the optimization of complex systems. - Initiate proof-of-concept development for non-Von Neumann architectures that can scale to very large numbers of devices, be manufactured reliably and have significant projected performance over conventional computing methods. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects a shift from system design to development and demonstration.			
Title: Artificial Social Intelligence for Successful Teams (ASIST)* ***Description:*** *Formerly Human-Machine Symbiosis 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 would 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 models. ASIST aims to provide the basis for machines that can participate effectively with humans on tasks where teamwork is required.	-	13.000	18.330

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
FY 2020 Plans: - Implement software agents that exhibit machine theory of mind in interactions with a single human partner. - Collect and register hypotheses and design experiments to identify factors that influence the performance of human-machine teams. - Initiate development of a scalable virtual testbed for evaluating the software agents in environments with one human partner. - Investigate and derive performance predictions for computational agents capable of advising and guiding humans in the performance of complex tasks. ***FY 2021 Plans:*** - Develop software agents that exhibit machine theory of mind in interactions with multiple human partners. - Conduct experiments to test hypotheses and quantify the importance of factors such as trust, communication, social cognition, and collective intelligence that influence the performance of human-machine teams. - Extend the virtual testbed to model environments where there are more humans and teams, and to situations where greater robustness and adaptability are required. - Develop computational simulations of knowledge-seeking behavior, and combine these with human-machine dialog techniques that can automatically generate efficacious questions for human experts. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects ramping up of efforts to develop software agents that exhibit machine theory of mind and initial experiments to quantify factors that influence the performance of human-machine teams.			
Title: Application-Tailored Artificial Intelligence (APTAI) ***Description:*** The Application-Tailored Artificial Intelligence (APTAI) program will develop concepts for AI capabilities whose designs and learning processes are influenced both by training data and by key concepts and features proposed by experts in the intended application domains. In this third wave approach, learning processes will incorporate both human experience and patterns extracted from data to converge on informative features, representations, abstractions, and inductive strategies. One expected benefit of this approach is the emphasis on features that humans find salient, thus reducing the number of counterintuitive mistakes made by AI methods and minimizing the vulnerability to adversarial attacks, both in training data and in operations. Another expected benefit relates to human interaction, because the use of domain concepts provides a built-in framing for explanations to human partners. An additional expected benefit is the facilitation of more rapid learning processes including potentially transfer learning and one-shot learning. The APTAI program will make use of specific national security domains to drive assessment and transition of these initial concepts. Candidate domains include undersea autonomous navigation, imagery analysis, multi-modal reasoning, and games in support of strategy and planning. ***FY 2021 Plans:***	-	-	20.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Formulate third wave learning processes that incorporate both human experience and patterns extracted from data to converge on informative features, representations, abstractions, and inductive strategies. - Propose multiple algorithms for advanced machine learning techniques such as transfer learning and one-shot learning, and develop complexity estimates to support feasibility assessments of competing approaches. - Develop concepts for national security domains potentially including undersea autonomous navigation, imagery analysis, multi-modal reasoning, and games in support of strategy and planning. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Formal Methods at Scale (FMaS) ***Description:*** The Formal Methods at Scale (FMaS) program will create new mathematical methodologies, techniques, and tools for proving and providing evidence of correctness for software systems whose size and complexity renders their modeling and analysis infeasible with current techniques. Formal methods are techniques for reasoning about and proving various properties for software code or design models, generally focusing on logical relationships that connect specifications and models with executable code. A key to scalability is to focus more narrowly on particular quality or functional attributes, such as security and safety, rather than address all features and functions of the components of a software system. A second key to scalability is to provide for composability, which enables trustworthy components to be efficiently assembled into trustworthy systems. The FMaS program will accelerate this new scalable formal methods paradigm by extending formal methods techniques, tools, and practices along several dimensions, including (1) the range of properties and qualities that are modeled and reasoned about, such as relating to security, safety, performance, fault tolerance, and real-time, (2) the complexity and the size of systems and their supply chains, including issues related to composability, (3) efficiency of formal methods-related modeling, tooling, and engineering practices, including more natural integration into mainstream tooling and practices, (4) ability to rapidly co-evolve systems and associated evidence, for example to respond to rapid evolution of threats and associated mission concepts, and (5) ease of use for non-expert developers and evaluators. FMaS aims to create formal methods applicable to software systems of the size and complexity commonly encountered in military and civilian mission-critical systems, and to speed the adoption of these methods into practice and tooling. ***FY 2021 Plans:*** - Formulate approaches for extending formal methods with respect to the range of properties and qualities that are modeled and reasoned about, such as relating to security, safety, performance, fault tolerance, real-time. - Address issues related to composability in order to increase the size and complexity of systems and their supply chains amenable to formal methods, including both custom mission-specific components, commodity components, and open source components.	-	-	10.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Develop approaches for increasing the efficiency of formal methods-related modeling, analysis, tooling, and engineering practices. - Initiate the implementation of scalable formal methods into tools for use by non-expert developers and evaluators. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Knowledge Management at Scale ***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 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:*** - Develop automated methods to identify and capture, fuse, and apply tacit organizational knowledge implicit in processes and actions of people acting on data. - 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. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.	-	-	8.600
Title: Building Resource Adaptive Software from Specifications (BRASS) ***Description:*** The Building Resource Adaptive Software from Specifications (BRASS) program is developing an automated framework that permits software systems to seamlessly adapt to changing resource conditions in an evolving operational environment. The current manual adaptation paradigm is based on corrective patching, which is time-consuming, error-prone, and expensive. Predicting the myriad of possible environment changes that an application may encounter in its lifetime is problematic, and existing reactive approaches are brittle and often incorrect. Effective adaptation is realized through rigorously defined specifications that capture application resource assumptions and resource guarantees made by the environment.	13.770	4.000	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The use of specification-based adaptation will allow BRASS applications to be correctly restructured in real time whenever stated assumptions or guarantees are broken. This restructuring is optimized to trade off execution fidelity and functionality for continuance of operation. BRASS creates tools to automatically discover and monitor resource changes, build new analyses to infer deep resource-based specifications, and implement compiler and runtime transformations that can efficiently adapt to resource changes. ***FY 2020 Plans:*** - Perform final improvements to adaptation modules and systems and transition technologies to open source repositories, industry, and DoD. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: Applied Mathematics ***Description:*** The Applied Mathematics thrust created the basic mathematics needed to support complex, multi-physics analysis ranging from uncertainty quantification to integrated, multi-system design. Focus areas of this thrust included application of geometry to challenge problems in optimization science and frameworks and advanced tools for propagating and managing uncertainty in the modeling and design of complex physical and engineering systems.	6.414	-	-
Accomplishments/Planned Programs Subtotals	187.334	220.824	289.803

	FY 2019	FY 2020
Congressional Add: DARPA Foundational and Applied Artificial Intelligence	15.000	-
FY 2019 Accomplishments: - Developed approaches to build, maintain, and reason over rich models of complex systems by interpreting and exposing scientific knowledge and assumptions in existing code and documentation. - Devised hybrid supervised-unsupervised machine learning (ML) approaches that can be trained using both labeled and unlabeled data. - Created preliminary systems to extract scientific laws and governing equations from data and assess the adequacy of the supplied data, identifying regions where additional data would be most beneficial. - Initiated research into the computational principles and architecture of reduced-scale, low energy systems in miniaturized insect species that could identify new computing paradigms for improved AI with considerably reduced training times and power consumption.		

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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	FY 2019	FY 2020
- Identified role of sensor control and signaling mechanisms in reduced-scale insect species and postulated underlying computational model.		
Congressional Adds Subtotals	15.000	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency			Date: February 2020
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CYS-01 / *CYBER SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
CYS-01: *CYBER SCIENCES*	-	12.946	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

The Cyber Sciences project supported long-term national security requirements through scientific research and experimentation in cyber security. Information technologies enabled important new military capabilities and drove the productivity gains essential to U.S. economic competitiveness. Meanwhile, cyber threats grew in sophistication and number, and put sensitive data, classified computer programs, mission-critical information systems, and future economic gains at risk. The basic research conducted under the Cyber Sciences project produced breakthroughs necessary to enhance the resilience of DoD information systems to current and emerging cyber threats.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Transparent Computing ***Description:*** The Transparent Computing program developed technologies that enabled the implementation of more effective security policies across distributed systems. The scale and complexity of modern information systems obscured the linkages between security-related events, making it hard to discover attacks such as advanced persistent threats (APTs). Transparent Computing technologies are particularly important for large integrated systems with diverse components such as distributed surveillance systems, autonomous systems, and enterprise information systems. The Transparent Computing program created the capability to propagate security-relevant information, track complete knowledge of event provenance, and ensured component interactions were consistent with established behavior profiles and policies.	9.346	-	-
Title: Space/Time Analysis for Cybersecurity (STAC) ***Description:*** The Space/Time Analysis for Cybersecurity (STAC) program developed techniques to detect algorithmic complexity vulnerabilities and side channel attacks in software. Historically, adversaries have exploited software implementation flaws through buffer and heap overflow attacks. Advances in operating systems have largely mitigated such attacks in modern systems, so cyber adversaries are now finding new ways of compromising software. Algorithmic complexity and side channel attacks are emerging as a new generation of attacks since they depend on intrinsic properties of software algorithms rather than implementation flaws. The STAC program developed analysis tools and techniques to detect vulnerabilities to these new attacks in the software on which the U.S. government, military, and economy depend.	3.600	-	-
Accomplishments/Planned Programs Subtotals	12.946	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

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C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

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Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
ES-01: *ELECTRONIC SCIENCES*	-	38.156	43.333	35.801	-	35.801	42.583	43.204	47.383	35.858	-	-

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 2019	FY 2020	FY 2021
Title: Magnetic Miniaturized and Monolithically Integrated Components (M3IC)	8.800	8.083	4.000

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 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 2020 Plans:
- Optimize micro-magnetic simulation codes and implement and insert models in industry-standard radio frequency (RF) circuit design tools.
- Explore and demonstrate integrated or miniaturized components and new functionalities, such as circulators and frequency selective limiters, by incorporating new materials or integration methods.

FY 2021 Plans:

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Implement and optimize micro-magnetic codes and validate circuit models in industry-standard radio frequency (RF) circuit design tools. - Demonstrate improved performance of integrated miniature components by utilizing design tools developed in the M3IC program. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects conclusion of the development effort and a shift in focus to final demonstrations.			
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 are up to a mile wide. 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 greater than 1,000x 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 2020 Plans:*** - Demonstrate and deliver scaled VLF and ULF transmitters capable of transmitting signals that meet the program specifications for magnetic field, power consumption, and maximum linear dimension. - Further improve the efficiency of mechanical modulation techniques. ***FY 2021 Plans:*** - Combine material and modulation technique advances at the element level to demonstrate high-efficiency mechanical modulation in optimized transmitter elements. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects transition from development to final demonstration of high-efficiency mechanical modulation in optimized transmitter elements.	6.824	7.900	2.000
Title: SHort Range Independent Microrobotics Program (SHRIMP)	4.132	13.350	11.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: The SHort Range Independent Microrobotics Program (SHRIMP) is developing microrobots with the ability to enter constrained disaster areas, such as collapsed buildings, for search and rescue operations. These sugar cube-sized microrobots will have integrated thermal, light, or audio sensors to assist with location of injured persons or critical infrastructure failures. The capabilities of the developed microrobots will be tested through a series of specific tests at the end of the program. The primary technical improvements needed for untethered mobility of centimeter-sized robotic platforms are in the efficiency, robustness, and force output of millimeter-scale actuators and in the power and energy capacity of batteries and chip-level power converters. Successful execution of the SHRIMP program will advance the micro-robotics field, allowing for practical robots to assist in disaster relief efforts in environments for which traditional robotics cannot efficiently operate due to their larger size. A companion applied research effort is funded in PE 0602716E, Project ELT-01. ***FY 2020 Plans:*** - Demonstrate actuator materials meeting program-defined metrics for volume, weight, and actuation force-displacement. - Demonstrate integrated power systems and batteries meeting program-defined metrics for volume, weight, length, and power performance. - Initiate development of high work density actuator mechanisms for microrobotic platforms. - Initiate development of improved integrated multi-mode power solutions with emphasis on smaller size, and performance across varied temperatures. ***FY 2021 Plans:*** - Demonstrate actuator materials and mechanisms meeting program-defined metrics for volume, weight, and actuation work density. - Demonstrate integrated power systems and batteries meeting program-defined metrics for length, weight, volume, and power performance. - Initiate development of actuator mechanisms for end-of-program tests. - Finalize power system and battery designs, including interfaces for pairing with actuator technologies for competition end-of-program tests. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the program shifting from development to demonstration of actuator materials, integrated power systems, and batteries.			
Title: Atomic-Photonic Integration (A-PhI)	5.000	14.000	13.000
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			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Perform a laboratory demonstration of a trapped atom gyroscope. - Demonstrate and characterize performance of a low phase noise oscillator. - Demonstrate a photonic integrated chip capable of atom trapping and cooling compatible with proposed clock architecture. ***FY 2021 Plans:*** - Demonstrate an atomic clock in an integrated photonic integrated circuit physics package. - Perform critical design of atomic gyroscope. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from preliminary design to fabrication and 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 bandgaps determine, among other things, a transistor's maximum operating voltage, current density, thermal resistance, frequency and color (wavelength) of light emission. Consequently, wide band gaps 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-energy heterogeneous epitaxially-grown UWBG devices. - Develop theoretical models with experimental verification of high-energy performance and avalanche breakdown in UWBG materials. ***FY 2020 to FY 2021 Increase/Decrease Statement:***	-	-	5.801

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The FY 2021 increase reflects program initiation.			
Title: High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC) ***Description:*** The High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC) program sought to develop compact Radio Frequency (RF) signal amplifiers for air, ground, and ship-based communications, sensing, and radar systems. HAVOC funded basic research in vacuum electronics to improve understanding of the various phenomena governing vacuum electronic amplifiers operating at mm-wave frequencies above 75 GHz. Focus areas included modeling and simulation techniques, advanced manufacturing methods, novel beam-wave interaction structures, high current density and long-life cathodes, and other relevant topics. Applied research efforts were funded in PE 0602716E, Project ELT-01.	3.000	-	-
Title: Precise Robust Inertial Guidance for Munitions (PRIGM) ***Description:*** The Precise Robust Inertial Guidance for Munitions (PRIGM) program aimed to identify, investigate, and demonstrate inertial sensor technologies for Positioning, Navigation, and Timing (PNT) in GPS-denied environments. The program exploited 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. PRIGM focused on two areas: development and transition of a Navigation-Grade Inertial Measurement Unit (NGIMU), a state-of-the-art MEMS device, to DoD platforms; development of Advanced Inertial MEMS Sensors (AIMS) that can provide gun-hard, high-bandwidth, high dynamic range navigation for GPS-free munitions. Applied research efforts were funded in PE 0602716E, Project ELT-01, and advanced technology development for the program is budgeted in PE 0603739E, Project MT-15.	4.400	-	-
Title: Signal Processing at RF (SPAR) ***Description:*** The Signal Processing at RF (SPAR) program investigated advanced analog components to process radio frequency (RF) signals for communications, radar, and electronic warfare applications. By using advancements in new semiconductor materials, processing, and novel signal interaction mechanisms, SPAR components were able to pick out friendly RF signals from both intentional and unintentional jamming signals, even when those signals sat on top of one another in frequency. This capability has enabled a range of new applications including communications in contested battlefield RF environments, jamming the RF spectrum while maintaining communication, and full-duplex radio communication.	6.000	-	-
Accomplishments/Planned Programs Subtotals	38.156	43.333	35.801

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
ES-02: *BEYOND SCALING SCIENCES*	-	51.283	47.000	59.025	-	59.025	38.700	53.290	53.290	53.290	-	-

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, 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 2019	FY 2020	FY 2021
Title: Beyond Scaling - Materials	11.000	7.000	11.000

Description: The Beyond Scaling - Materials program will investigate new materials to support next-generation logic and memory components. Historically, the DoD provided leadership in shaping the electronics field through research in semiconductor materials, circuits, and processors. However, as DoD focuses on military-specific components and as commercial technology reaches an inflection point in Moore's Law (silicon scaling), there is risk that future DoD needs will not be met. The Beyond Scaling - Materials program will pursue potential enhancements in electronics that do not rely on Moore's Law, including research not only into new materials but also 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, new methods to accelerate the identification and utilization of emerging materials, and innovative processes to vertically integrate these materials with others to realize superior computational mechanisms. Applied research for this program is funded within PE 0602716E, Project ELT-02.

FY 2020 Plans:
- Identify preliminary DoD-relevant benchmark algorithms and applications.
- Complete detailed analysis using hardware emulation/simulation in process showing performance benefits of technology approach.
- Design and fabricate memory elements that support new computational circuit topologies, including in-memory computation and stochastic computing.

FY 2021 Plans:
- Test memory elements supporting in-memory computation and stochastic computing.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects a shift in focus on analysis and benchmarking of components developed in FY 2019.			
Title: Beyond Scaling - Architectures and Designs	6.183	5.800	14.000
Description: The Beyond Scaling - Architectures and Design program will investigate 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 will investigate 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 will also explore 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 2020 Plans:*** - Deliver open source software for physical layout of digital circuits verified against a set of open source benchmark circuits that will fully automate mixed signal system-on-chip, package, and printed circuit board layout. - Demonstrate rapid, automated generation of digital circuits at multiple technology nodes using an open source software platform. - Initiate research to develop a range of capabilities that can ensure separation of sensitive data, including verifiable bus standards and board support packages, while maintaining high reliable throughput. - Research and develop high-level languages, modeling, and compilation techniques capable of generating physical board layouts and binaries that ensure the privacy of transactions. ***FY 2021 Plans:*** - Extend research and development of high level languages and novel modeling techniques while reducing transaction overhead on embedded devices. - Source training data for chip-level layout from published journals to use for design tools using machine learning techniques.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Improve accuracy and speed of machine-learning based algorithms for chip, package, and board design through incorporation of additional data. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects the program shifting from research to development of circuit technologies and design tools.			
Title: Lifelong Learning Machines (L2M) ***Description:*** The Lifelong Learning Machines (L2M) program will research and develop 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, 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 2020 Plans:*** - Generate common test data and distribute to performers for validating lifelong learning core capabilities. - Translate first sets of insights from biological experiments into machine learning algorithms, and show that developed algorithms improve lifelong learning capabilities. - Demonstrate first lifelong learning systems, each with core adaptation capabilities using performer test cases. - Demonstrate feasibility using the common test cases. ***FY 2021 Plans:*** - Study safety and security in L2M systems. - Refine the first set of algorithms on the common test cases, and add new algorithms to the test cases. - Integrate multiple L2M capabilities into a single system. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects minor program repricing.	16.100	16.200	16.025
Title: Joint University Microelectronics Program (JUMP) ***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,	18.000	18.000	18.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
revolutionary devices, advanced architectures, and unconventional computing. JUMP will therefore sponsor 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 2020 Plans:*** - Benchmark emerging materials, power efficient RF, THz, digital, and storage devices prototypes. - Demonstrate prototypes of novel distributed and centralized computing architectures and subsystems for efficient information extraction, processing, and autonomous control applications. - Identify new research directions and amend new projects to the JUMP university research portfolio. ***FY 2021 Plans:*** - Demonstrate promising materials, power efficient RF, THz, digital, and storage devices prototypes. - 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.			
Accomplishments/Planned Programs Subtotals	51.283	47.000	59.025

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
MS-01: *MATERIALS SCIENCES*	-	72.181	63.412	52.560	-	52.560	66.647	48.638	41.138	37.138	-	-

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 2019	FY 2020	FY 2021
Title: Molecular Systems and Materials Assembly	16.319	12.000	3.000
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 2020 Plans:*** - Define limitations associated with scale-up of nano- and micro-assembly processes. - Demonstrate operational molecular computing system by linking storage and processing components and execute processing approaches directly on molecular data. - Identify and quantify advantages of molecular computing over conventional computing and storage methods. - Characterize and mitigate error sources in storage and processing approaches and demonstrate repeatability of storage and processing approaches. ***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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease due to program evolution from demonstrations to systems refinement.			
Title: Fundamental Limits	30.000	20.712	19.500

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** MS-01 / *MATERIALS SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Extend capability of modeling tools to simulate centimeter-scale devices and confirm performance with characterization of cm-scale engineered materials. - Investigate the possibility of influencing electromagnetic biological sensing or regulation as a result of any newly discovered biological communications channels. - Demonstrate basic technical capabilities needed to validate and extend models for electromagnetic, or electromagnetically facilitated, biological signaling channels. - Develop experimental methods and setups to test predictive, parametric models of nascent light-matter interactions under investigation. - Analyze experimental results of nascent light-matter interactions and provide input back to parametric models to further optimize and refine the modeling framework. - Initiate development of multi-physics models that can predict atmospheric perturbations, such as plasma "holes" and acoustic shock waves, associated with small scale meteorological phenomena. ***FY 2021 Plans:*** - Use experimental methods and parametric models to demonstrate devices that meet government-approved challenge problem metrics. - 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. - Identify new approaches to improve the range and sensitivity of atmospheric measurements to enable routine characterization of the mesosphere. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease is due to program focus shifting from developing extended capability to demonstrations.			
Title: Non-Equilibrium Materials	9.600	16.000	16.000
Description: The Non-Equilibrium Materials thrust will explore 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			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** MS-01 / *MATERIALS SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Demonstrate fast current-induced motion of topological excitations. - Develop prototype devices for topologically protected memory. - Implement braiding operations in topologically protected qubits. - Experimentally demonstrate the enhancement of coherence time in a large quantum system. - Demonstrate extended lifetime for a correlated electron phase. ***FY 2021 Plans:*** - Develop advanced metrology for high-resolution space and time-resolved spin-textures. - Scale up braiding operations in topologically protected qubits. - Demonstrate many-body localization and increased coherence time for high-fidelity multi-qubit gates in spin-based quantum information processors. - Demonstrate Higgs lasing phenomenon with entangled photon pair generation via parametric amplification. - Advance metrology, particularly atomic clocks, beyond the standard quantum limit via entangled quantum matter stabilization. - Demonstrate compact, room-temperature solid-state color center gyroscope with shock insensitivity in the order of 1,000,000 meters per second squared linear acceleration. - Demonstrate significant increase in the time and temperature scales of light-induced superconductivity.			
Title: Basic Photon Science ***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 2020 Plans:*** - Demonstrate the feasibility of non-line-of-sight imaging around corners at a government facility to government partners. - Experimentally evaluate design advances in detectors driven by new fundamental theoretical models for photon detection. - Initiate efforts to develop and integrate physical models for passive multi-dimensional imagers.	16.262	14.700	14.060

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** MS-01 / *MATERIALS SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Initiate efforts to explore the potential for sub-diffraction limit imaging and improved information retrieval using quantum insights and spectral estimation theory. ***FY 2021 Plans:*** - Perform spectral analysis of passive thermal emission to mathematically determine object structures. - Develop and demonstrate imaging models to understand fundamental tradeoffs in information gathering and 3D resolution. - 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects minor program repricing.			
Accomplishments/Planned Programs Subtotals	72.181	63.412	52.560

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
TRS-01: *TRANSFORMATIVE SCIENCES*	-	46.995	57.715	42.769	-	42.769	32.948	28.735	24.105	20.802	-	-

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 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. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Social Simulation (SocialSim)	13.014	12.952	11.215

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 2020 Plans:
- Evaluate the performance of the extended models and mechanisms across multiple interconnected online environments.
- Integrate the multiple models and mechanisms into a prototype, and leverage ensemble modeling and meta-modeling techniques to support application of models.
- Demonstrate the capability to accurately represent online social phenomena, such as recurrent cascades of information, and to quantify the effects of small, persistent groups of information disseminators.

FY 2021 Plans:
- Evaluate performance on increasingly complex challenge scenarios, such as the spread of information on the dark web.
- Extend prototype using ensemble modeling and meta-modeling techniques, and evaluate application of the integrated models across multiple social media domains.
- Demonstrate and validate capabilities across multiple social media domains in applied settings relevant to operational users.

FY 2020 to FY 2021 Increase/Decrease Statement:

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The FY 2021 decrease reflects a shift from model development and prototype integration to evaluation and demonstration on complex social media domains.			
Title: Biology for Security (BIOSEC)	12.890	13.347	15.100
Description: Based on initial research conducted under the Biological Robustness in Complex Settings (BRICS) program, 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 2020 Plans:*** - Demonstrate unbiased high-throughput isolation of microbes from complex samples. - Develop strategies for the maintenance and growth of all bacterial types from complex environmental samples. - Demonstrate effective processes for phenotyping small numbers of bacteria for the three principal classes of pathogenic traits: niche finding, attacking a membrane, and self-defense. - Implement data fusion and remedial algorithms for machine learning and modeling of pathogenicity. - Demonstrate isolation and bioinformatics protocols on complex samples that show the potential for integration into a unified platform. ***FY 2021 Plans:*** - Demonstrate continued platform integration (e.g., combined bacterial processing for isolation, integration, and data collection). - Demonstrate isolation and interrogation platforms on increasingly complex samples that simulate complex environments. - Demonstrate the ability to combine bacterial phenotypes and single-cell omics to support pathogenic trait mapping. - Demonstrate increased algorithmic performance on predicting pathogenicity of unknown bacteria. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects additional efforts in high-throughput analyses and movement towards an integrated system.			
Title: Native Bioelectronic Interfaces	-	12.116	14.254

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: The Native Bioelectronic Interfaces effort will address 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 2020 Plans:*** - Identify effective stimuli for directing growth, development, and repair. - Identify critical physiological changes and biomarkers that can report on cell growth and differentiation. - Develop first set of algorithms that can deliver preliminary intervention strategies. ***FY 2021 Plans:*** - Demonstrate biocompatibility, reliable operation of actuators, and control of at least two physiological processes in animal models. - Demonstrate reliable operation of sensors able to track at least two physiological processes in an in vivo model. - Demonstrate that the algorithmic model is both descriptive and able to determine the current stage of healing from acquired sensor data. - 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. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects the initiation of IV&V efforts and demonstrations in animal models.			
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	10.955	9.350	2.200

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
impact military approaches to infrastructure design in austere environments as well as established methods for manufacture and maintenance of military platforms (e.g., tanks, planes, ships). ***FY 2020 Plans:*** - Demonstrate at least two-fold improvements in rate of growth and maintenance of the size and structure of produced material in controlled conditions. - Demonstrate engineered cell-cell interactions to organize and maintain the density/spacing of patterns. - Demonstrate increased strength, scaling, and robustness of materials in a built environment. - Demonstrate controlled healing in response to damage of advanced materials in controlled conditions. ***FY 2021 Plans:*** - Verify stability and scalability of material over a prolonged period under operational conditions. - Pressure test self-healing proficiency for deformation, puncture, and tearing resistance under operational conditions. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects completion of research and development efforts and demonstration of program technologies.			
Title: Biological Complexity (BioCom) ***Description:*** The Biological Complexity (BioCom) program seeks 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 expected from this research will include the identification of approaches to create stable, predictable, and dynamic control mechanisms of biological networks. Such information will allow the determination of a biosystem's state and enable the prediction of state. Applications range from infectious disease mitigation or prevention, maintaining warfighter health, to leveraging biological systems for optimal production of therapeutics. ***FY 2020 Plans:*** - Demonstrate solutions that counter pathogens and antibiotic resistance, regulate inflammation from Traumatic Brain Injury (TBI), and maintain a healthy gut. - Deliver new experimental tools and algorithms to engineer control of biological system behavior that is robust to perturbation. - Demonstrate real time characterization of cell and molecular responses to control algorithms. - Establish the limits on reproducibility of performance of biological control systems. ***FY 2020 to FY 2021 Increase/Decrease Statement:***	10.136	9.950	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
The FY 2021 decrease reflects program completion.			
Accomplishments/Planned Programs Subtotals	46.995	57.715	42.769

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	49.692	54.122	53.730	-	53.730	62.181	61.553	66.511	70.996	-	-
MED-01: *BASIC OPERATIONAL MEDICAL SCIENCE*	-	49.692	54.122	53.730	-	53.730	62.181	61.553	66.511	70.996	-	-

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 solving DoD challenges. Programs in this project address the Department's identified medical gaps in warfighter care related to health monitoring, restorative function of the body, 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 project will explore multiple diagnostic and therapeutic approaches, including developing techniques to protect against emerging pathogens; exploring methods to slow damage from pathological infection or traumatic injury; and leveraging fundamental and engineered biological mechanisms to enhance tolerance to insults such as pain and altitude.

B. Program Change Summary ($ in Millions)	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	46.575	54.122	51.337	-	51.337
Current President's Budget	49.692	54.122	53.730	-	53.730
Total Adjustments	3.117	0.000	2.393	-	2.393
• 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	3.471	0.000			
• SBIR/STTR Transfer	-0.354	0.000			
• TotalOtherAdjustments	-	-	2.393	-	2.393

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2019	FY 2020
Project: MED-01: *BASIC OPERATIONAL MEDICAL SCIENCE*		
Congressional Add: *TBI Treatment for Blast Injuries*	5.000	-
Congressional Add Subtotals for Project: MED-01	5.000	-
Congressional Add Totals for all Projects	5.000	-

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Change Summary Explanation

FY 2019: Increase reflects reprogrammings offset by the SBIR/STTR transfer.
FY 2020: N/A
FY 2021: Increase reflects the initiation of the Physiological Overmatch program.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Preventing the Emergence of Disease (PED)	12.819	12.598	8.449
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 2020 Plans:*** - Refine mathematical models of virus dynamics within and between two host species, and initiate validation with data from the field. - Integrate virus transmission dynamics, environmental data, and viral fitness metrics into spillover risk model for selected viruses. - Demonstrate proof-of-concept preemptive approaches for suppressing virus jump from one species to another in a relevant animal model. ***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 reservoir species. - Demonstrate scalability of preemptive approaches for suppressing virus jump from one species to another in a relevant animal model. - Demonstrate broad-spectrum preemptive approaches for suppressing virus transmission from vectors to animal models. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects completion of development efforts and subsequent focus on those mathematical models and interventions that have been demonstrated most effective in earlier proof-of-concept experiments.			
Title: Early Battlefield Interventions (EBI)	11.744	13.348	13.957

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: Based on initial research conducted under the Analysis and Adaptation of Human Resilience program, budgeted in this PE and project, 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 area may be applied to the development of both prophylactic and therapeutic medical countermeasures to forward-deployed service members. ***FY 2020 Plans:*** - Characterize the molecular mechanisms for reversibly slowing biological processes in cells. - Begin to test novel interventions to reversibly slow biochemical processes in multicellular biological systems (e.g., organoids, tissues). - Evaluate protein stabilization induced by interventions in multicellular biological systems. - Characterize intervention formulations to enhance cell penetration and reversibility. - Identify platform technologies to enable controlled systemic delivery of multiple orthogonal interventions to reset or establish healthy biological patterns. ***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. - Continue testing the ability of biostasis interventions to reversibly slow processes in biological systems of increasing complexity, ranging from single proteins through multicellular systems (e.g., organoids, organ chips, and tissues). - Optimize delivery protocols and formulations of biostasis interventions for biological uptake and distribution, and characterize molecular mechanisms of interventions. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects minor program repricing.			
Title: Outpacing Infectious Disease ***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 thrust 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	14.190	13.894	8.734

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Assess optimal route, dose, and timing of treatment for selected virus therapeutic interfering particle (TIP) candidates in relevant animal models. - Determine the broad-spectrum efficacy of TIPs against multiple viral strains. - Assess TIP transmission dynamics in animal models. - Prepare regulatory package for pre-clinical trial for TIPs. ***FY 2021 Plans:*** - Demonstrate TIP-based medical countermeasures rapid response platform proof-of-concept. - Prepare Good Manufacturing Practice (GMP) TIP product in quantities sufficient for Investigational New Drug (IND)-enabling studies and clinical trial. - Initiate clinical safety trial for TIPs. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects completion of exploratory research efforts and transition to applied countermeasure development.			
Title: Improved Interventions ***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. The Improved Interventions program builds upon the genomic and physiological analyses conducted under the Analysis and Adaptation of Human Resilience program, budgeted in this PE and project. ***FY 2020 Plans:***	-	14.282	13.575

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Generate preliminary datasets of proteins involved in a complex physiological process. - Begin to build computational tools that model complex physiological processes. - Begin development of informatics pipeline to predict targets regardless of prior knowledge. - Analyze biochemical processes associated with proteins of unknown function. - Identify chemical synthesis methods to build novel small molecules to target any protein or combination of proteins in the human proteome. - Begin identification of targets for modulation and interface with central and peripheral sensory neurons. ***FY 2021 Plans:*** - Employ a multi-tissue biological system to adequately characterize an indication of military operational relevance (e.g., pain/inflammation or metabolic stress under hypoxia). - Use computational approaches to predict and optimize drug activity profiles. - Begin synthesis, testing, and exploration of predicted chemical compounds for indications of interest (e.g., pain/inflammation and metabolic stress under hypoxia). - Begin validation of computational pipelines to determine highest-value targets without relying on previous knowledge. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects minor program repricing.			
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:*** - Demonstrate engineered cellular viability in vitro and the capability of cellular systems to mitigate degraded performance caused by disrupted circadian rhythms or contaminated food or water. - Demonstrate ex vivo synthetic biology circuit components enabling the delivery of a beneficial biomolecule at a clinically relevant level (e.g., medical countermeasure). - Demonstrate ex vivo engineered cells that can implement a therapeutic purification or detoxification process, such as removing viral, bacterial, or toxin threats.	-	-	9.015

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Begin development of biocompatible devices that control engineered cells in the body. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Analysis and Adaptation of Human Resilience ***Description:*** The Analysis and Adaptation of Human Resilience program explored new methods to maintain and optimize warfighter health in response to environmental insults such as new and emerging infectious diseases. Research efforts in this area applied recent advances in comparative biology, genetic sequencing, omics technologies, and bioinformatics to develop new tools for modulating health to ensure warfighter readiness. One approach to achieve the program's goal was to identify the fundamental mechanisms that enable certain species to be tolerant to various environmental insults. Genomic and physiological analyses of a wide array of resilient animal species were combined with sophisticated algorithms to identify important patterns of survival. By analyzing patterns in the underlying variability of host responses for resilient animals, a survival blueprint is being developed to restore and maintain warfighter homeostasis in response to infection. This approach was orthogonal to traditional infectious disease research, which primarily relies on reducing the pathogen load through drug intervention. Research efforts within this program may enable discovery of novel methods to optimize human health against infectious diseases caused by multi-drug resistant pathogens.	5.939	-	-
Accomplishments/Planned Programs Subtotals	44.692	54.122	53.730

	FY 2019	FY 2020
Congressional Add: TBI Treatment for Blast Injuries ***FY 2019 Accomplishments:*** Conduct research in TBI treatment for blast injuries.	5.000	-
Congressional Adds Subtotals	5.000	-

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	94.423	92.771	107.568	-	107.568	110.953	115.878	125.768	136.352	-	-
BT-01: *BIOMEDICAL TECHNOLOGY*	-	94.423	92.771	107.568	-	107.568	110.953	115.878	125.768	136.352	-	-

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 disease forecasting, detection, and therapeutic response. Example programs include a predictive platform for forecasting disease outbreak, 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, enabling control of robotic prosthetic-limb technology. Additionally, advanced evidence-based techniques will be developed to supplement warfighter healthcare, including the diagnosis of post-traumatic stress disorder (PTSD) and traumatic brain injury (TBI) and treatment of spinal cord injury.

B. Program Change Summary ($ in Millions)	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	101.300	97.771	123.570	-	123.570
Current President's Budget	94.423	92.771	107.568	-	107.568
Total Adjustments	-6.877	-5.000	-16.002	-	-16.002
• Congressional General Reductions	0.000	-5.000			
• 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	-3.471	0.000			
• SBIR/STTR Transfer	-3.406	0.000			
• TotalOtherAdjustments	-	-	-16.002	-	-16.002

Change Summary Explanation

FY 2019: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2020: Decrease reflects congressional reduction.
FY 2021: Decrease reflects completion of the Prosthetic Hand Proprioception & Touch Interfaces (HAPTIX) program in FY 2020.

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Validate system designs for prototyping and manufacture. - Harden size, weight, and power of complete integrated system. - Perform in vivo demonstration of the fully integrated input-output platform. ***FY 2021 Plans:*** - Submit regulatory documentation to acquire regulatory approval for clinical testing. - Construct a sensory restoration testbed for the fully integrated input-output platform. - Quantify improvements offered by large-scale recording capabilities. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects reduction of research activities to conduct final system validation and demonstration.	14.485	13.676	11.217
Title: Neural Signal Interfaces and Applications (NSIA) ***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 facilitate standard human-machine interfaces for improved workload balance between man and machine. ***FY 2020 Plans:*** - Initiate experiments toward achieving regulatory approval for clinical studies. - Complete critical design review of read and write components. - Verify and validate the safety, resolution, and stability of subcomponents. ***FY 2021 Plans:*** - Integrate neural read and write subcomponents.	15.895	19.125	17.924

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects completion of system design and integration plans of the neural interface system.			
Title: Pandemic Prevention	24.985	24.450	24.250
Description: Military personnel are deployed all over the world for traditional operations, 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 rapidly 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. ***FY 2020 Plans:*** - Investigate the kinetic profile of gene-encoded antibodies in large animal models. - Conduct, in under 60 days, a demonstration of integrated technologies identifying, maturing, and delivering a gene-encoded antibody to provide protection against viral challenge in animal models. - Demonstrate, in less than 20 days, the ability to identify a highly potent antibody, targeting a viral pathogen. - File an Investigational New Drug (IND) application with the Food and Drug Administration for a gene-encoded antibody product. - Initiate a Phase I clinical safety study of a gene-encoded antibody. - Initiate IND enabling studies for a nucleic acid construct encoding multiple antibodies. - Initiate development of chemical assays for the distributed, rapid synthesis and purification of biomolecules. ***FY 2021 Plans:*** - Demonstrate the ability to manufacture clinical doses of gene-encoded antibody product at scale for use in clinical trials. - Conduct a demonstration of integrated technologies identifying, maturing, and delivering a gene-encoded antibody to provide protection against viral challenge in vivo for a second viral indication. - Conduct a demonstration of integrated technologies identifying, maturing, and delivering a gene-encoded antibody against a virus revealed just prior to demonstration.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Investigate the potential for a link between antibody sequence and level of expression from a nucleic acid construct. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects minor program repricing.			
Title: Forensic Indicators of Threat Exposure (FITE) ***Description:*** Based on initial research conducted under the Enhanced Monitoring of Health and Disease program, 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 2020 Plans:*** - Develop bioinformatics algorithms to decode and characterize differences in the complex epigenetic marks associated with each exposure event. - Complete validation efforts to understand sensitivity and specificity of the forensic and diagnostics signatures when combined with detection algorithms. - Select molecular analysis methods for integration into the deployable platform. - Develop a platform prototype to integrate discovered molecular analysis techniques and perform forensic and diagnostic assessment of exposure. ***FY 2021 Plans:*** - Perform pressure tests to assess the ability to distinguish viral from bacterial signatures in clinical samples. - Generate epigenetic signatures that reveal temporal resolution of exposure events from WMD or WMD precursor exposure events. - Refine bioinformatics algorithms for increased sensitivity and specificity of the epigenetic signatures. - Finalize selection of module components and complete system design for deployable platform prototype. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the completion of research activities to focus on final system design and integration tasks.	13.995	14.404	13.285
Title: Improved Personnel Placement (IPP) ***Description:*** Building upon work initiated under the Forensic Indicators of Threat Exposure (FITE) program, the Improved Personnel Placement (IPP) program aims to improve force lethality and overmatch by identifying and training candidates for	-	16.967	17.167

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 develop technology to measure how someone uses their own genes to yield specific performance traits. This knowledge will help the individual leverage this information to improve training, thus maximizing their potential. Measuring an individual's biological system will ensure that they achieve their maximum potential while facilitating readiness and resilience for the DoD. ***FY 2020 Plans:*** - Identify initial set of traits that separate retrospective performance and resilience. - Compare attributes of specialized warfighters to identify biomarkers associated with specialized military roles. - Build data analysis approaches that can integrate proteomic, genomic, and epigenetic results to characterize elite performers. - Implement novel phenotypic detection assays in a performance cohort. ***FY 2021 Plans:*** - Conduct multi-omics assays to create layered biological data for building gene expression circuits. - Identify gene expression circuits related to elite performance. - Refine analytical approaches to improve sensitivity and selectivity. - Determine signal transduction method for biosensors. - Develop initial indicators that can measure how gene expression changes over time to drive human performance. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects minor program repricing.			
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 (MCM) 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 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 biomolecules in a laboratory setting.	-	-	10.728

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Demonstrate the ability to biochemically or chemically synthesize and purify biomolecules. - Demonstrate the efficacy of biochemically or chemically synthesized nucleic acids (DNA and/or RNA). - Demonstrate the ability to purify and analyze synthesized nucleic acids in a laboratory setting. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Bridging the Gap after Spinal Cord Injury ***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:*** - Research and design initial prototype sensors that will monitor the state of the spinal cord injury. - Initiate assessment of the prototype devices that will help stabilize injury and restore lost function. - Establish preliminary design plans for system integration. - Initiate the design of a software development kit that will facilitate system modularity. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.	-	-	12.997
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 is 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 will create and transition clinically relevant technology in support of wounded warriors suffering	14.985	4.149	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
from single or multiple limb loss. Research in this area will also address similar interface technologies with other nerve pathways such as the spinal cord. The anticipated transition partner is the Army. ***FY 2020 Plans:*** - Initiate take-home studies of the HAPTIX system. - Evaluate benefits of sensory feedback during extended system use outside the laboratory. - Complete surgical implants and perform proof of concept testing of the percutaneous spinal cord injury device. - Review and assess efforts to build novel sensors, stimulators, and algorithms for spinal cord injury stabilization and functional restoration. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: Neuro-Adaptive Technology ***Description:*** The Neuro-Adaptive Technology program explored and developed advanced technologies for real-time detection and monitoring of neural activity. One shortcoming of today's brain functional mapping technologies was the inability to obtain real-time correlation data that links neural function to human activity and behavior. Understanding the structure-function relationship as well as the underlying mechanisms that link brain and behavior is a critical step in providing real-time, closed-loop therapies for military personnel suffering from a variety of brain disorders. Efforts under this program examined the networks of neurons involved in post-traumatic stress disorder (PTSD), traumatic brain injury (TBI), depression, and anxiety as well as determined how to best ameliorate these disorders. The objective for this program was to develop new hardware and modeling tools to better discriminate the relationship between human behavioral expression and neural function and to provide relief through novel devices. These tools allowed for an improved understanding of how the brain regulates behavior and enabled new, disorder-specific, dynamic neuro-therapies for treating neuropsychiatric and neurological disorders in military personnel. Technologies developed under this program include devices for real-time detection of brain activity during operational tasks, time synchronized acquisition of brain activity and behavior, and statistical models that correlate neural activity with human behavioral expression.	6.078	-	-
Title: Enhanced Monitoring of Health and Disease ***Description:*** The Enhanced Monitoring of Health and Disease program has improved military health and force readiness by leveraging advanced data collection methods and prognostic capabilities to predict changes in health and spread of infectious disease from the individual to the population scale. While new technology platforms have enhanced our ability to respond to illness and disease, there is a need for predictive and pre-emptive technologies that enable us to correctly prepare a response prior to its obvious need, such as in a barracks or in a confined environment (e.g., submarine). Research in this program investigated new methods for the collection and detection of multiplexed biological markers as well as the analysis, correlation,	4.000	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021
and ultimate integration of vast personalized data into the clinical care information technology infrastructure. Additionally, this program developed new approaches to integrate multi-source data streams to create effective predictive models of disease outbreak and spread. Technologies developed in this program have enabled clinically actionable information, even when an individual exhibiting no symptoms, that will extend to infectious disease forecasting into a real-time, accurate capability for decision support.			
Accomplishments/Planned Programs Subtotals	94.423	92.771	107.568

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	401.453	428.556	435.920	-	435.920	454.599	467.755	468.030	417.627	-	-
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	46.513	16.277	6.576	-	6.576	0.000	0.000	0.000	0.000	-	-
IT-03: *CYBER SECURITY*	-	249.979	251.111	236.182	-	236.182	246.677	257.132	257.043	207.888	-	-
IT-04: *ARTIFICIAL INTELLIGENCE AND HUMAN-MACHINE SYMBIOSIS*	-	104.961	161.168	193.162	-	193.162	207.922	210.623	210.987	209.739	-	-

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.

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 2021 Defense Advanced Research Projects Agency	Date: February 2020
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*

B. Program Change Summary ($ in Millions)	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	404.967	442.556	435.746	-	435.746
Current President's Budget	401.453	428.556	435.920	-	435.920
Total Adjustments	-3.514	-14.000	0.174	-	0.174
• Congressional General Reductions	0.000	-15.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	1.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	5.104	0.000			
• SBIR/STTR Transfer	-8.618	0.000			
• TotalOtherAdjustments	-	-	0.174	-	0.174

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2019	FY 2020
Project: IT-03: *CYBER SECURITY*		
Congressional Add: *Distributed Ledger Technology*	-	1.000
Congressional Add Subtotals for Project: IT-03	-	1.000
Project: IT-04: *ARTIFICIAL INTELLIGENCE AND HUMAN-MACHINE SYMBIOSIS*		
Congressional Add: *DARPA Foundational and Applied Artificial Intelligence*	25.000	-
Congressional Add Subtotals for Project: IT-04	25.000	-
Congressional Add Totals for all Projects	25.000	1.000

Change Summary Explanation

FY 2019: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.
FY 2020: Decrease reflects congressional adjustments.
FY 2021: Increase reflects minor program repricing.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	46.513	16.277	6.576	-	6.576	0.000	0.000	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 2019	FY 2020	FY 2021
Title: RF Machine Learning Systems (RFMLS)	21.329	16.277	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 by, for example, 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 2020 Plans:
- Complete final phase development of machine learning algorithms and architectures for two of the four challenge problems.
- Create test and demonstration plan for final open-air demonstration of RFMLS algorithms.
- Begin integration of machine learning solutions into an RF hardware system to host field testing and demonstrations.
- Begin technology transition applications.

FY 2021 Plans:
- Complete final phase development of machine learning algorithms and architectures for all of the four challenge problems.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Complete a real-time, open-air demonstration of RFMLS capabilities. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The decrease in FY 2021 reflects completion of a real-time open-air demonstration of RFMLS capabilities.			
Title: Spectrum Collaboration Challenge (SC2) ***Description:*** The Spectrum Collaboration Challenge (SC2) program catalyzed the development of systems, called Collaborative Intelligent Radios (CIRs) that intelligently share and optimize wireless spectrum usage without prior knowledge of each other's operating characteristics. SC2 addressed the increasing demand for and reliance on unfettered wireless access. Today, assured access to the wireless spectrum involves restricting particular types of radios and radio operators to certain sets of fixed, pre-determined frequencies. Although this spectrum allocation approach helps ensure different radio signals do not interfere with each other, it is inherently inefficient and vulnerable to attack. First, allocated portions of the spectrum can remain unused or underutilized. Second, adversaries can easily characterize static spectrum allocations, identifying which ones to exploit or attack. SC2 addressed these challenge by leveraging artificial intelligence and machine learning to optimize use of the spectrum in real-time. In particular, SC2 participants were challenged to develop techniques that allow collaboration among dissimilar communications technologies. SC2 conducted two preliminary competitions and one championship event over three years. The resulting technology will define a new class of radio systems that efficiently thrive in the absence of pre-planned spectrum.	25.184	-	-
Accomplishments/Planned Programs Subtotals	46.513	16.277	6.576

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
IT-03: *CYBER SECURITY*	-	249.979	251.111	236.182	-	236.182	246.677	257.132	257.043	207.888	-	-

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 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 2019	FY 2020	FY 2021
Title: Memory Optimization (MemOp)	9.500	17.960	19.500

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 2020 Plans:
- Reduce the complexity of algorithms that map software tasks to processing units to achieve scalability to large scale memory systems.
- Develop methods to interface to memory more efficiently, and to accelerate processing pipelines.
- Establish a testbed to evaluate memory transaction improvements in systems incorporating GPUs and FPGAs.
- Begin testing algorithms and architectures for improving memory transaction performance in hardware and software, and evaluate on testbed.

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.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Optimize algorithms and architectures for memory transaction performance in hardware and software, and evaluate on testbed. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects continued development of memory interface methods and accelerated processing pipelines, and expanded use of an enhanced evaluation testbed.			
Title: Cyber-Hunting at Scale (CHASE) ***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 no tools exist to efficiently extract the right data from the right device at the right time to analyze these attacks for DoD-scale information networks. For example, analysis of an in-memory exploit would require detailed data from a few devices, while analysis of a global botnet attack would require 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 2020 Plans:*** - Integrate threat detection, threat characterization, and data planning components, and demonstrate integrated data management feedback loops in real networks. - Evaluate effectiveness of threat detection and data planning components using operational datasets from transition partners. - Identify foundational protective measures for adversarial actions such as data exfiltration and lateral movement. - Demonstrate global analysis methods on distributed enterprise networks. ***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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease is the result of development and integration work decreasing, and the focus shifting to demonstration and evaluation on distributed enterprise networks.	20.485	19.000	18.200
Title: Harnessing Autonomy for Countering Cyber-adversary Systems (HACCS)	19.000	17.700	15.550

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
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 navigate within botnet-conscripted networks, identify botnet implants, and curtail their ability to operate while minimizing side effects to systems and infrastructure. HACCS technologies aims to enable U.S. agencies possessing the appropriate authorities to safely conduct Internet-scale counter-botnet operations. ***FY 2020 Plans:*** - Enhance botnet-tracking algorithms to detect conscripted networks by characterizing botnet management infrastructure. - Expand discovery techniques for additional classes of software vulnerabilities. - Evaluate botnet-tracking algorithms for detecting stealthy command-and-control protocols, and evaluate autonomous agent behavior in contained environments. - Collaborate with transition partners to determine how counter-botnet technologies may be integrated into existing architectures and exercises. ***FY 2021 Plans:*** - Enhance botnet-tracking algorithms to provide near-real-time assessment for the identification and tracking of botnet-conscripted networks. - 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 representative environments. - Collaborate with transition partners to evaluate counter-botnet technology in synthetic environments. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease is the result of reduced counter-botnet technology development and prototype integration work, and expanded demonstrations on synthetic environments in collaboration with transition partners.			
Title: Configuration Security	13.800	14.800	15.207
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			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
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 2020 Plans:*** - Develop techniques to automatically generate baseline secure configurations for complex cyber-physical-human systems, including the translation of human-readable standard operating procedures into machine-understandable formats. - Develop algorithms to reconfigure a system automatically to a safer, quantifiably more secure baseline that assures required functionality and can justify the new configuration parameter selection with generated human-readable explanations. - Mature a capability to both detect and prevent malicious modification of configurations from the system-generated baseline, and to assist system operators in changing between operational contexts. ***FY 2021 Plans:*** - Test and evaluate techniques to automatically generate baseline secure configurations for operationally relevant, complex cyber-physical-human systems, including the translation of human-readable standard operating procedures into machine-understandable formats. - Apply algorithms to automatically reconfigure a critical infrastructure system to a safer and more secure baseline that provides required functionality and supports the new configuration parameter selection with 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects ramping up of algorithm and software development, and expanded demonstrations and evaluation of an automated capability to detect and prevent malicious modification of configurations from the system-generated baseline.			
Title: Computers and Humans Exploring Software Security (CHESS) ***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 no 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.	13.000	17.500	14.775

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
FY 2020 Plans: - Develop 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. - Implement emerging vulnerability discovery techniques in an initial proof-of-concept computer-human software reasoning system. - Assess computer-human vulnerability discovery techniques on a synthetic vulnerability challenge corpus representative of complex software. ***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. - Demonstrate an end-to-end, integrated computer-human software reasoning system to DoD and Intelligence Community transition partners. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects ramping down of work to integrate technologies in a proof-of-concept, computer-human software reasoning system, and expanded performance assessments on a synthetic challenge corpus.			
Title: Resilient Anonymous Communication for Everyone (RACE) ***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. RACE security is based on rigorous security arguments or in statistical arguments based on realistic simulations, and not on ad hoc security claims. ***FY 2020 Plans:*** - Develop and implement techniques to prevent a cyber adversary from discovering the presence of and compromising the secure message-passing system by obfuscating communication protocols and encrypting data on the nodes at all times, even during computation. - Build components for a secure message-passing system that can defeat the efforts of a cyber adversary with limited ability to observe the network.	8.760	12.700	13.900

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Develop a testbed that includes representative networks on which to evaluate implementations of the obfuscation and cryptographic technologies and the integrated secure message-passing system against a simulated cyber adversary. ***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 by incorporating an active simulated cyber adversary that seeks to compromise the obfuscation and cryptographic technologies and demonstrate the integrated secure message-passing system. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects expanded development of obfuscation and encryption technologies, continued implementation of a secure message-passing system, and enhancement of a testbed on which to evaluate the system against a simulated cyber adversary.			
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 2020 Plans:*** - Create the capability to autonomously detect social engineering attacks across multiple communication platforms and to semi-autonomously attribute social engineering attacks. - Develop the capability for multiple, coordinated, counter-social-engineering bots to conduct autonomous investigations of social engineering attacks. - Evaluate effectiveness and efficiency of social engineering detection and investigation techniques. ***FY 2021 Plans:*** - Create the capability to autonomously detect and defend against social engineering attacks across Internet-based communication platforms. - Demonstrate automated attribution of social engineering attacks across multiple communication platforms.	14.524	12.500	10.750

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Assess performance of a bot-based defense system that increases the cost to an adversary of conducting a social engineering attack. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects shift from development of counter-social-engineering bot technologies, to expanded performance assessment across multiple communication platforms.			
Title: Dispersed Computing	18.000	16.300	10.200
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-purposed 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 Dispersed Computing technology, the network becomes the cloud, and computation is performed where it is most efficient to do so. ***FY 2020 Plans:*** - Develop automated mechanisms for redistributing workloads across dispersed network computation elements to achieve reliable and near-optimal performance even in the presence of dynamic failures and impairments. - Extend the user interface to provide operators with fine-grained visibility into the workloads being handled by the dispersed network computation elements on applications of interest. - Evaluate integrated prototype network-compute elements and demonstrate prototypes to the Defense Information Systems Agency (DISA) and commercial network providers. ***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.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Harden, demonstrate, and transition integrated network-compute capabilities to DISA and commercial network providers. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects ramping down of development of the technologies and software prototypes for distributing workloads to network-compute elements, and continuation of testing, demonstration, and transition activities.			
Title: Cyber Assured Systems Engineering (CASE)	21.400	15.100	10.000
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. 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 2020 Plans:*** - Enhance cyber resilience design tools based on the results of cyber resilience challenge problems. - Apply design tools and techniques to exemplar cyber-physical systems including a military helicopter. - Integrate cyber resilience design tools into the engineering workflow of a defense system provider. - Use integrated design tools to re-engineer a portion of a defense platform to improve cyber resiliency in coordination with potential transition partners and other stakeholders. ***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. - 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 2020 to FY 2021 Increase/Decrease Statement:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The FY 2021 decrease reflects ramping down of development of techniques and software tools to design-in cyber resiliency requirements, and continued demonstrations on exemplar cyber-physical challenge problems.			
Title: Enhanced Attribution ***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 2020 Plans:*** - Integrate new data sets and develop new algorithms to increase resolution from an adversary's infrastructure to an individual actor. - Develop and evaluate predictive analytic algorithms for anticipating adversary actions across a cyber campaign, and adversary pattern matching algorithms for discovering previously unknown campaigns. - Integrate tools and event extraction techniques into an enterprise wide automated attribution platform. - Collaborate with transition partners to test and evaluate the attribution platform's ability to track adversary threat groups. ***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 government-provided data sets and transition the attribution technologies. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects ramping down of development and integration of a prototype platform for attribution, and continued evaluation on government data sets.	20.830	18.100	8.800
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	7.400	11.000	8.100

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Implement machine reading, cyber entity extraction, and activity correlation techniques in an integrated software system. - Evaluate cyber analytical technologies on large-scale data, and implement algorithmic improvements to address scalability and performance. - Develop natural language processing capability in text-based data other than English. - Create test protocols to evaluate technical progress with respect to automated generation of cyber leads. ***FY 2021 Plans:*** - Implement and evaluate new methods of machine learning for the generation of cyber-specific content. - Implement and evaluate new methods of identifying cyber threats across heterogeneous data, in multiple languages. - Provide initial software capabilities to potential transition partners for performance assessments in operational environments. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects shift from efforts to implement and evaluate an integrated cyber analytical system to transition of technology to operational partners.			
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 2020 Plans:*** - Develop a unified framework for network QoS requirements for diverse distributed applications having differing and dynamic priorities. - Implement QoS adaptation schemes on programmable network elements such as software-defined routers and switches. ***FY 2021 Plans:***	3.800	5.300	6.100

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Develop initial implementation of a system integrating automated application inference, network inference, and QoS management. - Evaluate the integrated system in terms of its capability to enable QoS management of heterogeneous distributed applications. - Formulate transition approaches with DoD and commercial network service providers. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects expanded work to integrate QoS adaptation schemes on programmable network elements and to evaluate techniques on heterogeneous distributed applications.			
Title: Rapid Attack Detection, Isolation and Characterization Systems (RADICS)	27.310	20.350	5.000
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. RADICS 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. RADICS 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. RADICS technology development is coordinated with and will transition to U.S. government elements responsible for defense of critical infrastructure. ***FY 2020 Plans:*** - Provide integrated capability for grid physics anomaly detection and Supervisory Control and Data Acquisition (SCADA) spoofing detection. - Refine secure network communication technologies that optimize the use of available communications links to create ad hoc secure emergency communications networks under conditions of substantial uncertainty. - Demonstrate capabilities to maintain and expand situational awareness in the aftermath of a cyber-enabled attack on the power grid. - Evaluate capability for rapid localization, isolation, and characterization of cyber weapons targeting a wide range of industrial control system devices and networks, and develop automated approaches to support cyber first responders in remediation efforts. - Collaborate with private industry, DoE, and other USG organizations to conduct robust exercises demonstrating enhanced capabilities to support black start restoration of a power grid amidst a cyber attack, and transition technologies. ***FY 2021 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Harden demonstrated capabilities to maintain and expand situational awareness in the aftermath of a cyber-enabled attack on the power grid in response to utility company feedback. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects ramping down of development and integration of prototypes for rapid recovery of the power grid from a cyber attack, continuation of exercises to establish technology operational readiness, and technology transition.			
Title: Intent-Defined Adaptive Software (IDAS)	-	8.000	17.400
Description: The Intent-Defined Adaptive Software (IDAS) program, addressing issues encountered in the Cyber Assured Systems Engineering (CASE) program, budgeted within this PE and Project, will develop 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 2020 Plans:*** - Formulate novel software engineering approaches that create and enforce strict separation between an abstract problem, including goals, constraints, and preferences, and concrete implementations. - Explore alternative approaches for automating the synthesis of code given its intent, quality goals, and operational constraints. - Develop an approach for using formal methods to verify that synthesized implementations will respect the goals and constraints of the problem. ***FY 2021 Plans:*** - Develop algorithms for deferring software concretizations until uncertainties are resolved for complex systems. - Develop techniques that permit optimization of multiple implementations, and enable more efficient encoding of quality goals and operational constraints. - Implement alternative software synthesis algorithms for automated modification by revising the representation of the intent of the software. ***FY 2020 to FY 2021 Increase/Decrease Statement:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The FY 2021 increase reflects ramping up of development of techniques for deferring software concretization and initial implementation of alternative synthesis algorithms.			
Title: Assured Micropatching (AMP)	-	7.100	16.800
Description: The Assured Micropatching (AMP) program, building on technical challenges encountered in the Computers and Humans Exploring Software Security (CHESS) program, also budgeted in this PE and Project, will develop 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. ***FY 2020 Plans:*** - Devise approaches for decompiling binary programs that can meet objectives such as alignment with available source code or fitness for a specified task. - Formulate strategies for producing a binary patch that is minimal with respect to the original binary when recompiled, with strong guarantees that the patch will not impair the functions of the system. - Design challenge tests for evaluating binary micropatching capabilities including challenges involving heavy vehicle firmware and other embedded and military systems. ***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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects a shift from initial designs to developing prototype decompilers and recompilers.			
Title: Securing Information for Encrypted Verification and Evaluation (SIEVE)	-	7.700	14.900

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: The Securing Information for Encrypted Verification and Evaluation (SIEVE) program, expanding on technical opportunities discovered in the Brandeis program, budgeted within this PE and Project, will develop technology to enable 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 2020 Plans:*** - Build efficient ZK proof generation compilers optimized for large and complex problem statements, and that can operate in an efficient manner. - Explore asymptotically efficient ZK constructions in the post-quantum setting. - Develop methodology to validate the functionality of ZK techniques and software on a set of possible DoD applications. ***FY 2021 Plans:*** - Extend ZK proof generation compilers to permit optimization for any subset of prover computation, verifier computation, total communication, and total number of communication rounds. - 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects expanded development work to extend cryptographic technologies and to validate their functionality, information leakage potential, and robustness to attack on a set of possible DoD applications.			
Title: Fast Network Interface Cards (FastNICs)	-	6.500	13.900
Description: The Fast Network Interface Cards (FastNICs) program, expanding on technical opportunities discovered in the Dispersed Computing program, budgeted within this PE and Project, will create 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			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
memory subsystems. FastNICs aims to enable a dramatic increase in computational throughput for distributed applications such as iterative training of machine learning systems. ***FY 2020 Plans:*** - Design improved architectures for the interface between an external network and a computing system that better balance communications bandwidth and processing throughput. - Extend the most widely used distributed systems software and operating systems to accommodate massively parallel input data streams. - Design algorithms and software for distributed computing applications, such as machine learning, that effectively utilize massively parallel data streams. ***FY 2021 Plans:*** - Implement and evaluate alternative architectures for the network interface, and quantify achievable communications bandwidth and processing throughput. - Demonstrate versions of widely used distributed systems software and operating systems that accommodate massively parallel input data streams. - Implement distributed computing applications, such as machine learning, that effectively utilize massively parallel data streams, and demonstrate performance improvements. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects expanded work to implement improved network interfaces and to demonstrate the technology on important distributed applications.			
Title: Open, Programmable, Secure 5G (OPS-5G) ***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. is 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 USG stakeholders.	-	-	12.100

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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, prevention, remote diagnosis and recovery. - Devise in-network sensors and reactive defenses for onset detection and scalable resilience against distributed denial of service (DDoS) attacks in 5G networks. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Cyber Course of Action Analysis (C2A2) ***Description:*** The Cyber Course of Action Analysis (C2A2) program will develop technologies for automatically generating and analyzing cyber courses of action (COAs) represented as graph structures. At present, developing cyber COAs to achieve specified effects, and assessing the risks associated with these COAs, is largely a manual process requiring many hours of effort. C2A2 aims to enable U.S. cyber operators to conduct cyber operations more rapidly and with greater degrees of success. ***FY 2021 Plans:*** - Develop analyst interface to enable automated cyber report generation. - Evaluate the utility of the interface and reports for quantifying the risk of cyber operations. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.	-	-	5.000
Title: Leveraging the Analog Domain for Security (LADS) ***Description:*** The Leveraging the Analog Domain for Security (LADS) program is developing 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 will 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. ***FY 2020 Plans:***	15.300	10.981	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Explore distance versus accuracy tradeoffs for discriminating between known and unknown code running on a device, and develop techniques to improve performance by integrating multiple analog side channels. - Extend and apply signal analysis techniques to complex devices, including those with field programmable gate arrays. - Support potential transition partners in test and evaluation using complex devices operating in both correct and compromised states. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease is the result of program completion.			
Title: Brandeis ***Description:*** The Brandeis program is creating 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 will 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 being designed to work with the virtualization, cloud computing, and software-defined networking technologies now widely used in both civilian and military environments. ***FY 2020 Plans:*** - Extend techniques to address challenging use cases, such as collaborative surveillance allocation and privacy-preserving combination of sensitive data sets. - Participate in exercises that demonstrate data communication privacy protection in collaboration with allies and non-governmental organizations. - Transition secure multi-party computation libraries and privacy preserving technologies to open source repositories and to U.S. government and DoD partners. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease is the result of program completion.	18.870	6.520	-
Title: Extreme Distributed Denial of Service Defense (XD3) ***Description:*** The Extreme Distributed Denial of Service Defense (XD3) program is developing 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	10.000	5.000	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
their botnets. XD3 will develop 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 ultimately thwart DDoS attacks. ***FY 2020 Plans:*** - Finalize testing and verification of the prototype defensive architectures by subjecting techniques to simulated DDoS attacks. - Harden, demonstrate, and transition technologies to the Defense Information Systems Agency (DISA) and commercial network providers. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease is the result of program completion.			
Title: Cyber Fault-tolerant Attack Recovery (CFAR) ***Description:*** The Cyber Fault-tolerant Attack Recovery (CFAR) program developed novel architectures to achieve cyber fault-tolerance with commodity computing technologies. The proliferation of processing cores in multi-core central processing units provides the opportunity to adapt fault-tolerant architectures proven in aerospace applications to mission-critical, embedded, and real-time computing systems. The CFAR program combined techniques for detecting differences across functionally replicated systems with novel variants that exhibit differences in behavior under cyber attack, so that CFAR-enabled computing systems can quickly detect deviations in processing elements at attack onset and rapidly reboot to restore affected services. CFAR technologies were developed in coordination with operational users.	5.000	-	-
Title: Edge-Directed Cyber Technologies for Reliable Mission Communication (EdgeCT) ***Description:*** The Edge-Directed Cyber Technologies for Reliable Mission Communication (EdgeCT) program developed technologies to enable reliable communications for military forces that operate in the presence of disrupted, degraded or denied wide-area networks. EdgeCT algorithms and software prototypes are implemented exclusively at the network edge, specifically on end hosts and/or on proxy servers fronting groups of such end hosts within a user enclave. EdgeCT systems sense and respond rapidly to network failures and attacks by dynamically adapting protocols utilized to exchange packets among these hosts, thereby implementing fight-through strategies that restore networked communication. This enables highly reliable networked communication for the military in the face of a wide variety of common network failure modes, as well as cyber attacks against network infrastructure. EdgeCT technologies were developed in coordination with operational commands and commercial service providers.	3.000	-	-
Accomplishments/Planned Programs Subtotals	249.979	250.111	236.182

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	FY 2019	FY 2020
Congressional Add: Distributed Ledger Technology ***FY 2020 Plans:*** - Conduct research in distributed ledger technology.	-	1.000
Congressional Adds Subtotals	-	1.000

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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
IT-04: *ARTIFICIAL INTELLIGENCE AND HUMAN-MACHINE SYMBIOSIS*	-	104.961	161.168	193.162	-	193.162	207.922	210.623	210.987	209.739	-	-

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 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. 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 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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Symbiotic Design*	10.701	16.883	23.582
Description: *Formerly Human-Machine Symbiosis (HMS) 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 reduce time to deployment. The current generation of DoD systems and platforms integrate cyber and physical subsystems. 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 this challenge by transforming the human-focused, model-based design flows used today into a symbiotic process of collaborative discovery by humans and continuously-learning AI-based co-designers. The program will create technologies essential for AI co-design, notably 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, and innovation metrics.			
FY 2020 Plans:			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Explore alternative means for human designers to communicate design intent via domain-specific design artifacts such as seed designs, design fragments, or abstract designs, in addition to traditional specifications such as performance and functional objectives. - Formulate approaches by which an AI co-designer can learn from past successful designs to propose new designs and refinement alternatives. - Introduce techniques for defining design spaces and for evaluating design points using domain-specific analysis and simulation tools. ***FY 2021 Plans:*** - Develop prototype mining engines and feature extractors to enable query generation from seed designs and 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. - Produce design challenge problems, and evaluate the effectiveness of symbiotic design technologies on sub-systems and systems of interest to the DoD. - Incorporate learning capabilities in computational agents that offer personalized guidance and anticipate the specific needs of each individual user. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects ramping up of development and implementation of symbiotic design techniques and evaluation on systems of interest to DoD.			
Title: Assured Autonomy ***Description:*** The Assured Autonomy program is developing rigorous design and analysis technologies for continual assurance of learning-enabled autonomous systems to guarantee safety properties 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 2020 Plans:***	19.520	25.550	19.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *ARTIFICIAL INTELLIGENCE AND HUMAN-MACHINE SYMBIOSIS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Develop scalable methods addressing formal verification of a preliminary set of safety properties for learning-enabled autonomous systems, and scalable algorithms for dynamic evaluation of assurance cases. - Construct monitors to detect data-distribution shifts as the operating environment diverges from the training environment. - Assess the reliability and sensitivity of techniques that diverge from modeling assumptions for different learning-enabled autonomous systems. - Apply technologies to assurance challenge problems for several learning-enabled autonomous platforms of interest to the DoD. ***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. - Develop scalable techniques for runtime verification of learning-enabled systems, and integrate safety constraints in online learning algorithms. - Demonstrate technologies on assurance challenge problems for several learning-enabled autonomous platforms of interest to the DoD. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from development efforts to technologies being demonstrated on several learning-enabled autonomous platforms.			
Title: Active Interpretation of Disparate Alternatives (AIDA) ***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, resulting in insufficient 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 2020 Plans:*** - Enhance multimedia analytics through use of feedback from generated hypotheses. - Develop techniques to limit the over-generation of hypotheses by automatically discarding irrelevant or duplicated hypotheses.	19.780	25.000	18.600

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *ARTIFICIAL INTELLIGENCE AND HUMAN-MACHINE SYMBIOSIS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Develop an intuitive interface that allows users to modify the extracted semantic elements and generated hypotheses at any stage of the analysis. - Collaborate with transition partners to assess the validity and completeness of generated hypotheses using real-world data. ***FY 2021 Plans:*** - Develop the means to rank hypotheses according to relevance and confidence, and the capability to verify and explore hypotheses injected 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. - Collaborate with transition partners to conduct experiments to evaluate performance on operational data. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects ramping down of development of techniques for generating multiple alternative interpretations from multimedia data, and continued evaluations of techniques on synthetic and real-world data.			
Title: Explainable Artificial Intelligence (XAI) ***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 too detailed, 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 will develop the tools necessary to build explainable AI systems, in particular (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. XAI implementations will be developed and demonstrated in next-generation data analytics and autonomous systems. ***FY 2020 Plans:*** - Refine the cognitive model of explanation, and show increased effectiveness of explanations generated by the systems. - Optimize explainable machine learning techniques and user interfaces for integration into prototype systems. - Expand the set of test problems in data analytics and autonomy for evaluating performance, explanation accuracy, and effectiveness of the systems.	20.830	26.050	17.380

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *ARTIFICIAL INTELLIGENCE AND HUMAN-MACHINE SYMBIOSIS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Evaluate performance and explanation effectiveness against test problems in data analytics and autonomy. ***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 with operational users. - Measure system explainability, accuracy, and learning performance against additional datasets and scenarios. - Select and integrate subsets of explainable model techniques in an operational prototype system for capability demonstrations coordinated with DoD and Intelligence Community (IC) partners. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects ramping down of development of explainable machine learning techniques, continued integration of techniques in machine learning systems, and expanded testing on problems in data analytics and autonomous systems.			
Title: Accelerating Artificial Intelligence (AAI) ***Description:*** The Accelerating Artificial Intelligence (AAI) program seeks to go beyond commercially-driven advances in AI and 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; (2) knowledge management tools that can efficiently capture, analyze and reason with expertise, experience, and data to prevent loss and increase value of critical national security knowledge/expertise; and (3) social context informed AI approaches to enable reliable and robust forecasting and decision aiding tools for stabilization, deterrence and gray zone operations. ***FY 2020 Plans:*** - Identify technical and programmatic criteria for military applications for testing and evaluating novelty-aware AI technologies. - Establish evaluation criteria and effective performance goals for novelty aware AI technologies in real military AI applications. - Identify data sources for development and training of AI systems for machine assisted human interviews and vetting processes.	-	24.100	29.400

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *ARTIFICIAL INTELLIGENCE AND HUMAN-MACHINE SYMBIOSIS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Develop, demonstrate, and evaluate pilot applications using algorithmic game theory based AI techniques for complex military decision problems. - Perform initial assessment of data, tools, and models associated with molecular design systems for relevance to DoD applications. - Develop and test AI system capabilities to provide plausible counterfactual predictions as evidence of AI contextual reasoning. - Develop sensing theories and concepts with a focus on information-shaping, data security, and personal privacy. - Implement prototype test bench systems, using commercial of the shelf (COTS) Field-Programmable Gate Array, photonic, and electronic components, to demonstrate the real-world system/process of the targeted signature detection applications. - Develop techniques to implement shallow neural networks (SNNs) with a non-multiply-accumulate based compute primitive. - Demonstrate a 10x reduction in SNN parameters with accuracy comparable to state of the art deep neural networks. - Develop and demonstrate algorithms that show progress towards enabling computers to learn real world concepts expressed in natural language, based on our understanding of how children learn language focusing on naming of visible objects and their attributes. - Demonstrate benchtop SNN in a DoD relevant communications or sensing application for edge AI, and performance projections of the SNN to a custom digital integrated circuit. - Develop adaptive signal processing kernels based on physics models and use generative training to improve accuracy of neural network kernels. - 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. - Determine extensibility and limitations of the approach by implementing the methodology and second game of different type/ architecture. - Develop and exercise exploration architectures including mission ontologies for representing contextual knowledge necessary to address primary research questions. Research questions center around machine teaming methods, especially decentralized heterogeneous machine teaming. - Initiate efforts to accelerate Artificial Intelligence with a focus on third wave AI. ***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. - Validate process and property optimization capabilities of molecular design systems through challenges informed by DoD applications. - Commence development of information-shaping sensor prototypes to validate privacy-assured sensing concepts. - Continue efforts to accelerate Artificial Intelligence with a focus on third wave AI. ***FY 2020 to FY 2021 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *ARTIFICIAL INTELLIGENCE AND HUMAN-MACHINE SYMBIOSIS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
FY 2021 increase reflects a shift from initial planning and exploration to system development.			
Title: Automated Rapid Certification Of Software (ARCOS)*	-	24.100	27.000
Description: *Formerly Automated Knowledge Acquisition (AKA) The Automated Rapid Certification of Software (ARCOS) program is developing technologies that automate the evaluation of software assurance evidence to enable certifiers to determine earlier in the process that system risks are acceptable. Current software certification practices do not scale with the amount of software being deployed by the DoD, so certification is becoming a bottleneck to new system deployment. ARCOS technologies will address DoD software system certification time and cost. ARCOS technology will automatically 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. ***FY 2020 Plans:*** - Design languages and tools for generating assurance case arguments suitable for integration in software development environments. - Develop techniques for extracting a model or specification of legacy software, and for analyzing the legacy assurance evidence. - Develop techniques for integrating diverse assurance evidence within a single structured representation. - Architect approaches for automatically generating and validating assurance case arguments and calculating their confidence level. ***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. - Demonstrate and validate automatically-generated assurance case arguments. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects ramping up of development of assurance case engineering tools, and demonstration of techniques on evidence from representative military platforms.			
Title: Knowledge-directed AI Reasoning Over Schemas (KAIROS)	-	15.485	21.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 society. 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 use existing event-representation schemas and, when needed, create 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 2020 Plans:*** - Develop and apply AI techniques for automated learning of new schemas for simple and complex events from open source data. - Develop temporal schemas to recognize patterns in complex event sequences. - Develop techniques for quantifying the degree to which a temporal schema models a complex sequence of event elements, and for quantifying the degree of confidence in those models. - Explore approaches for using partial matches to temporal schemas to interpolate or predict missing or future event elements. ***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. - 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. - In collaboration with potential transition partners, establish thresholds for mission utility for anticipating future events that are part of partially-observed complex events in operational data. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects ramping up of development of techniques for learning complex schemas, and initiation of assessment of techniques on operational data.			
Title: Stylized Language Processing (SLP) ***Description:*** The Stylized Language Processing (SLP) program will develop automated language processing techniques for sources that exhibit high degrees of domain-specific specialization. Natural language processing (NLP), a venerable sub-field of AI, has produced advanced but inexact capabilities for computers to process, translate, capture, transform, and utilize the	-	-	20.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
information contained in the text and speech humans use for their everyday communications. Highly stylized language, for which standard NLP is dubitable, has been encountered in new language genres such as the language intrinsic to social media, for which style may be so heavy as to resemble a code. Importantly, stylized language in a constrained form is also characteristic of technical, legal, scientific, and other more formal sources encountered in specialized domains. Finally, the challenges that arise from language manifestations as influenced by culture, emotion, and media choice provide further motivation for language processing capabilities that exploit features of style. These cases challenge standard NLP but also offer opportunities for greater accuracy. The SLP program will develop language processing technologies for stylized language as it is used in specialized domains, new communication and social media, and by diverse cultures and populations. The techniques developed under the SLP program will be coordinated with DoD operators and applied to military application areas such as the engineering development of complex systems and intelligence analysis of foreign language information in cultural context. ***FY 2021 Plans:*** - Formulate automated techniques to process, translate, capture, transform, and utilize the information contained in technical, legal, scientific, and/or other stylized sources encountered in specialized domains. - Formulate automated techniques for understanding language manifestations as influenced by culture, emotion, and media choice. - Formulate initial applications of stylized language processing technologies to military application areas such as the engineering development of complex systems and intelligence analysis of foreign language information in cultural context. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Engineering Artificial Intelligence Systems Implementations (EAISI) ***Description:*** The Engineering Artificial Intelligence Systems Implementations (EAISI) program will create technologies and tools to support the development of viable and trusted system 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 machine learning (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 researchers 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	-	-	17.200

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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. - Initiate the implementation of AI engineering technologies into tools for use by non-expert developers and evaluators. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Low Resource Languages for Emergent Incidents (LORELEI) ***Description:*** The Low Resource Languages for Emergent Incidents (LORELEI) program is developing 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 takes a different approach by leveraging language-universal resources, projecting from related-language resources, and fully exploiting a broad range of language-specific resources. These are targeted capabilities that will be exercised to rapidly provide situational awareness based on information from any language in support of emergent missions such as humanitarian assistance/disaster relief, terrorist attack response, peacekeeping, and infectious disease response. ***FY 2020 Plans:*** - Implement final improvements, and demonstrate capabilities on languages of interest to potential transition sponsors. - Integrate the situational awareness platform into the work space of transition partners, and support field tests. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease is the result of program completion.	9.130	4.000	-
Accomplishments/Planned Programs Subtotals	79.961	161.168	193.162

	FY 2019	FY 2020
Congressional Add: DARPA Foundational and Applied Artificial Intelligence	25.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *ARTIFICIAL INTELLIGENCE AND HUMAN-MACHINE SYMBIOSIS*

	FY 2019	FY 2020
FY 2019 Accomplishments: - Defined temporal schemas for a broad range of event sequences including in particular events of potential interest to military decision makers. - Formulated top-down approaches for associating events under analysis with existing temporal schemas. - Developed approaches for integrating and enforcing safety constraints in learning-enabled systems. - Enabled natural language learning as a child would, based on visual cues gleaned from events, objects, and their properties. - Initiated effort to develop AI systems that can leverage disparate data sources for counterfactual reasoning and prediction. - Implemented comprehensive photonic reservoir algorithms, architectures and hardware for the performance requirements of targeted signature detection applications. - Investigated next-generation AI technologies to develop long-lasting, high-bandwidth neural prosthetics.		
Congressional Adds Subtotals	25.000	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	31.951	34.588	26.950	-	26.950	25.071	30.536	38.536	41.035	-	-
BW-01: *BIOLOGICAL WARFARE DEFENSE*	-	31.951	34.588	26.950	-	26.950	25.071	30.536	38.536	41.035	-	-

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 included: 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 also includes development of a unique set of platform technologies and medical countermeasures synthesis that will dramatically decrease the timeline from military threat detection to countermeasure availability.

B. Program Change Summary ($ in Millions)	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	33.640	34.588	29.836	-	29.836
Current President's Budget	31.951	34.588	26.950	-	26.950
Total Adjustments	-1.689	0.000	-2.886	-	-2.886
• 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	-0.558	0.000			
• SBIR/STTR Transfer	-1.131	0.000			
• TotalOtherAdjustments	-	-	-2.886	-	-2.886

Change Summary Explanation

FY 2019: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2020: N/A
FY 2021: Decrease reflects repricing of the Defense Against Mass Terror Threats program.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Defense Against Mass Terror Threats	31.951	34.588	26.950

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021
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 2020 Plans:*** - Initiate development of a continuous, wide-area sensing, full spectrum WMT sensing platform that integrates developments in physical sensors, automated intelligence and network algorithms, open source IT platforms, and adversary models. - Test and further develop initial chemical and biological sensor suite based on sensor specificity, sensitivity, and time to detection performance to enable scalable and robust wide-area sensing. - Continue development of an open source, continuous, wide-area sensing IT platform capable of simultaneous ingress and fused analysis of thousands of real-time, multi-modal physical sensor and information feeds. - Continue development of algorithms capable of multi-modal sensor and information fusion, informed by potential adversary behaviors learned from scaled social science models, for threat detection that maximizes sensitivity while minimizing false alarms. - Mature collaborations with law enforcement, Federal and international partners to support testing of sensor and network systems, support access to relevant data sets, and enable future transition activities. - Conduct demonstrations and data collects of chemical and biological sensor systems. ***FY 2021 Plans:*** - Continue spiral development of chemical and biological sensors to include initial 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. - Continue spiral development of a network backbone and operating system supporting sensor and transactional data ingestion, including structured and unstructured data via natural language processing and assemblage of world graphs. - 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 transactional data sets and sensor data. - 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 2020 to FY 2021 Increase/Decrease Statement:***			

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021
FY 2021 decrease reflects shift from design and development to evaluation and demonstration.			
Accomplishments/Planned Programs Subtotals	31.951	34.588	26.950

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 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	295.118	313.002	233.271	-	233.271	199.803	225.225	245.549	334.744	-	-
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	40.493	42.859	14.890	-	14.890	13.059	29.059	36.059	59.059	-	-
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	119.409	113.440	69.883	-	69.883	33.548	21.491	38.951	75.951	-	-
TT-07: *AERONAUTICS TECHNOLOGY*	-	46.696	53.119	56.119	-	56.119	70.119	84.519	75.528	72.528	-	-
TT-13: *INFORMATION ANALYTICS TECHNOLOGY*	-	88.520	103.584	92.379	-	92.379	83.077	90.156	95.011	127.206	-	-

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 2021 Defense Advanced Research Projects Agency	**Date:** February 2020
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 2019**	**FY 2020**	**FY 2021 Base**	**FY 2021 OCO**	**FY 2021 Total**
Previous President's Budget	309.466	337.602	283.854	-	283.854
Current President's Budget	295.118	313.002	233.271	-	233.271
Total Adjustments	-14.348	-24.600	-50.583	-	-50.583
• Congressional General Reductions	0.000	-24.600			
• Congressional Directed Reductions	-1.500	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-2.442	0.000			
• SBIR/STTR Transfer	-10.406	0.000			
• TotalOtherAdjustments	-	-	-50.583	-	-50.583

Change Summary Explanation

FY 2019: Decrease reflects reprogrammings, the SBIR/STTR transfer, and a congressionally-directed transfer for the National Security Commission on Artificial Intelligence.

FY 2020: Decrease reflects congressional reduction.

FY 2021: Decrease reflects completion of the Squad X and Mobile Force Protection (MFP) programs in FY 2020 in the Advanced Land Systems Technology Project.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	40.493	42.859	14.890	-	14.890	13.059	29.059	36.059	59.059	-	-

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 2019	FY 2020	FY 2021
Title: Multi-Azimuth Defense Fast Intercept Round Engagement System (MAD-FIRES)	28.493	29.859	7.534

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.

FY 2020 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.
- Begin detailed planning for end-to-end system demonstration against surrogate targets.

FY 2021 Plans:
- Begin end-to-end tests leading up to demonstrations against flying targets.

FY 2020 to FY 2021 Increase/Decrease Statement:

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
The FY 2021 decrease reflects completion of end-to-end system demonstrations.			
Title: Port Defense / Mine Counter Measures (MCM) ***Description:*** The Port Defense / Mine Counter Measures (MCM) program will explore novel technologies and concepts of operations to mature a capability to protect U.S. waterways, thus enabling unencumbered naval operations. The program will conduct research and development for expendable unmanned underwater vehicles (UUVs) that will be used to support MCM payloads. This will allow for a paradigm shift in mine clearance efforts away from human-intensive and time-intensive approaches, towards rapid and autonomous sweeping by a large number of UUVs. ***FY 2021 Plans:*** - Begin design of miniaturized payloads. - Conduct a trade space analysis of UUVs, payloads, and employment concepts. - Begin preliminary design and risk reduction activities to advance novel technologies and concept of operations. - Begin developing a prototype UUV as a pilot study for expansive and rapid MCM payload support. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.	-	-	7.356
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 approaches to support mission execution, and autonomy approaches that do not rely on human intervention. Starting in FY 2020, this program is also funded in PE 0603766E, Project NET-02. The anticipated transition is to the Navy. ***FY 2020 Plans:*** - Complete Conceptual Design Review (CoDR). - Conduct Preliminary Design Review (PDR). - Test robot subsystems in laboratory or simulation environments. ***FY 2020 to FY 2021 Increase/Decrease Statement:***	12.000	13.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
The FY 2021 decrease reflects the budget shift from Project TT-03 to Project NET-02.			
Accomplishments/Planned Programs Subtotals	40.493	42.859	14.890

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	119.409	113.440	69.883	-	69.883	33.548	21.491	38.951	75.951	-	-

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. 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, and 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 2019	FY 2020	FY 2021
Title: Urban Reconnaissance through Supervised Autonomy (URSA)	19.800	23.000	19.000

Description: The Urban Reconnaissance through Supervised Autonomy (URSA) program is developing and demonstrating new autonomous agents and techniques that can rapidly discriminate hostile intent and filter out threats during missions ranging from minutes to hours, leveraging natural or created stimuli to elicit behavioral responses among humans in an area. 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 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 with hostile intent. 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 probing behaviors to expose human intent 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 probing actions to improve confidence in its decisions, and building a novel framework for escalating nonlethal force.

FY 2020 Plans:
- Demonstrate initial URSA system capabilities in limited, controlled, performer-selected environments.
- Continue to develop URSA system architectures.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Assess URSA system capabilities and use cases through URSA Integrated Testbed (UIT) environments. - Demonstrate improved URSA system capabilities in limited, controlled, performer-selected environments. - Continue quarterly LME working group meetings and facilitate engagements with technology performers. - Identify URSA end-to-end system capabilities to inform future prototype system development and field experimentation campaign. ***FY 2021 Plans:*** - Continue to develop and increase the fidelity of the UIT for iterative evaluation of expanding URSA system capability. - Develop test infrastructure for live URSA field demonstrations. - Evaluate URSA performance with incremental field demonstrations in increasingly complex urban environments. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects transition to field demonstrations.			
Title: Subterranean (SubT) Challenge	25.060	34.000	20.800
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 2020 Plans:*** - Conduct baseline design, development, and integration of proposed solutions in the subdomain of urban underground. - Conduct circuit competition in the subdomain of urban underground. - Conduct baseline design, development, and integration of proposed solutions in the subdomain of cave networks. - Conduct circuit competition in the subdomain of cave networks. - Continue development and enhancement of the virtual testbed. ***FY 2021 Plans:*** - Conduct baseline design, development, and integration of proposed solutions in the combined subdomains of tunnel systems, urban underground, and cave networks. - Conduct final competition in the combined subdomains of tunnel systems, urban underground, and cave networks.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Continue development and refinement of the virtual test bed. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects completion of the challenge events.			
Title: Underminer* ***Description:*** *Formerly Tactical Networks of Tunnels (TNT) The Underminer effort, an outgrowth of the Subterranean Challenge program, is exploring the development and integration of technologies to investigate, create, and employ technologies that drill/bore, build, and use the underground environment for tactical operations in rapid, secure resupply. 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 2020 Plans:*** - Complete initial trade studies. - Initiate development of Underminer concept of operation, system architecture, and demonstration test plans. - Begin development and demonstration of enabling technologies. ***FY 2021 Plans:*** - Continue development and demonstration of enabling technologies. - Verify that the technologies developed meet the required speed and accuracy thresholds. - Test subsystems in laboratory or representative environments. - Conduct system demonstrations in representative environments. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program final demonstrations and reporting.	8.140	10.000	8.601
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 seeks to enable warfighters to manipulate the urban environment through the application of novel materials research. Rapunzel envisions 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	-	4.000	4.482

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
and concealment. The program will identify 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 will leverage 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. ***FY 2020 Plans:*** - Conduct trade space analysis and technical assessments regarding novel materials that are quickly field assembled and fabricated into lightweight components. - Initiate development of mobility, counter-mobility, survivability, and concealment core requirements and systems architectures. - Initiate development of critical systems engineering approaches and perform baseline demonstrations derived from primitives of existing technologies that can be leveraged to refine program metrics. - Develop operational and technical performance models. ***FY 2021 Plans:*** - Initiate development of technology area/task-based core integrated materials system components. - Test materials and systems performance in a lab environment at preliminary scales, masses, and ranges without system packing, volume, or density concerns. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects completion of trade space analysis and shift to the lab environment materials tests.			
Title: Proportional Weapons ***Description:*** The Proportional Weapons program will create 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 absolutely effective from the air or ground against several scales of primarily urban, concealed threats while not being catastrophically destructive. Current approaches to identifying, engaging, and assessing effects against evasive ground targets in complex terrain requires significant human oversight combined with human semantic reasoning tied to rules of execution, resulting in slow and methodical engagements. Proportional weapons will develop next generation effects for ground systems that provides extended range and tunable effects with greatly minimized impact to a warfighter operator. 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:***	-	-	6.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Begin developing systems architectures and analysis approaches for the proportionality of effects systems at multiple scales against multiple land-based threats. - Execute performance trade studies, develop concepts, and assess technical effects analysis. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY2021 increase reflects program initiation.			
Title: Sustained Combat Operations in Undefined Terrain (SCOUT)*	-	5.000	11.000
Description: *Formerly Highly Networked Dissemination of Relevant Data (3HNDRED) The Sustained Combat Operations in Undefined Terrain (SCOUT) program will explore an integrated system to aid ground troops in understanding and shaping the battlefield environment before, during, and after tactical operations. SCOUT will develop ground robotic platforms with enhanced, all-terrain mobility, extended endurance, and novel movement techniques to increase platform survivability and reduce detection. This capability will enable long-duration pre-mission reconnaissance, extending the timeline of current human scouts by 5-10x, and will support continuous patrolling or tactical resupply during sustainment operations. SCOUT is envisioned to host mission payloads that will integrate with other heterogeneous sensors, such as soldier-borne, vehicle-borne, weapon status indicators, and manned or unmanned ground/air assets, to form a complete picture of an area of interest. This will enable new, networked capabilities at the tactical level, such as automatic generation of reports populated with event, location, and status of forces, both manned and unmanned, to support response. SCOUT developed systems will provide mobility and extended endurance to enable increased payload access and information to pro-actively stage forces, enable on-demand resupply, or rapidly call for fires in support of timely operations. The confluence of mobility, endurance, and survivability developed under the SCOUT program will push the state of the art in unmanned ground systems and support on-the-fly battlefield management, providing an asymmetric advantage to U.S. forces. ***FY 2020 Plans:*** - Complete preliminary design and research of sensor architecture. - Fabricate multiple sensor hardware kits. - Perform at least two data collection events with military users to assess performance of integrated sensor system and data processing algorithms. ***FY 2021 Plans:*** - Initiate system design for SCOUT robotic platforms. - Initiate development of SCOUT enabling technologies. - Initiate definition of SCOUT platform assessment events. ***FY 2020 to FY 2021 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
The FY 2021 increase reflects initiation of robotic platform design work and enabling technology development.			
Title: Squad X	29.009	21.440	-
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 is 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 includes increased human stand-off, a smaller force density, and adaptive sensing to allow for responses at multiple scales. Squad X is exploring 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 is 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 2020 Plans:*** - Continue expanded squad system development efforts focusing on enhanced situational awareness and engagement capabilities. - Continue to develop and optimize the real-world environment abstraction layer for squad activities. - Demonstrate mission planning, rehearsal, and playback capabilities using the squad-leader-in-the-loop (SLIL) 3D simulation environment. - Continue to leverage the squad-leader-in-the-loop (SLIL) environment to plan and rehearse missions with increased squad system/subsystem and threat capabilities. - Optimize autonomous cross-cuing of squad assets and sensor nodes, and integrated kinetic and non-kinetic engagement capabilities. - Integrate multiple unmanned nodes into the squad system, with enhanced mobility and/or payload capabilities. - Conduct increasingly complex system-level experimentation and evaluation with operational units, to include: increased number of humans and unmanned systems in the squad and new squad technologies/capabilities. - Experiment with system performance in multiple locations, terrains and environments. - Experiment with system performance against multiple, technology-enabled adversaries with capabilities analogous to near-peer/peer states. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: Mobile Force Protection (MFP)	37.400	16.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
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 (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 2020 Plans:*** - Fabricate and integrate on the move end-to-end demonstration system. - Integrate 3rd party sensors and interceptors to demonstrate interoperability and software openness. - Validate and complete MFP system engagement modeling and simulation tool for transition. - Complete affordability and unit cost analysis for transition. - Conduct open-air demonstrations that include realistic threats, performance models, signatures, networks, and environmental factors. - Explore opportunities for alternative kill mechanisms with larger magazines for greater effectiveness against swarms. - Transition prototypes to Services for field testing. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Accomplishments/Planned Programs Subtotals	119.409	113.440	69.883

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
TT-07: *AERONAUTICS TECHNOLOGY*	-	46.696	53.119	56.119	-	56.119	70.119	84.519	75.528	72.528	-	-

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 2019	FY 2020	FY 2021
Title: OFFensive Swarm-Enabled Tactics (OFFSET)	19.500	13.000	8.000
Description: The OFFensive Swarm-Enabled Tactics (OFFSET) program will design, develop, and demonstrate 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 2020 Plans:*** - Demonstrate interfaces for and execution of viable swarm tactics-based courses-of-action. - Continue integration of advanced swarm tactics for capability-based experimentation. - Commence swarm sprints focusing on advancing the virtual environment, applying artificial intelligence methods, and augmenting the physical testbed to enable operationally relevant objectives. ***FY 2021 Plans:*** - Conduct capability-based field experimentation events that demonstrate swarm tactics for scaled missions of relevance. - Continue advancing the virtual environment and augmenting the physical testbed. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from swarm sprint integration efforts to field experimentation.			
Title: Advanced Aeronautics Technologies	3.000	3.000	3.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-07 / *AERONAUTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: The Advanced Aeronautics Technologies program will examine and evaluate 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 or improvement of existing systems. ***FY 2020 Plans:*** - Perform studies to support development of innovative prototypes. - Initiate new studies of novel technologies to improve speed and range. ***FY 2021 Plans:*** - 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.			
Title: Control of Revolutionary Aircraft with Novel Effectors (CRANE)	-	20.000	25.000
Description: The Control of Revolutionary Aircraft with Novel Effectors (CRANE) program will demonstrate 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; broadly defined, it is a control mechanism which alters 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 2020 Plans:*** - Conduct technology analysis of AFC components and control scheme. - Complete conceptual design. - Perform risk reduction and experimentation. - Initiate preliminary design of technology demonstrator. ***FY 2021 Plans:*** - Complete Preliminary Design Review (PDR). - Initiate detailed design of technology demonstrator. - Initiate flight software and control law development.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-07 / *AERONAUTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Perform wind tunnel and component level testing. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program focus on detailed design and component testing.			
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 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 2020 Plans:*** - Demonstrate the applicability of artificial intelligence advances in large-scale autonomous system threats. - Initiate research and development in machine learning advances and adversarial games to identify salient swarm attributes. - Establish baseline technology advances needed for counter swarm engagement decisions. ***FY 2021 Plans:*** - Conduct capability-based field experimentation events that demonstrate artificial intelligence advances in large-scale autonomous system threats. - Continue to establish technology advances needed for counter swarm engagement decisions. - Develop an integrated software and middleware architecture with limited-scale field demonstrations in relevant operational contexts.	-	5.000	5.000
Title: Counter High Energy Lasers (C-HEL) ***Description:*** The Counter High Energy Lasers (C-HEL) program will provide a system that detects, locates and disrupts HEL adversary kill chains before irreversible damage occurs and offers survivability protection and concept of operations (CONOPS) for multi-domain U.S. assets. The system will develop novel sensing and detection techniques to detect and locate HEL signatures before and during HEL firing during day/night conditions and will leverage material advances for protective coatings to improve warfighter endurance during HEL attacks. Potential detection modalities include low-light scattering detection of high-energy laser systems and coherent detection. CONOPS, protective materials, and obscurants will be evaluated for potential	-	-	15.119

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-07 / *AERONAUTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
improvements to survivability of systems targeted by HEL weapons. Many elements of HEL systems are vulnerable, and HEL defeat systems may include kinetic and optical approaches. ***FY 2021 Plans:*** - Develop initial point-of-departure designs for operational C-HEL system. - Initiate trade studies and modeling and simulation to refine operational system concept. - Develop C-HEL operational system requirements, demonstration plans for proof-of-concept prototype, and risk reduction/ technology maturation approach. - Conduct conceptual design review for initial operational system. - Demonstrate and test component level technologies. - Conduct field test of protective coatings in a relevant environment. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Gremlins ***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, variable geometry stores, 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. ***FY 2020 Plans:*** - Conduct preliminary airborne recovery flight demonstrations. - Conduct final flight test demonstrating full recovery capability. - Conduct flight analysis and reporting of final program objectives. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.	15.567	12.119	-
Title: Aircrew Labor In-cockpit Automation System (ALIAS) ***Description:*** The Aircrew Labor In-cockpit Automation System (ALIAS) program designed, developed, and demonstrated a kit enabling affordable, rapid automation of selected aircrew functions across a broad range of aircraft. ALIAS enabled reduction of	8.629	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-07 / *AERONAUTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
aircrew workload and/or the number of on-board aircrew to improve performance. The program developed hardware and software to automate select aircrew functions and will employ novel, low impact approaches to interface with existing aircraft monitoring and control systems. The program also developed tractable approaches to rapidly capture crew-station specific skills and aircraft unique behaviors. To accomplish this, ALIAS leveraged recent advances in perception, manipulation, machine learning, reusable software architectures, autonomous systems architecture, and verification and validation. ALIAS culminated in a demonstration of the ability to rapidly adapt a single system to multiple aircraft and execute simple missions. This reliability enhancement capability enables new operational concepts for reuse of existing air assets and allows a reduction in the number of aircrew required.			
Accomplishments/Planned Programs Subtotals	46.696	53.119	56.119

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
TT-13: *INFORMATION ANALYTICS TECHNOLOGY*	-	88.520	103.584	92.379	-	92.379	83.077	90.156	95.011	127.206	-	-

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, 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. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Warfighter Analytics using Smartphones for Health (WASH)	11.810	18.580	20.000

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 produce a mobile application that continuously and reliably assesses warfighter health and mission readiness. WASH is coordinated with the Naval Health Research Center.

FY 2020 Plans:
- Develop and conduct periodic audits of the security and privacy controls of the cloud-based data ingest and storage infrastructure, and perform upgrades as appropriate.
- Refine digital biomarker computation to enable discrimination of noise based on context, for example, vehicular vibration versus behavioral movement.
- Perform field assessments of sensitivity and specificity of smartphone-based digital biomarkers for detection and diagnosis of physiological disease and assessment of cognitive state in collaboration with Naval Health Research Center.

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.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Evaluate algorithms to associate digital biomarkers with physiological and cognitive state across a diverse set of relevant ambient contexts. - Increase scale of cloud-based data ingest and storage infrastructure for a larger study in collaboration with Naval Health Research Center. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase is due to continued work to develop and integrate techniques to analyze user smartphone data, and additional work to evaluate the performance of techniques to assess user physiological health and cognitive state.			
Title: Adapting Cross-domain Kill-Webs (ACK)	8.000	15.000	17.000
Description: The Adapting Cross-domain Kill-Webs (ACK) program will assist 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 2020 Plans:*** - Develop capability (sensors, weapons, communications, etc.) representations necessary to support the ACK program concept. - Begin development of the supplier-side, virtual liaison offer generation algorithms, and the consumer-side, C2 node algorithms for adjudicating amongst the offered capabilities. - Begin development of a supporting user interface that enables an operator to visualize recommendations and select a final plan. - Begin development of the evaluation test bed. ***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 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Identify Service partners and develop plans for demonstration of cross-domain mission adaptation. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** FY 2021 increase is due to shift from tool and test bed development to demonstration, testing, and enhancement.			
Title: Modeling Adversarial Activity (MAA)	9.500	18.500	14.225
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 graph models reflecting prototypical WMT pathways, develop methods for creating merged activity graphs by aligning entities across multiple intelligence modalities, develop algorithms to match 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 the Defense Threat Reduction Agency (DTRA) and the Department of Homeland Security (DHS). ***FY 2020 Plans:*** - Evaluate methods to support partial pathway matching and adapt pathway models, including mechanisms for refining prototype pathway recognizers that are generating high rates of false alarms. - Generalize the graph alignment and matching techniques to noisy knowledge graphs derived from multiple structured and unstructured sources. - Develop techniques for approximate matching of activity graphs for real world data with rich semantics. - Scale methods to enable calculations on realistically large graph models. ***FY 2021 Plans:*** - Evaluate the scalability of techniques for both construction of large, semantically-rich graphs and approximate matching of activity graphs with rich semantics on real world data. - Extend real-time graph alignment capabilities to environments with frequent information updates. - 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 2020 to FY 2021 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
The FY 2021 decrease reflects ramping down of work to develop techniques and software for WMT pathway discovery, and the focus shifting to evaluation on realistic data.			
Title: Data-Driven Discovery of Models (D3M)	18.310	16.000	12.034

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 analysis of sensor and open source data. The DoD and the Intelligence Community (IC) are fundamentally limited by a shortage of 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 2020 Plans:
- Extend modeling primitives to handle heterogeneous and unstructured data from disparate sources and integrate into toolkits.
- Extend composability techniques to enable the construction of data analytic pipelines for complex problems, such as predicting events utilizing a combination of open source intelligence data and data from protected sources.
- Formulate measures and models for normal/anomalous behavior of financial markets, and propose indications and warnings to quickly detect and characterize attacks on financial infrastructure.
- Collaborate with transition partners from the DoD and IC to perform quantitative assessments of automatically-generated models and to compare these with their internal-expert-developed models on real-world data.

FY 2021 Plans:
- Complete the library of modeling primitives with support for unsupervised and semi-supervised machine learning, including unsupervised data discovery.
- Extend automated data collection to support discovery and augmentation of datasets with limited or no human-in-the-loop, and with support for non-traditional application domains where insufficient or no training data exists.
- Develop scalable techniques for integrating heterogeneous, high-volume financial data streams to enable near-real-time situational awareness of financial markets.
- Enable transition and deployment of complete open source end-to-end software systems.

FY 2020 to FY 2021 Increase/Decrease Statement:

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
The FY 2021 decrease is the result of development work ramping down and the focus shifting to demonstrations in collaboration with transition partners.			
Title: Causal Exploration of Complex Operational Environments	18.400	20.500	11.500
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 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 will develop 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 2020 Plans:*** - Demonstrate techniques to model degrees of uncertainty through all parts of the system, to enable users to quickly assess the robustness of operational designs, and to update models of operational environments as new information arrives. - Integrate language processing and social media analysis technologies to enable indications and warnings of adversary information operations campaigns. - Conduct collaborative experiments in which military planners and program developers work together to further refine the technology on simulated operations, and an operational evaluation to measure usability and suitability of the system. - Transition system and support incorporation of training materials into Service school curriculum. ***FY 2021 Plans:*** - Develop scalable social media analytics for real-time effectiveness assessment of adversary information operations campaigns and countermeasures. - Identify additional transition partners and tailor system functionality to meet key needs for operational deployment. - Conduct final operational evaluation to measure usability and suitability of the system for operational deployment. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease is due to ramping down of work to develop technologies, and focus shifting to operational evaluation with military users.			
Title: Semantic Forensics (SemaFor)	-	9.700	17.620

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: The Semantic Forensics (SemaFor) program, building on technologies introduced in MediFor, will develop 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, and purely statistical detection methods are now insufficient. 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 will create 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 generated or manipulated for malicious purposes. SemaFor aims to create technologies to identify, deter, and understand adversary disinformation campaigns. ***FY 2020 Plans:*** - Devise initial algorithms that reason about semantic inconsistencies in multi-modal media assets to detect if they have been manipulated, if their purported sources are correct, or if the manipulation would have a negative real world impact. - Create baseline approaches for fusing multi-source semantic and statistical information into summary indicators for detection, attribution, and characterization of impact. - Formulate an architecture for a semantic media analysis system to support demonstration and evaluation. ***FY 2021 Plans:*** - Develop general semantic characterization algorithms that reason about whether a media asset or narrative is synthetic. - Develop mechanisms for explaining algorithmically-generated semantic inferences, and apply semantic analysis techniques to multimedia. - Develop a system prototype and evaluate performance on existing and purpose-built text, image, video, and audio libraries. - Develop challenge problems that emphasize threat scenarios in collaboration with DoD and Intelligence Community (IC) partners. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 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: Media Forensics (MediFor) ***Description:*** The Media Forensics (MediFor) program is creating technologies for analyzing media content to determine trustworthiness for military and intelligence purposes. Current approaches to media forensics are labor intensive, requiring analysts and investigators to undertake painstaking analyses to establish context and provenance. The program will develop, integrate, and extend image and video analytics to provide forensic information that can be used by analysts and automated	17.500	5.304	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
systems to quickly determine the integrity of open source and captured images and video. Technologies will transition to operational commands and the Intelligence Community (IC). ***FY 2020 Plans:*** - Enhance robustness of integrity assessment approaches to deep-fake and other generative attacks. - Harden the integrity assessment prototype, and demonstrate on large scale datasets in collaboration with transition partners from the DoD and IC. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: Distributed Battle Management (DBM) ***Description:*** The Distributed Battle Management (DBM) program developed mission-driven architectures, protocols, and algorithms for battle management (BM) in contested environments. The military is turning to networked weapons and sensors onboard a heterogeneous mix of multi-purpose manned and unmanned systems. In contested environments, it is a challenge for BM networks to communicate with subordinate platforms due to extensive adversarial cyber and electronic warfare operations, anti-satellite attacks, and the need for emissions control in the face of a formidable integrated air defense system. The DBM program developed a distributed command architecture with decentralized control of mission-focused asset teams. The architecture enabled rapid reaction to ephemeral engagement opportunities and maintained a reliable BM structure, despite limited communications and platform attrition in continuously evolving threat environments. The program incorporated highly automated decision making capability while maintaining vital human-in-the-loop operator approval. DBM technologies transitioned to the Air Force.	5.000	-	-
Accomplishments/Planned Programs Subtotals	88.520	103.584	92.379

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	192.774	214.976	250.107	-	250.107	245.748	263.598	290.037	308.873	-	-
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	86.508	100.803	100.041	-	100.041	102.122	123.993	149.593	153.199	-	-
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	106.266	114.173	150.066	-	150.066	143.626	139.605	140.444	155.674	-	-

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.

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.

B. Program Change Summary ($ in Millions)	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	208.898	223.976	245.397	-	245.397
Current President's Budget	192.774	214.976	250.107	-	250.107
Total Adjustments	-16.124	-9.000	4.710	-	4.710
• Congressional General Reductions	0.000	-9.000			
• 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	-4.099	0.000			
• SBIR/STTR Transfer	-12.025	0.000			
• TotalOtherAdjustments	-	-	4.710	-	4.710

Exhibit R-2, **RDT&E Budget Item Justification:** PB 2021 Defense Advanced Research Projects Agency	**Date:** February 2020
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*

Change Summary Explanation

FY 2019: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2020: Decrease reflects congressional reduction.
FY 2021: Increase reflects minor program repricing.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	86.508	100.803	100.041	-	100.041	102.122	123.993	149.593	153.199	-	-

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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Multi-Scale Modeling	14.208	17.000	11.500

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 2020 Plans:
- Implement promising approaches that dynamically utilize computational architectures (adaptive meshes, vector processing and cloud architecture) to increase space weather prediction forecast accuracy out to 72 hours.
- Demonstrate in simulation the ability to predict and track space weather phenomena with scale lengths as small as one hundred kilometers.
- Implement and demonstrate an extensible 4D assimilation data framework, incorporating visualization and machine learning algorithms, capable of processing data sources from at least two major space environment observations networks in less than fifteen minutes.

FY 2021 Plans:
- Using actual atmospheric event data, demonstrate the ability to predict perturbations and disturbances within lengths on the order of 100 km within 72-hour window.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Demonstrate the capability of plasma physics models to simulate wave/particle interactions necessary to inform understanding of electron depletion by electromagnetic (EM) waves. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects transition from heavy system development to testing and demonstrations.			
Title: Functional Materials and Devices	17.300	18.652	28.250
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 2020 Plans:*** - Initiate development of prototype test beds for transportable gamma ray sources that feature high intensity, tunability, and narrow bandwidth. - Conduct initial component and system modeling efforts to support realization of prototype test beds for high intensity, narrow band-width, and high-energy, modest intensity gamma-ray sources. - Identify and develop component technologies with potential for enabling intense, tunable, mono-energetic gamma-ray sources. ***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, transportable, mono-energetic gamma-ray sources. - Explore the potential for improved precision and accuracy in hybrid classical/quantum sensors that exploit a new class of high quality mechanical resonators that can be coherently manipulated at room temperature. - Develop algorithms for quantum sensing that significantly outperform current classical methods. ***FY 2020 to FY 2021 Increase/Decrease Statement:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The FY 2021 program increase reflects transition from component development to program integration and testing phases.			
Title: Chemical Processing for Force Protection	12.000	12.501	12.000
Description: Research in this 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 combines existing strategies for destruction of chemical agents with development of new processing methods to provide a remediation system that can process any chemical agent at the site of storage. In addition, investments in this thrust will advance chemical characterization, information management and analysis, and automation. ***FY 2020 Plans:*** - Demonstrate continuous flow synthesis of a molecule requiring a convergent approach (e.g., synthesis and subsequent combination of two intermediates). - Demonstrate full integration of molecular chemistry software and hardware, including route planning, system configuration, and molecular synthesis. - Initiate efforts to leverage new tools such as molecular discovery software, continuous flow reactors, and high throughput screening platforms for developing advanced energetic molecules and formulations. ***FY 2021 Plans:*** - Develop standardized protocols for conducting energetic-relevant experimentation using minimal quantities of energetic compounds. - Demonstrate, through modeling and simulations, scalability of approaches that consider final formulation for energetic ingredient development. - Leverage new energetic synthesis pathways to initiate development of advanced energetic formulations for one or more DoD relevant applications. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects minor program repricing.			
Title: Accelerating Discovery and Innovation	12.000	11.800	11.300
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			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Create and evaluate software tools to expedite the synthesis of multi-disciplinary conversations about emerging science and technology into evidence supported research proposals. - Develop and evaluate tools that allow for incorporation of the needs of research and development requirement generators with the capabilities of research and development performers. - Develop new features for the technology exchange website for the transition partner, the Marine Corps. ***FY 2021 Plans:*** - Apply and evaluate online, multi-platform structured conversation tools to rapidly identify evidence-based development opportunities. - Employ and evaluate online conversation tools to expedite the identification, vetting, and funding of research ideas. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY2021 decrease reflects minor program repricing.			
Title: Materials for Extreme Environments*	9.000	28.200	36.991
Description: *Previously part of Materials Processing and Manufacturing. The Materials for Extreme Environments thrust is exploring new materials, materials architectures, and materials 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 architected materials, high entropy alloys, and carbon fiber composites 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. Building on technologies developed under the Materials Processing and Manufacturing program, also in this Program Element, exemplar areas of research within the Materials for Extreme Environments thrust include the following: 1) high temperature materials for hypersonic platforms; 2) high temperature			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Explore approaches that leverage new architected materials and computational tools to fabricate complex structures that reduce heat load and enhance platform survivability in harsh environments. - Leverage recent breakthroughs in metrology to characterize atomic- through meso-scale materials behaviors. - Develop model guided testing tools to validate the behavior of new materials under extreme environmental conditions. - Evaluate technical approaches for mitigating thermal-optical interference in high temperature apertures. - Identify materials that are amenable to manufacture in the space environment. ***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 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 technologies such as friction stir extrusion or robotic self-assembly, that can be modified for zero gravity operation. - Identify metrology approaches to enable more precise assembly of structures in space. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects a shift from design to development and testing phases.			
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.	10.000	9.650	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
FY 2020 Plans: - Demonstrate redesign of coordinated functions to achieve maximum resilience. - Demonstrate dynamic adaptive response to achieve system re-design. - Demonstrate system design for adaptive response to a co-evolving threat coupled to attrition and environment change. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY2021 decrease reflects program completion.			
Title: Materials Processing and Manufacturing ***Description:*** The Materials Processing and Manufacturing thrust is exploring new manufacturing and processing approaches that will dramatically lower the cost and decrease the time required to fabricate DoD 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 is 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. ***FY 2020 Plans:*** - Demonstrate that a multifunctional element can be incorporated into the feedstock while maintaining performance. - Leverage advanced modeling tools to identify ideal use case for new composite materials and processing parameters. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.	12.000	3.000	-
Accomplishments/Planned Programs Subtotals	86.508	100.803	100.041

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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	106.266	114.173	150.066	-	150.066	143.626	139.605	140.444	155.674	-	-

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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Defend Against Crop System Attack	13.424	12.718	11.498

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 2020 Plans:
- Ensure two week-long stable viral transformation resulting in gene-based protection in plant target.
- Determine adequate virus concentration to achieve adult plant transformation.
- Perform risk mitigation of potential delivery challenges within complex laboratory environments.
- Integrate virus delivery approach to achieve adult plant transformation.

FY 2021 Plans:
- Demonstrate successful delivery of a virus carrying multiple genes for downstream plant trait modification.
- Demonstrate insect dispersal to targeted plants in a diverse plant community without transmission to non-target plants in a contained environment.
- Employ multi-faceted conditional lethal approach to limit survival of vector insects.

FY 2020 to FY 2021 Increase/Decrease Statement:

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The FY 2021 decrease reflects a reduction in initial proof-of-concept research activities to progress toward final integrated system demonstrations at scale.			
Title: Persistent Terrestrial Living Sensors	11.988	13.174	12.525
Description: The Persistent Terrestrial Living Sensors program is developing engineered biological sensor platforms capable of detecting land-based threats (e.g., chemicals, radiation, explosives) and relaying unique signals to existing DoD ground, air, and space assets. Unlike conventional methods that passively 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 detecting improvised explosive devices (IEDs) and protecting infrastructure. These sensors will provide a flexible suite to complement conventional sensor systems within the DoD. ***FY 2020 Plans:*** - Demonstrate genetic modification of plant-expressed sensory proteins associated with DoD-relevant compounds. - Demonstrate genetic modification of plant-expressed reporting signals at detectable levels. - Identify internal plant resource issues that will have to be addressed to develop a real-world detection platform. - Identify external biotic and abiotic challenges that need to be addressed to avoid practical use of plants as sensors. - Test methods for stand-off detection of signals produced by microorganisms in response to subterranean sensing. ***FY 2021 Plans:*** - Integrate plant platform to align threat detection with plant resource and ecology traits. - Demonstrate the capability of stress resistant plants to sense and detect threats at stand-off. - Develop a simulated environment containing co-occurring plant, insect, and microbial species representing realistic competitive, predator, parasitic, and mutualistic interactions. - Demonstrate the adaptability to grow plants in multiple simulated environments under realistic environmental stressors. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects minor program repricing.			
Title: Preemptive Expression of Protective Alleles (PREPARE)	15.118	16.097	16.899
Description: The Preemptive Expression of Protective Alleles (PREPARE) program is creating a transient, near immediate prophylaxis 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			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
within this project will provide novel solutions that extend beyond the DoD's limited protective capabilities to respond to re-emerging, newly emerging, or engineered threats. ***FY 2020 Plans:*** - Demonstrate multiplexed targeting of cellular resistance genes to resist multiple threats. - Demonstrate and optimize specificity and duration of modulation of gene modulators in animal models. - Optimize delivery tool specificity for gene modulators in vitro. - Begin demonstration of target-agnostic platform that can address multiple threats using a common set of gene modulation and delivery components. - Investigate timing of optimal countermeasure administration to maximize therapeutic and prophylactic performance. ***FY 2021 Plans:*** - Establish Target Product Profile (TPP) to guide initial regulatory discussions and inform preclinical studies to determine efficacy of programmable gene modulator based medical countermeasures against Chemical, Biological, Radiological and Nuclear (CBRN) threats. - Determine optimal delivery formulations to deliver programmable gene modulators in vivo to appropriate cells and tissues with high specificity and for threat-relevant periods of time. - Demonstrate and optimize specificity to targets and duration and magnitude of modulation of programmable gene modulators in vivo. - Demonstrate effectiveness of programmable gene modulator platform to protect against a biological, radiological, or chemical threat in vivo. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects minor program repricing.			
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 2020 Plans:***	18.204	27.066	25.720

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Characterize biological responses to targets and confounders at greater distances and in more realistic environments. - Investigate approaches to evoke biological responses in marine organisms. - Harden engineered components for persistent deployments. - Develop fully integrated seaworthy prototype combining biology and engineered components. - Develop hardware and software to detect and classify targets and confounders in ecosystem-style aquaria or open waters, analyze results, and produce alerts via satellite link. ***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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects minor program repricing.			
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 will investigate 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 2020 Plans:*** - Conduct advanced in vivo testing of genome editors to include characterization of off-target effects, failure modes, target editing efficiency, and stability. - Design safety measures and characterize toxicity and immunogenicity of genome editors. - Determine safety and efficacy and characterize off-target effects of genome editor countermeasure candidates in vivo. - Incorporate empirical data such as gene flow, fitness, generational stability, and failure modes into advanced computational models. - Demonstrate the ability to revert or eliminate target genes in organisms in laboratory environments.	16.762	13.150	12.603

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Begin development of tools for measurement of genomic sequence targets that provide sufficient coverage of genomic diversity, while also enabling single-nucleotide level specificity. - Begin development of gene editing based detection 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects minor program repricing.			
Title: Expanding Human Resiliency	-	13.425	13.500
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 (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 2020 Plans:*** - Investigate ways to improve methods for interpretation and prediction of microbial interactions. - Initiate testing of methods to alter chemical production by microbiomes. - Begin longitudinal studies to track microbial interactions with changes in the microbiome. - Begin development of initial microbiome modulation approaches. ***FY 2021 Plans:*** - Test methods in vitro to alter chemical production by microbiomes and validate that alterations reduce attraction and feeding of mosquitoes or other disease vectors. - Initiate in vivo testing of methods to alter chemical production by microbiomes. - Investigate methods to deliver interventions to skin for altering chemical production by the microbiome. - Investigate methods to improve physical and computational models of microbiomes. ***FY 2020 to FY 2021 Increase/Decrease Statement:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The FY 2021 increase reflects minor program repricing.			
Title: Restoring Cognitive Capability ***Description:*** The Restoring Cognitive Capability program, building upon efforts initiated in the Enhancing Neuroplasticity program also budgeted in this PE and Project, will develop 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 will develop and test 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. ***FY 2020 Plans:*** - Identify structure-guided design principles for chemotype interactions with receptor subtype. - Identify model systems for in vivo functional validation. ***FY 2021 Plans:*** - Develop pipeline for design and synthesis of novel molecules. - Develop novel biosensors for assessment of drug uptake and distribution. - Begin assembly and validation of behavioral bioassays. - Begin in vitro functional testing of novel molecules. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects initiation of biosensor development for assessment of drug uptake and distribution and phenotypic effects.	-	4.750	11.178
Title: Food and Feedstocks on Demand ***Description:*** The Food and Feedstocks on Demand program, building upon research conducted in the Living Foundries program also budgeted in this PE and Project, will develop 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 will use 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	-	5.250	14.053

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
that warfighters can independently produce material support to extend mission duration and/or expand operational flexibility in resource-limited environments. ***FY 2020 Plans:*** - Investigate the ability for controllable, predictable microorganisms co-occurring in a consortia to alter the composition of chemical compounds. - Examine varied biological, chemical, and combinatorial approaches to breakdown waste for reuse. ***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. - Optimize the process for strategic material generation starting from increasingly complex mixtures. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects the integration of system components for conversion of waste at scale.			
Title: Unburdening the Warfighter from Chemical/Biological (CB) Defense ***Description:*** The Unburdening the Warfighter from Chemical/Biological (CB) Defense program aims to increase warfighter survivability by developing improved personal protective equipment (PPE) strategies for CB attacks. 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 agents for the warfighter. This research will innovate PPE through the discovery of compounds 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:*** - Investigate approaches such as special coatings, enzymes, biological, or other active components that can provide agent neutralization or decontamination. - Initiate development of novel components, including biomolecules to provide skin, airway and ocular protection from threats, minimizing the need for external protective equipment. - Investigate formulations and delivery methods to provide the warfighter with biological systems capable of mitigating threats.	-	-	9.040

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Determine duration of protection provided by system components in mission-relevant operating environments and concept of operations (CONOPS). ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Gene Editing Enabled Diagnostics & Biosurveillance ***Description:*** The Gene Editing Enabled Diagnostics & Biosurveillance program will develop 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.	-	-	13.550
Title: Atmospheric Water Extraction (AWE) ***Description:*** The Atmospheric Water Extraction program aims to leverage new materials and advanced engineering and manufacturing techniques to extract potable water directly from the atmosphere. 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. This program will develop the technology to provide potable water on-site without the need for an external water supply and will do so with size, weight, power, and water output requirements tailored to the needs of the individual warfighter, as well as larger groups (e.g., Humanitarian and Disaster Relief [HADR] missions). The ability to liberate the warfighter from the water supply chain through the technology developed by this program will provide strategic and tactical advantages aligned with the DoD shift to more distributed and self-sustaining forces. ***FY 2021 Plans:***	-	-	9.500

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Enhancing Neuroplasticity ***Description:*** The DoD needs tools to rapidly and effectively train military personnel in multifaceted and complex tasks. The Enhancing Neuroplasticity program is exploring and developing peripheral nerve stimulation methods and non-invasive devices to promote synaptic plasticity for improved learning paradigms. Key advances anticipated from this research will both create an anatomical and functional map of the underlying biological circuitry that mediates plasticity and optimize stimulation and training protocols to enable long-term retention for military personnel. Once successfully identified, the underlying mechanisms of targeted plasticity training can be applied to a broad range of cognitive skill training within the DoD, including foreign language learning, or data and intelligence analysis. ***FY 2020 Plans:*** - Utilize biomarkers to guide effective engagement of nerve targets in clinical studies. - Evaluate combined efficacy of pharmacological neuromodulation with peripheral nerve stimulation for learning. - Assess the longevity of effects of targeted peripheral nerve stimulation on cognitive, motor, or sensory task performance. - Demonstrate statistically valid improvement in performance and/or decrease in the time to achieve proficiency after pairing peripheral nerve stimulation with training. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.	12.427	8.543	-
Title: Living Foundries ***Description:*** The goal of the Living Foundries program was to create a revolutionary, biologically based manufacturing platform for the DoD and the Nation. With its ability to perform complex chemistries, be flexibly programmed through DNA code, scale, adapt to changing environments, and self-repair, biology represents one of the most powerful manufacturing platforms known. Living Foundries sought to develop the foundational technological infrastructure to transform biology into an engineering practice, speeding the biological design-build-test-learn cycle and expanding the complexity of systems that could be engineered. Ultimately, Living Foundries aimed to provide game-changing manufacturing paradigms for the DoD, enabling adaptable, on-demand production of critical and high-value molecules.	5.704	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
Research thrusts focused on the development and demonstration of open technology platforms to prove out capabilities for rapid (months vs. years) design and construction of new bio-production systems. The result was an integrated, modular infrastructure across the areas of design, fabrication, debugging, analysis, optimization, and validation -- spanning the entire development life-cycle and enabled the ability to rapidly assess and improve designs. Success was predicated on tight coupling of computational design, fabrication of systems, debugging using multiple characterization data types, analysis, and further development such that iterative design and experimentation would be accurate, efficient and controlled. Demonstration platforms were challenged to build a variety of DoD-relevant, novel molecules with complex functionalities, such as synthesis of advanced, functional chemicals, materials precursors, and polymers (those tolerant of harsh environments).			
Title: Adaptive Immunomodulation-Based Therapeutics ***Description:*** The Adaptive Immunomodulation-Based Therapeutics program developed platform technologies to interrogate and define the biological pathways to enhance operational readiness for DoD personnel. This program aided the warfighter by improving immune response, minimizing inflammation, and restoring critical organ function. One approach to achieve this capability required the development of new tools to stimulate and measure responses of the nervous system in order to harness the bioelectric code, enabling targeted therapy without the need for pharmacological products, ultimately reducing logistical requirements. An additional approach involved characterizing the host response in patients with severe infections, which provides a quantitative framework to guide therapy. Algorithms were developed to evaluate and predict various physiological conditions for military personnel. Advances made under the Adaptive Immunomodulation-Based Therapeutics program will offer new avenues for treating disease or organ function to improve force readiness.	12.639	-	-
Accomplishments/Planned Programs Subtotals	106.266	114.173	150.066

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	331.905	317.192	322.693	-	322.693	357.162	370.355	414.550	416.015	-	-
ELT-01: *ELECTRONIC TECHNOLOGY*	-	99.777	120.882	122.986	-	122.986	153.262	166.145	210.340	211.805	-	-
ELT-02: *BEYOND SCALING TECHNOLOGY*	-	232.128	196.310	199.707	-	199.707	203.900	204.210	204.210	204.210	-	-

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.

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 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	348.847	332.192	340.000	-	340.000
Current President's Budget	331.905	317.192	322.693	-	322.693
Total Adjustments	-16.942	-15.000	-17.307	-	-17.307
• Congressional General Reductions	0.000	-15.000			
• 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	0.551	0.000			
• SBIR/STTR Transfer	-17.493	0.000			
• TotalOtherAdjustments	-	-	-17.307	-	-17.307

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2019	FY 2020
Project: ELT-02: *BEYOND SCALING TECHNOLOGY*		
Congressional Add: *DARPA Electronics Resurgence Initiative*	30.000	-
Congressional Add Subtotals for Project: ELT-02	30.000	-
Congressional Add Totals for all Projects	30.000	-

Change Summary Explanation

FY 2019: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.
FY 2020: Decrease reflects congressional reduction.
FY 2021: Decrease reflects completion of several Electronic Technology programs in FY 2020.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
ELT-01: *ELECTRONIC TECHNOLOGY*	-	99.777	120.882	122.986	-	122.986	153.262	166.145	210.340	211.805	-	-

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. 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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Modular Optical Aperture Building Blocks (MOABB)	17.000	19.000	14.141

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 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 2020 Plans:
- Synthesize multiple light beams from a single optical phased array aperture of one square centimeter area.
- Demonstrate integration of laser sources and optical phased arrays on photonic chips.
- Create and characterize a prototype LIDAR module using optical phased arrays.

FY 2021 Plans:
- Improve optical phased array LIDAR range.
- Demonstrate optical phased array LIDAR on un-manned ground and air vehicles.

FY 2020 to FY 2021 Increase/Decrease Statement:

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019**	**FY 2020**	**FY 2021**
The FY 2021 decrease reflects final demonstrations.			
Title: Atomic Magnetometry for Biological Imaging In Earth's Native Terrain (AMBIIENT)	11.540	10.000	9.000
Description: The Atomic Magnetometry for Biological Imaging In Earth's Native Terrain (AMBIIENT) program will develop novel magnetic sensors capable of providing high-sensitivity signal measurements in the presence of ambient magnetic fields. In recent years, the value of magnetic imaging, for example for cardiac and other biological signals, has shown tremendous potential for advanced research and clinical diagnosis. Practical application, however, has been limited. Interference from natural and manmade ambient magnetic fields has required that the measurements be performed in specialized, magnetically-shielded research facilities. 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 2020 Plans:*** - Complete sensor package architecture meeting AMBIIENT size weight and power, accuracy, and sensitivity goals. - Fabricate and test architectures for direct gradient sensing of magnetic fields. ***FY 2021 Plans:*** - Design sensor package architecture meeting AMBIIENT size weight and power, accuracy, and sensitivity goals. - Integrate control electronics for direct gradient sensing of magnetic fields. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the program going from initial to final design of the sensor package architecture.			
Title: Dynamic Range-enhanced Electronics and Materials (DREaM)	13.000	17.000	15.000
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 2020 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Manufacture and characterize transistor unit cells with both a three times improvement over the state of the art in output power density and ten times higher linearity. - Optimize fabrication processes and explore novel transistor topology to enable higher breakdown voltage, for design of transistors with four times higher power density than the state of the art. - Exploit new channel materials and perform device modeling to enable scaling to 30 times higher linearity than state of the art at 30 gigahertz operational frequency. ***FY 2021 Plans:*** - Design, simulate and optimize transistor unit cells with both a five times improvement over the state of the art in output power density and ten times higher linearity. - Optimize novel transistor topology and fabrication processes to enable higher breakdown voltage, for design of transistors with five times higher power density than the state of the art, and identify thermal solution for high power operation. - Exploit new channel materials, device topology and modeling to enable scaling to 100 times better linearity than state of the art at 30 gigahertz operational frequency. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the program transitioning from developing advanced transistor architectures to manufacturing transistor unit cells.			
Title: SHort Range Independent Microrobotic Platforms (SHRIMP) ***Description:*** The SHort Range Independent Microrobotic Platforms (SHRIMP) program is developing and demonstrating 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 will leverage 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 microrobotic platform capabilities enabled by SHRIMP will provide the DoD with significantly more access and capability to operate in small spaces that are practically inaccessible to today's state-of-the-art robotic platforms. Such capability will have impact in search and rescue, disaster relief, infrastructure inspection, and equipment maintenance, among other operations. Foundational research efforts are funded in PE 0601101E, Project ES-01. ***FY 2020 Plans:*** - Demonstrate tethered microrobotic platforms meeting program metrics on length, weight, and duration of operation. - Initiate development of untethered microrobotic platforms with an emphasis on size, weight, and performance. ***FY 2021 Plans:***	4.500	9.000	8.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Demonstrate untethered microrobotic platforms meeting improved program metrics on length, weight, and duration of operation. - Refine and optimize untethered microrobotic platforms for competition in Olympic-style events. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the program shifting from demonstrating tethered to refining and optimizing untethered microrobotic platforms.			
Title: Focal Arrays for Curved Infrared Imagers (FOCII)* ***Description:*** *Formerly Intelligent Spectroscopic & Temporal Fusion (INSPECT) The Focal Arrays for Curved Infrared Imagers (FOCII) program will add curved focal plane arrays to broadband infrared (IR) imagers to enhance battlefield detection and discrimination while maintaining situational awareness. The resulting desired capability is analogous to human vision that enables wide fields of view in a compact optical system package. Currently fielded imaging systems are flat broadband infrared sensors that rely on large and complex optics to correct aberrations and improve illumination and resolution. FOCII will (1) 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, and (2) 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 2020 Plans:*** - Develop mechanical stress models for use with existing broadband imaging hardware. - Fabricate initial curved focal plane array prototypes that meet program goals for radius of curvature and size of pixels. ***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. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects the program shifting from fabricating initial curved focal plan array prototypes to measuring mechanical stress of curved large area focal arrays.	-	13.000	17.000
Title: Wideband Adaptive RF Protection (WARP)* ***Description:*** *Formerly Instinctual RF	-	11.200	16.845

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
The Wideband Adaptive RF Protection (WARP) program will develop 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. Today's advanced wideband DoD systems, such as multi-function phased arrays, are open to all frequencies by design with little or no RF filtering. This is due to a lack of tunable and reconfigurable filters that are small enough to integrate into the arrays, limiting the use of wideband multi-function arrays in contested environments. The ability to create tunable and reconfigurable bandpass and bandstop filters in the range of 2-18 GHz will be important for implementing transmit/ receive modules in next generation multi-function arrays. Another important area of interference mitigation is self-interference. Specifically, in electronic warfare, it would be advantageous to be able to receive and perform signal intelligence functions while simultaneously transmitting a high-power jamming self-protect signal. WARP will develop the signal cancellation technology that will listen to the transmitted jamming 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 2020 Plans:*** - Begin investigating 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. - Begin investigating 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 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. - 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects the program shifting from investigating to demonstrating 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.			
Title: Quantum Imaging of Vector Electromagnetic Radiation (QuIVER) ***Description:*** The Quantum Imaging of Vector Electromagnetic Radiation (QuIVER) program, building upon technologies developed in the AMBIIENT program, budgeted within this PE and Project, will develop full tensor magnetic /electric field sensors and demonstrate them in DoD relevant applications and concept of operations. Magnetometers and electrometers are widely	-	12.000	20.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
used within the DoD and industry. The medical community utilizes sensitive magnetometers for magnetoencephalography and magnetocardiography. In addition to being diagnostically relevant, such sensitive magnetometers could enable future human-machine/brain-machine interfaces. The DoD and industry also uses 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. High sensitivity electrometers are used by industry to locate live current and static electricity sources. Recent developments have resulted in the potential to develop highly sensitive vector electrometers and 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 2020 Plans:*** - Design prototype tensor gradient magnetometer and/or tensor gradient electrometer. ***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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects a shift from design to building preliminary magnetic/electric field sensors.			
Title: High Operating Temperature Sensors for Hypersonics and Turbine Engines (HOTSHOT) ***Description:*** The High Operating Temperature Sensors for Hypersonics and Turbine Engines (HOTSHOT) program seeks to enable electronics and sensing in harsh temperature environments for next generation vehicles. Currently, sensing systems are not robust to the temperature extremes expected over a mission lifetime. This technology gap hampers the ability to capture flight test data from air vehicles (boost glide, air-breathing, etc.) during development. HOTSHOT will develop the material, device, and sensor technologies required to create high-temperature capable sensing systems. These new material choices allow transduction, signal conditioning, digitization, and processing at elevated temperatures, thus reducing the need for temperature shielding of these components. Reduced shielding drops the on-vehicle size, weight, and power requirements for many components. HOTSHOT will enable faster and more predictable design of new air vehicles, which will lead to more efficient system performance. ***FY 2021 Plans:*** - Demonstrate initial results of transduction and signal conditioning at elevated temperatures. - Release of initial design parameters for selected electronics process.	-	-	11.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Develop base electronics that can perform logic functions. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
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. The DoD is increasingly reliant on cloud computing services and storage. Cloud-enabled virtualized storage and the accompanying virtualized computing play a key role in data processing for planning and operations. Networks are also becoming more virtualized spaces, such as in 5G systems. The growing virtualization storage, computing, and networking puts data privacy of all users at risk. 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. ***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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.	-	-	12.000
Title: High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC) ***Description:*** The High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC) program seeks to develop compact radio frequency signal amplifiers for air, ground, and ship-based communications and sensing systems. HAVOC amplifiers would enable these systems to access the high-frequency millimeter-wave portion of the electromagnetic (EM) spectrum, facilitating increased range and other performance improvements. Today, the effectiveness of combat operations across all domains increasingly depends on DoD's ability to control and exploit the EM spectrum and to deny its use to adversaries. However, the proliferation of inexpensive commercial RF sources has made the EM spectrum crowded and contested, challenging our spectrum dominance. Operating at higher frequencies, such as the millimeter-wave, helps DoD to overcome these issues and offers numerous tactical advantages such as high data-rate communications and high resolution and	6.000	6.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
sensitivity for radar and sensors. Technology transfer efforts will follow a spiral development process to mitigate risk and provide the opportunity to incorporate new technological developments as they occur. Basic research for this program is funded within PE 0601101E, Project ES-01. ***FY 2020 Plans:*** - Fabricate single-beam vacuum amplifiers and test at high average-power output. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: Precise Robust Inertial Guidance for Munitions (PRIGM) ***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. When GPS is not available, these inertial sensors can provide autonomous PNT information. The program will exploit 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 can suffer from inaccuracies due to factors such as temperature sensitivity, new photonics-based PNT techniques have demonstrated the ability to mitigate these inaccuracies. PRIGM will focus on two areas. By 2022, it aims to develop and transition a Navigation-Grade Inertial Measurement Unit (NGIMU), a state-of-the-art MEMS device, to DoD platforms. By 2030, it aims to develop advanced inertial MEMS sensors that can provide gun-hard, high-bandwidth, high dynamic range navigation for GPS-free munitions. 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 will advance state-of-the-art MEMS gyros from TRL-3 devices to a TRL-6 transition platform, eventually enabling the Service Labs to perform TRL-7 field demonstrations. Basic research for this program was funded within PE 0601101E, Project ES-01 and advanced technology development for the program is budgeted in PE 0603739E, Project MT-15. ***FY 2020 Plans:*** - Demonstrate inertial sensor survival and operation through representative launch environments in the laboratory. - Demonstrate two-chip, low power, near tactical grade Inertial Measurement Unit (IMU). - Demonstrate single-chip, low power, tactical grade IMU capable of gun-hard operation. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.	9.069	5.000	-
Title: Wafer-scale Infrared Detectors (WIRED)	12.000	5.682	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
Description: The WIRED program addresses the need for low-cost, high-performance imaging sensors in the short-wave and mid-wave infrared (SWIR/MWIR) bands. These sensors will provide 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 proposes to manufacture these sensors at the wafer scale, which reduces costs by processing dozens to hundreds of camera imaging arrays at a time. Wafer-scale manufacturing has already driven a revolution in optical imaging in both the visible and the long-wave infrared (LWIR) spectrum, with high-resolution digital cameras and LWIR sensors having become commonplace or widely-available. However, no similar technologies exist for the SWIR/MWIR bands. WIRED could therefore drive a similar revolution in SWIR/MWIR. The program aims to significantly reduce the weight and volume of MWIR detectors, which today require heavy cryogenic cooling systems, and increase the resolution of SWIR detectors by dramatically reducing their pixel size relative to the state-of-the-art. ***FY 2020 Plans:*** - Demonstrate improved performance of the MWIR imager compatible with requirements for relevant DoD applications. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: Atomic Clock with Enhanced Stability (ACES) ***Description:*** The Atomic Clock with Enhanced Stability (ACES) program is developing extremely stable chip-scale atomic clocks for unmanned aerial vehicles and other low size, weight, and power (SWaP) platforms with extended mission durations. Atomic clocks provide the high-performance backbone of timing and synchronization for DoD navigation; communications; electronic warfare; and intelligence, surveillance, and reconnaissance systems. However, atomic clocks are limited, particularly by temperature sensitivity, aging over long timescales, and a loss of accuracy when power cycled. By employing alternative approaches to confining and measuring atomic particles, ACES could yield a 100x - 1,000x improvement in key performance parameters related to each of these limitations. ACES will also focus on developing the component technologies necessary for low-cost manufacturing and for deployment in harsh DoD-relevant environments. Among its many benefits, program success could help 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. ***FY 2020 Plans:*** - Fabricate a fully integrated prototype including electronics and physics package meeting SWaP objectives such that prototypes can be delivered and tested. - Deliver prototype to government facility for testing and verification of GPS-independent timing accuracy. ***FY 2020 to FY 2021 Increase/Decrease Statement:***	16.000	6.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2019**	**FY 2020**	**FY 2021**
The FY 2021 decrease reflects program completion.			
Title: Limits of Thermal Sensors (LOTS) ***Description:*** The Limits of Thermal Sensors (LOTS) program aims to demonstrate long-wave infrared (LWIR) detector technologies with both high performance and low-size, weight, power, and cost (SWaP-C). The resulting technologies would enable improvements in imaging systems such as night-vision goggles, infrared-guided missiles, and missile threat warning systems. Currently, LWIR-enabled systems must choose between large and expensive cryogenically-cooled detectors, which offer high sensitivity and low response times, and uncooled detectors called microbolometers, which offer significant SWaP-C reductions at lower performance. LOTS seeks to develop 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. ***FY 2020 Plans:*** - Demonstrate microbolometer arrays on improved read-out integrated circuits and develop design variants appropriate for different platforms and use cases. - Build final cameras for demonstration in relevant environments. - Demonstrate the utility of high performance microbolometers for low-cost infrared search and track applications, including evaluating the impact of jitter. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.	7.668	7.000	-
Title: Direct On-Chip Digital Optical Synthesis (DODOS) ***Description:*** The Direct On-chip Digital Optical Synthesis (DODOS) program aimed to integrate diverse electronic and photonic components to create a compact, robust, and highly-accurate optical frequency synthesizer for various mission-critical DoD applications. DODOS leveraged recent developments in the field of integrated photonics to enable the development of a ubiquitous, low-cost optical frequency synthesizers. The program lead to disruptive DoD capabilities, including high-bandwidth optical communications, higher performance Light Detection And Ranging (LiDAR), portable high-accuracy atomic clocks, and high-resolution detection of chemical/biological threats at a distance. Basic research for this program was funded within PE 0601101E, Project ES-01.	3.000	-	-
Accomplishments/Planned Programs Subtotals	99.777	120.882	122.986

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
ELT-02: *BEYOND SCALING TECHNOLOGY*	-	232.128	196.310	199.707	-	199.707	203.900	204.210	204.210	204.210	-	-

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 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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Beyond Scaling - Materials	44.349	44.000	37.000

Description: The Beyond Scaling - Materials program is demonstrating the integration of novel materials into next-generation logic and memory components. Historically, the DoD had taken the lead in shaping the electronics field through research in semiconductor materials, circuits, and processors. However, as DoD focuses on military-specific components and commercial investments eschew the semiconductor space, U.S. fundamental electronics research is stagnant just as an inflection point in Moore's Law (silicon scaling) is about to occur. This program is pursuing potential enhancements in electronics that do not rely on Moore's Law, including research not only into new materials but also into the implications of those materials at the device, algorithm, and packaging levels. Research areas include heterogeneous integration of multiple materials, "sticky logic" 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 will support innovation in the technology cycle by working with entrepreneurs focused on DoD-relevant businesses. The program is demonstrating the manufacturability of functioning switches, memory, and novel computational units in a large-scale system. Previous DARPA work on unconventional computing, integration, and reprogrammable memory give confidence in this approach. Basic research for this program is funded within PE 0601101E, Project ES-02.

FY 2020 Plans:
- Demonstrate fabrication of fully integrated monolithic 3D circuits at a commercial fabrication facility.
- Release distribution quality design tools to enable external design of monolithic 3D circuits.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Demonstrate large-scale fully functional chips using alternative materials fabricated in a 90 nm foundry with capabilities that are competitive with advanced technology nodes. - Demonstrate superconductor multi-chip module carrier production on 300 mm wafers by a commercial foundry. - Simulate critical high-speed circuit blocks for supporting mixed-mode integrated circuitry to be fabricated at a commercial foundry. - Design and simulate highly scaled transistors with new materials and device topology for high speed mixed-mode electronics based on advanced silicon complementary metal oxide semiconductor fabrication processes. - Develop and demonstrate innovative component technologies for next-generation photonic interconnect, targeting concepts for 100x improvement to link energy and bandwidth over current state-of-the-art performance. - Leverage access to Federally Funded Research and Development Centers (FFRDC)-based entrepreneurial research hubs to refine and develop select academic discoveries for delivery into DoD systems. ***FY 2021 Plans:*** - Demonstrate operational digital signal processing circuits using novel superconductor electronics. - Test critical mixed-mode demonstration circuit blocks fabricated at a commercial foundry. - Integrate innovative component technologies and characterize link performance towards next-generation photonic interconnect capabilities. - 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. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the program transitioning towards demonstrating the ability to take alternative materials through a full commercial process flow.			
Title: Beyond Scaling - Architectures ***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 productivity 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 2020 Plans:***	43.000	35.000	36.707

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Demonstrate initial reconfigurable architecture simulation and emulation environment that will drive hardware design decisions and definitions. - Emulate a specialized processor design and demonstrate an emulation of the processor executing two simultaneous applications. - Define diverse data flow management approaches, and develop architecture simulations to drive architecture decisions and definitions. - Develop initial architecture field programmable gate array based emulation environment and software development environments. - Design and demonstrate a prototype system or the detection of hardware Trojans in commercial-off-the-shelf hardware commonly found in DoD systems. - Develop a compilation architecture, domain-specific framework, and system modeling approach compatible with high productivity/high performance compilation for extreme parallelism and heterogeneity. ***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 system-on-chips (SoCs) with heterogeneous components that can be easily reprogrammed for specialized applications. - Complete full architecture designs. - Demonstrate FPGA-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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects minor program repricing.			
Title: Beyond Scaling - Design ***Description:*** The Beyond Scaling - Design program is developing and demonstrating the tools required for rapidly designing and deploying specialized circuits. As Moore's Law slows and the nation loses the benefit of free, exponential improvements in electronics cost, speed, and power derived from silicon scaling, the DoD will need to maximize the benefits of available silicon technologies by using design tools that enable circuit specialization. Research efforts are exploring technologies and techniques such as intelligent design tools, automated physical layout generation, and open-source circuit designs. 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 will 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	33.000	22.000	25.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
developed will also consider the need to incorporate security into DoD hardware. Basic research for this program is funded within PE 0601101E, Project ES-02. ***FY 2020 Plans:*** - Deliver software for physical layout of integrated circuits, packages and boards that is 100% automated and achieves 50% power, performance and area compared to traditional best in class techniques. - Demonstrate fabrication of circuits generated from high-level schematics using a fully automated intelligent design flow. - Publically release open source Intellectual Property (IP) modules developed in the program and demonstrate portability between multiple technology nodes. - Publically release a hardware verification platform with functionality evaluated through simulation and emulation of a comprehensive set of digital and mixed signal circuits. ***FY 2021 Plans:*** - Optimize algorithms and the physical design platform to demonstrate 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 technology nodes. - Develop initial SoC design leveraging open source IP building blocks verified with open source simulation technology. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects the transition from initial design and development to the delivery of functional tools, software, intellectual property, and fabricated hardware.			
Title: Common Heterogeneous integration & IP reuse Strategies (CHIPS) ***Description:*** The Common Heterogeneous integration & 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 could 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 2020 Plans:*** - Complete module fabrication and testing to demonstrate functionality of the CHIPS interface and chiplets in representative applications.	15.500	17.800	7.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Initiate design of upgraded modules to determine performance and program benefits of new processes enabled by the program. - Complete study of the system level impact of IP re-use for the optimal use of digital functional blocks. ***FY 2021 Plans:*** - Complete design of upgraded modules to determine performance and benefits of new processes enabled by the program. - 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from module design to module fabrication.			
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 that 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 2020 Plans:*** - Complete development of the Field Programmable Gateway Array (FPGA) emulator and porting of government workflows. - Finalize the chip architecture and deliver design for fabrication. - Complete application programming interface for runtime environment. ***FY 2021 Plans:*** - Fabricate functional HIVE architecture prototype. - Deliver graph analytic tool set and software stack for use with HIVE chip. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease is the result of development work on architectural design concluding and focusing on delivering final design for fabrication.	17.600	16.510	12.000
Title: Digital RF Battlespace Emulator (DRBE) ***Description:*** The Digital RF Battlespace Emulator (DRBE) program is developing a large-scale, interactive, emulated radiofrequency (RF) environment, providing the DoD with much needed capability to cost-effectively evaluate adaptive, intelligent,	8.000	15.000	24.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
and spatially distributed next-generation RF systems. Current U.S. test infrastructure is no longer able to successfully exercise RF systems in relevant environments, which should account for hundreds of DoD systems coordinating against hundreds of adversary systems. Due to the critical dependency of nearly all platforms and missions on the RF spectrum and the increasingly advanced RF capabilities of peer adversaries, current infrastructure limitations represent a critical capability gap. Existing test approaches are either: 1) small-scale laboratory tests under well controlled but unrealistic conditions or 2) massive training exercises, which occur at most annually due to the required cost and manpower and do not fully collect necessary data. To overcome these limitations, DRBE is leveraging advances in massively multi-core computing hardware and high-bandwidth digital cross connects to emulate realistic RF environments that account for RF platform movement, signal propagation effects and delays, signal interference, and interactions between RF systems. The electronics architecture which supports these goals is beyond anything that exists today, based on the power and latency requirements that this emulation environment demands. 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 100 km 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 2020 Plans:*** - Complete first-generation DRBE system design to the level of a Concept Design Review (CoDR). - Complete DRBE real-time High-Performance Computer (HPC) design to the level of a CoDR. - Emulate first-generation DRBE system performance using non-real-time software. ***FY 2021 Plans:*** - Complete DRBE system design to the level of a Preliminary Design Review (PDR). - Complete DRBE real-time HPC design to the level of a PDR. - Design first-spin computational accelerator chips to the level of tape-out. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects the program shifting from beginning fabrication to completing design of the DRBE system.			
Title: Automatic Implementation of Secure Silicon (AISS)* ***Description:*** *Previously part of Beyond Scaling - Design The Automatic Implementation of Secure Silicon (AISS) program will enable 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	-	12.000	20.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 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, the DoD applications will benefit from more secure chips becoming pervasive whether designed specifically for the defense systems or commercially procured. ***FY 2020 Plans:*** - Demonstrate three proof-of-concept (PoC) systems implemented at low, medium and high security levels. - 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 2021 Plans:*** - Demonstrate rapid power and security estimation models executed on the auto-integrated PoC systems and accurately grade their relative attack resistivity. - Demonstrate that the three selected PoC designs can be semi-automatically built out of AISS IP and the design finalized. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects a shift from demonstrating the three selected PoC designs can be semi-automatically built out of AISS IP to the final design.			
Title: Guaranteed Architectures for Physical Security (GAPS)* ***Description:*** *Previously a part of Beyond Scaling - Architectures The goal of the Guaranteed Architectures for Physical Security (GAPS) program is to develop 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 track that such protections are enforced at run-time. GAPS will reduce the inherent complexity through the development of hardware and software that will be 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: a) fast computer-to-computer transactions; b) physical spatial isolation reducing the need for unreliable software partitioning solutions; and c) more complex missions without putting sensitive data at risk.	-	7.000	12.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
FY 2020 Plans: - Initiate research to develop a range of capabilities, including verifiable bus standards and board support packages (BSPs), around required components and develop topologies that require minimal feedback while maintaining high reliable throughput. - Research and develop high-level languages capable of expressing unidirectional data-flow assertions and transactions. - Develop novel modelling and compilation techniques to produce physical layouts and multiple binaries. - Identify and create security frameworks for emerging needs for DoD systems and provide interface control documents. ***FY 2021 Plans:*** - Continue research and development of verifiable bus standards and 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 DoD platforms. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects a shift from research and development to demonstration of techniques on DoD platforms.			
Title: Lasers for Universal Microscale Optical Systems (LUMOS)* ***Description:*** *Previously a part of Beyond Scaling - Design The Lasers for Universal Microscale Optical Systems (LUMOS) program will integrate high performance light sources into integrated silicon photonics to enable 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 2020 Plans:*** - Complete a process development evaluation of heterogeneous integration approaches including a discussion of potential risks and component specifications. - Begin development of heterogeneous integration of optical gain on a capable photonics platform. ***FY 2021 Plans:***	-	8.000	21.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Develop heterogeneous integration technology for optical gain and nonlinear photonics components in a complementary metal-oxide semiconductor 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. - Investigate new materials and components for high-performance lasers at unique wavelengths on emerging platforms. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program going from initial design to fabrication of integrated photonic circuits.			
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 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 2020 Plans:*** - Implement new hardware architectures on field programmable gate array (FPGA) platforms that demonstrate scalable, flexible, and robust protection against external attacks on complex, high-performance, out-of-order processing hardware. - Develop distribution-ready design tools to implement SSITH hardware protection methods in new hardware. - Formalize security metrics and establish a clear distribution mechanism for those metrics. ***FY 2021 Plans:*** - Utilize hardware demonstrations to evaluate the tradeoffs between security, power, and performance of hardware. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the program transitioning from implementing hardware design to testing hardware.	21.279	19.000	5.000
Title: Circuit Realization At Faster Timescales (CRAFT) ***Description:*** The Circuit Realization At Faster Timescales (CRAFT) program developed novel integrated circuit (IC) design flows to reduce the design and verification time required for high-performance military electronics by a factor of ten. CRAFT	9.400	-	-

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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 2019	FY 2020	FY 2021
reduced barriers to the design and fabrication of custom ICs in leading-edge complementary metal oxide semiconductor (CMOS) technology. The program investigated and leveraged novel design flows that utilize recent advances in electronic design automation and software design methodologies. CRAFT also explored increased design reuse and flexibility, which will allow DoD to migrate chip fabrication between different foundries or to more advanced technology nodes.			
Title: Near Zero Energy RF and Sensor Operations (N-ZERO) ***Description:*** The Near Zero Power RF and Sensor Operations (N-ZERO) program developed and demonstrated the technologies required to extend the lifetimes of remotely-deployed sensors from months to years. N-ZERO sought to develop electronics with passive or extremely low-power devices that continuously monitor the environment and wake up active electronics upon detection of a specific trigger. In doing so, N-ZERO enabled wireless sensors with drastically increased mission life to meet DoD's unfulfilled need for a persistent, event-driven sensing capability.	10.000	-	-
Accomplishments/Planned Programs Subtotals	202.128	196.310	199.707

	FY 2019	FY 2020
Congressional Add: DARPA Electronics Resurgence Initiative ***FY 2019 Accomplishments:*** - Enhanced ongoing efforts to demonstrate electronics that can enforce security and privacy protections for electronics components critical to DoD overmatch capabilities. - Confirmed via emulation and physical demonstration, that DARPA-developed hardware security technologies can improve the protection of hardware architectures and national critical infrastructure. - Completed abstractions for the physical design of cryptographic hardware intellectual property for use in critical DoD applications. - Incorporated techniques for the physical isolation of sensitive data processing transactions into an application associated with an ongoing DoD program.	30.000	-
Congressional Adds Subtotals	30.000	-

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 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	287.907	279.741	230.978	-	230.978	191.443	185.811	207.034	213.608	-	-
AIR-01: *ADVANCED AEROSPACE SYSTEMS*	-	287.907	279.741	230.978	-	230.978	191.443	185.811	207.034	213.608	-	-

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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	302.463	279.741	217.434	-	217.434
Current President's Budget	287.907	279.741	230.978	-	230.978
Total Adjustments	-14.556	0.000	13.544	-	13.544
• 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	-3.000	0.000			
• SBIR/STTR Transfer	-11.556	0.000			
• TotalOtherAdjustments	-	-	13.544	-	13.544

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2019	FY 2020
Project: AIR-01: *ADVANCED AEROSPACE SYSTEMS*		
Congressional Add: *Hypersonics Weapons Programs Development and Transition*	30.000	-
Congressional Add Subtotals for Project: AIR-01	30.000	-
Congressional Add Totals for all Projects	30.000	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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Change Summary Explanation

FY 2019: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2020: N/A
FY 2021: Increase reflects initiation of the Gunslinger program.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Tactical Boost Glide	140.568	152.100	116.508

Description: The Tactical Boost Glide (TBG) program is a Joint DARPA / Air Force effort that will develop and demonstrate 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 2020 Plans:
- Complete Static Test Article (STA) aeroshell thermo-structural testing.
- Complete Assembly, Integration, and Test (AI&T) of Engineering Development Unit (EDU) and first flight test vehicle.
- Conduct test readiness review (TRR) for first flight, conduct flight test, and complete post-flight analysis.
- Continue AI&T of second and third flight test vehicles.
- Continue additional aerodynamic and aero-thermodynamic risk reduction testing.
- Continue additional material and thermo-structural risk reduction testing.
- Continue additional materials arc-jet testing.
- Plan additional tests for expanded risk reduction.
- Continue procuring hardware for additional tests and AI&T of test articles.
- Begin second TBG performer's engineering component testing and design verification testing.
- Complete second TBG performer air vehicle and all-up round (AUR) subsonic, transonic, and hypersonic performance and control tests.
- Conduct second TBG performer demonstration system solid rocket motor static fire test.
- Continue second TBG performer material and thermo-structural risk reduction testing, and conduct engineering environmental and static loads testing.
- Continue second TBG performer's material and thermo-structural risk reduction testing.

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021
- Continue procurement of second TBG performer's long-lead hardware for flight vehicles. - Continue second TBG performer's detailed flight test and range safety planning, coordination, and documentation. - Complete second TBG performer's subsystem and system-level critical design reviews. - Begin second TBG performer's detailed design, procurement of remaining hardware, and build of flight test vehicles. - Plan and conduct Navy variant risk reduction testing. - Continue detailed Navy variant test planning. ***FY 2021 Plans:*** - Conduct TRRs for two flights, conduct flight tests, and complete post-flight analysis. - Continue detailed planning of additional tests for expanded risk reduction. - 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. - Complete fabrication and integration and begin test of second TBG performer's inert operating missiles including ground testing and captive carriage flight testing. - Continue second TBG performer's detailed flight test and range safety planning, coordination, and documentation. - Continue second TBG performer's detailed design, procurement of remaining hardware, and build of flight test vehicles. - Continue Navy variant risk reduction testing. - Conduct Navy variant demonstration article critical design review. - Conduct Navy variant subsystem preliminary and critical design reviews. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program progression from the first performer's flight tests to Vertical Launch System(VLS) risk reduction and second performer's design to assembly, integration, and test phase.			
Title: Advanced Full Range Engine (AFRE) ***Description:*** The Advanced Full Range Engine (AFRE) program will establish the feasibility of a hypersonic aircraft reusable propulsion system through a two-pronged approach. AFRE will demonstrate turbine to Dual Mode Ramjet (DMRJ) transition of a Turbine-Based Combined Cycle (TBCC) propulsion system utilizing an off-the-shelf turbine engine. Large scale components of this complex propulsion system will be developed and demonstrated independently; to be followed by a full-scale freejet TBCC propulsion system mode transition ground test. Accomplishing these objectives will enable future airfield-based hypersonic	36.221	40.741	13.700

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Complete full-scale turbine/common nozzle with water injection ground test. - Complete full-scale combustor (DMRJ) fabrication and ground test demonstration. - Complete installation and testing of common inlet aerodynamic model. - Complete full-scale inlet fabrication, test installation, and checkout test. - Complete component (combustor, turbine, and nozzle) post-test inspection and refurbishment. - Begin integrated TBCC system assembly, installation and checkout tests. ***FY 2021 Plans:*** - Complete integrated TBCC system freejet test and final report. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects completion of full-scale testing and final program reporting.			
Title: Glide Breaker ***Description:*** Glide Breaker will develop 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 2020 Plans:*** - Complete preliminary design reviews. - Continue to execute trade studies, identify key technologies and estimate system performance. ***FY 2021 Plans:*** - Complete critical design review for technology demonstration. - Complete component level bench testing. - Complete test readiness review for critical, long-lead technology demonstration. - Conduct critical, long-lead technology demonstration. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects completion of bench testing and movement to technology demonstration.	26.546	10.000	3.000
Title: Operational Fires	20.099	50.000	40.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 OpFires program will conduct a series of subsystem tests designed to evaluate component design and system compatibility, and culminate in integrated end-to-end flight tests. OpFires will leverage and integrate ongoing investments in hypersonics to achieve these objectives. The transition partner is the Army. ***FY 2020 Plans:*** - Perform propulsion system risk reduction testing. - Complete propulsion system Critical Design Review (CDR). - Complete integrated weapon System Requirements Review (SRR). - Develop integrated weapon system technology maturation plan and initial flight test plan. - Complete Operational Fires integrated system trade studies. ***FY 2021 Plans:*** - Conduct integrated weapon system risk reduction testing. - Complete integrated weapon system Preliminary Design Review (PDR). - Conduct full-scale propulsion system static hot-fire testing. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects completion of hot-fire/static fire tests and the transition to weapon system integration planning and design.			
Title: Hypersonic Air-breathing Weapon Concept (HAWC) ***Description:*** The Hypersonic Air-breathing Weapon Concept (HAWC) program is a Joint DARPA / Air Force effort that will develop and demonstrate 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, and affordable system designs and manufacturing approaches. 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 2020 Plans:*** - Complete software-in-the-loop testing for the demonstration vehicle.	20.598	19.900	7.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Complete hardware-in-the-loop testing for the demonstration vehicle. - Complete assembly, integration, and test of demonstration vehicle. - Complete flight test planning for the demonstration system. - Complete flight certification reviews with the test range. - Complete range safety analysis. - Conduct mission readiness review. - Conduct first flight. - Conduct interim flight test data analysis. - Complete flight tests. ***FY 2021 Plans:*** - Conduct final flight data review. - Conduct final program reviews. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects completion of flight tests.			
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 of consideration 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 2020 Plans:*** - Conduct proof-of-concept demonstrations to verify technology feasibility. - Perform initial development of novel aircraft and power plant configurations. ***FY 2021 Plans:*** - Conduct modeling of concept system designs. - Perform sub-system viability experiments.	3.000	3.000	3.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Demonstrate enabling technologies that support sub-system components.			
Title: Air-Ground Autonomous VEhicles (AGAVE) ***Description:*** The Air-Ground Autonomous VEhicles (AGAVE) program will explore the seams between air and ground vehicles. New approaches are required to address one of the most symmetric of all warfighting domains - ground combat. The program will seek to provide improved mobility solutions for supporting combat operations that place unmanned assets forward to explore and inform troops prior to entering an area, or to provide continued perimeter and overhead surveillance during operations. Technologies will be explored to allow increased levels of autonomy, improved operating ranges, improved mobility through complex 3-dimensional battlespaces, and integration of the requirements for both ground and air mobility in complex urban warfare settings. Reduced manning requirements will be a part of the design space evaluation, with unmanned vehicles operating in a supporting role instead of a traditional supported role. Novel approaches to multi-modal platforms, platform states, and manned-unmanned teaming that reduce the need for highly trained personnel dedicated to monitoring unmanned vehicles will be explored. Problems that cross all domains, such as high energy density power supplies, navigation through uncertain and changing environments, and supervisory autonomy of vehicles will be addressed. Novel networking and teaming approaches to achieve tactical tasks will also be explored to close the seams between ground and air unmanned vehicles and to improve confidence in identifying risks associated with both natural hazards and enemy actions prior to ground personnel entering an area. Cueing from other assets and long range, long duration autonomous assets will be included in the overall tradespace explored. ***FY 2020 Plans:*** - Refine design space and develop system requirements. - Initiate studies in the areas of autonomy, mobility, and energy to define technology development areas. - Begin development of concepts of operations and system architecture. ***FY 2021 Plans:*** - Define field experiment approaches, terrains, and candidate platform scale. - Finalize concept of operation systems architecture. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects a shift from initial studies and designs to final concept of operations.	-	4.000	12.500
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	-	-	22.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
could capitalize upon a slower speed, higher fuel-efficient air vehicle for ingress, while retaining highly energetic air-to-air missiles for endgame 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. - Conduct system requirements review of the demonstration system. - Complete preliminary design of the demonstration system and conduct preliminary design review. - Conduct risk reduction studies in support of design activity. - Mature operational analysis showing mission utility of performer design approaches. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Gunslinger ***Description:*** The Gunslinger program will develop and demonstrate technologies to enable an air-launched tactical range missile system capable of multi-mission support. This system will utilize the high maneuverability of a missile system coupled with a gun system capable of scalable effects and engagement of multiple targets. These mission sets addressed will include counter insurgency (COIN) operations, close air support (CAS) and air-to-air engagements. The metrics associated with this system include total range (which includes transit to target, loiter and engagement) and weapon system effectiveness. The program will address the system and technology issues required to enable development of a robust missile system considering (1) vehicle concepts possessing the required aerodynamic, propulsion, and payload capacity for a wide operational envelope, (2) the algorithms that support maneuvering and target recognition to enable expedited command decision making for selecting and engaging targets and (3) approaches to incorporating modularity of design to reduce cost throughout the design and development process. The anticipated transition partners for this effort are the Air Force and the Navy. ***FY 2021 Plans:*** - Conduct trade studies, to include propulsion, munitions, sensors, GPS and communications. - Develop higher fidelity modeling and simulation environment to support program concept of operations. - Conduct conceptual design sizing and synthesis activities. ***FY 2020 to FY 2021 Increase/Decrease Statement:***	-	-	13.270

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The FY 2021 increase reflects program initiation.			
Title: Collaborative Operations in Denied Environment (CODE) ***Description:*** The goal of the Collaborative Operations in Denied Environment (CODE) program was to enhance mission performance, reduce cost, confound adversaries, and reduce reliance on space assets for navigation and communication by distributing mission functions such as sensing, communication, precision navigation, kinetic, and non-kinetic effects to small platforms and increasing their level of autonomy. Collaboration of multiple assets offered new possibilities to conduct military missions using smaller air platforms to enhance survivability, reduce overall acquisition cost, create new effects, increase communications range and robustness in denied environments, increase search area, increase areas held at risk, reduce target prosecution reaction time, and provide multi-mission capabilities by combinations of assets. This effort focused on developing and demonstrating approaches that will expand the mission capabilities of legacy air assets through autonomy and collaborative behaviors, within a standard based open architecture. CODE transitioned to the Navy.	5.000	-	-
Title: Aircraft and Vehicle IntegrAted Team (AVIATE) ***Description:*** The Aircraft and Vehicle IntegrAted Team (AVIATE) program studied the use of an Unmanned Aerial System (UAS) that is an integrated subsystem of a ground vehicle with features to autonomously land, attach, stow, detach, and take-off from its parent ground vehicle while it is on the move to enable on-demand capabilities and drastically improved protection. Ground vehicles could perform traditional UAS missions such as intelligence, surveillance and reconnaissance (ISR) and fires support, as well as unique missions such as electronic attack, sensor emplacement, infrastructure attack, and active protection without having to rely on brigade and theater level assets. This effort explored design interfaces between the air and ground vehicle, attributes to allow for launch and recovery on the move, and design considerations to enable operations in contested environments.	5.875	-	-
Accomplishments/Planned Programs Subtotals	257.907	279.741	230.978

	FY 2019	FY 2020
Congressional Add: Hypersonics Weapons Programs Development and Transition	30.000	-
FY 2019 Accomplishments: - HAWC: Performed risk reduction efforts and initiated ground testing of the demonstration system. - HAWC: Conducted additional inlet cover ejection test. - HAWC: Completed additional high temperature instrumentation. - TBG: Conducted risk reduction efforts on additional leading edge materials and additional coating systems. - TBG: Conducted instrumentation development for the leading edge.		

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	FY 2019	FY 2020
- TBG: Began fabrication of additional aeroshell.		
Congressional Adds Subtotals	30.000	-

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	256.181	190.306	158.439	-	158.439	108.126	106.726	128.726	137.163	-	-
SPC-01: *SPACE PROGRAMS AND TECHNOLOGY*	-	256.181	190.306	158.439	-	158.439	108.126	106.726	128.726	137.163	-	-

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 as well as exploring novel in-space manufacturing technologies and techniques 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.

B. Program Change Summary ($ in Millions)	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	254.671	202.606	168.926	-	168.926
Current President's Budget	256.181	190.306	158.439	-	158.439
Total Adjustments	1.510	-12.300	-10.487	-	-10.487
• Congressional General Reductions	0.000	-12.300			
• 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	5.074	0.000			
• SBIR/STTR Transfer	-3.564	0.000			
• TotalOtherAdjustments	-	-	-10.487	-	-10.487

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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Change Summary Explanation

FY 2019: Increase reflects reprogrammings offset by the SBIR/STTR transfer.
FY 2020: Decrease reflects congressional adjustment to the RSGS program.
FY 2021: Decrease reflects the completion of the DARPA Launch Challenge in FY 2020, and rescoping of efforts in the Experimental Spaceplane (XSP) program to focus on completion of the critical design review.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Experimental Spaceplane (XSP)	57.793	37.000	-
Description: The goal of the Experimental Spaceplane (XSP) program is to design a scalable, responsive, prototype reusable launch system capable of inserting commercially and militarily relevant payloads (greater than 3000 lbs.) into low earth orbit and suborbital trajectories. There is a $5M cost goal to drive down the expense of space access by an order of magnitude versus traditional expendable launch vehicles. This is 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 traces to the responsiveness necessary in a military system. The system will be designed to fly greater than Mach 6.5 multiple times, which directly translates to a reusable hypersonic capability. The anticipated transition partner is the Air Force. ***FY 2020 Plans:*** - Complete final design iteration of the system prior to development of detailed drawings. - Complete the new Design Reference Mission (DRM) concept of operations. - Define all quality and risk requirements. - Complete Guidance Navigation and Control (GN&C) final analysis cycle to prepare for Critical Design Review (CDR). - Complete all quarterly program and design reviews with updates to the Key Performance Parameters (KPP) and Technical Performance Measurements (TPM). ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: Robotic Servicing of Geosynchronous Satellites (RSGS)	119.508	47.306	46.329
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			

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021
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 develop and publish non-binding, consensus-based standards for safe operational approaches. ***FY 2020 Plans:*** - Test interim build of flight software. - Complete build and test of second robotic arm and both tool changers. - Continue build of flight units of robotic tools and tool holders. - Continue integration of robotic payload. - Test integrated robotic payload. - Complete build of rendezvous and proximity operations sensors. - Publish revised CONFERS consensus standards inclusive of lessons learned from on-going commercial and government activity. - Lead International Standards Organization (ISO) Technical Committee review and publication of CONFERS Standard Operational Principles and Practices. ***FY 2021 Plans:*** - Complete flight software for integration. - Complete payload structures fabrication. - Complete build of flight units of robotic tools and tool holders. - Test robotic tools and integrate onto spacecraft. - Continue integration of robotic payload. - Convene CONFERS third general assembly and open forum. - Publication of CONFERS Standard Operational Principles and Practices by ISO. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects completion of system builds and extension of schedule due to acquisition of new commercial partner.			
Title: Blackjack ***Description:*** The Blackjack program will develop 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;	20.180	50.000	75.710

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
target identification, tracking, and characterization; 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. The anticipated transition partners are the Air Force and the Army. ***FY 2020 Plans:*** - Begin modeling and simulation with bus, payload, and autonomy element emulators for risk reduction efforts. - Complete Critical Design Review (CDR) for commoditized satellite bus. - Complete CDR for sensor payloads. - Complete Preliminary Design Review (PDR) for autonomous control element. - Initiate spacecraft bus manufacturing. - Initiate sensor payload manufacturing. ***FY 2021 Plans:*** - Complete CDR for autonomous control element. - Initiate autonomous control element manufacturing. - Complete CDR for satellite integrator. - Procure missile tracking payload sensor for in-space experiments. - Initiate assembly, integration, and testing for initial two satellites. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects procurement of missile tracking payload sensor and satellite assembly, integration and testing.			
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 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 programs or refocus ongoing work. Topics of consideration include advanced or novel propulsion systems, novel sensors, advanced lightweight structures, advanced miniature radio frequency (RF) technology, navigation technologies, avionics, structures, advanced communications and on-orbit software environments.	2.000	2.500	3.400

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
FY 2020 Plans: - Conduct feasibility studies for new system concepts. - Examine technology developments supporting space propulsion and power systems and resilient space architectures. ***FY 2021 Plans:*** - Initiate studies of new concepts and novel approaches for space systems. - Examine the use of new technologies to provide resilient space system capabilities. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects minor program repricing.			
Title: Planar Imager ***Description:*** The Planar Imager program seeks to disrupt the state-of-the-art in optical sensors by developing a lightweight, compact, affordable optical payload that can be integrated into a ride-share compatible satellite bus with equivalent imaging performance to current commercial conventional optical imaging satellites. This technology will 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 with a rapid reconstitution ability. To achieve this goal, Planar Imager will exploit recent developments in materials science and nanofabrication by maturing small-scale ultra-thin optics demonstrated in the laboratory to meter-scale and demonstrate a proof-of-concept optical system in space. The reduction in optical payload SWAP-C will disrupt the paradigm of costly custom large meter-scale aperture ISR satellites on dedicated launches to satellites with high-performance ISR systems that are ride-share compatible. These compact optical payloads will enable a large number of meter-scale aperture ISR satellites packed into a single launch vehicle fairing, dramatically reducing launch costs as well. A more persistent and pervasive space-based ISR architecture will increase warfighter readiness and lethality. These planar optics will also have applications to any optical imaging system and will impact all areas of optical remote sensing and imaging as well as any system that requires optical components including laser systems. The anticipated transition partner is the Air Force. ***FY 2020 Plans:*** - Evaluate small-scale lens performance in relevant imaging environment. - Select planar lens design approach and define lens design goals based on results of small-scale prototype efforts. - Conduct trade studies to identify optimal scale-up technique for thin lens fabrication approach to meet concept threshold and objective goals. - Produce medium-scale prototype lens and verify performance in laboratory. ***FY 2021 Plans:*** - Field test medium-scale prototype system in relevant environment, evaluate optical performance, and evaluate space resilience.	-	5.000	12.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Initiate preliminary design of full-scale lens system. - Create detailed design of full-scale lens system and identify fabrication method to achieve high performance full-scale planar lens. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects progression from initial design and laboratory testing to field tests and design of full-scale system.			
Title: Demonstration Rocket for Agile Cislunar Operations (DRACO)* ***Description:*** *Formerly Reactor on a Rocket (ROAR) The Demonstration Rocket for Agile Cislunar Operations (DRACO) program will develop and demonstrate a High-Assay Low-Enriched Uranium (HALEU) nuclear thermal propulsion (NTP) system. The capability afforded by NTP will expand the operating presence of the U.S. in space to the cislunar volume and enhance domestic operations to a new high-ground, which is in danger of being defined by the adversary. The program will initially develop the use of additive manufacturing (AM) approaches to print NTP fuel elements. This program will be the first demonstration of AM printing of uranium fuel elements. The results will be used to enable optimized NTP reactor designs that are not constrained by traditional manufacturing. The anticipated transition partner is the Air Force. ***FY 2020 Plans:*** - Demonstrate ability to additively manufacture uranium nuclear thermal propulsion (NTP) fuel elements. ***FY 2021 Plans:*** - Complete system requirements review for NTP demonstration reactor. - Demonstrate a design of NTP fuel elements in representative test environments. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program focus shift from feasibility studies to design and initial demonstration.	-	10.000	21.000
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 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	19.250	38.500	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 will reward competitors who can 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. The U.S. Government can make future use of commercial contracting mechanisms for rapid space launch with successful performers. The anticipated transition partners are the Air Force and NASA. ***FY 2020 Plans:*** - Conduct first and second launches at specified ranges to demonstrate rapid timescale and flexibility. - Award challenge prizes for the first and second launches. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects completion of the challenge events.			
Title: Radar Net ***Description:*** The Radar Net program developed a lightweight, low power, wideband capability for radio frequency (RF) communications and remote sensing for a space-based platform. The enabling technologies of interest are extremely lightweight and space capable deployable antenna structures. Current deployable antenna options have not been sufficiently developed to be dependable on small payload launches, leaving current capabilities trending to large and more costly satellite systems. These satellite systems are expected to have long operational lifetimes, which can leave them behind the pace of state-of-the-art technical developments. The technologies developed under Radar Net enabled small, low-cost sensor payloads on short timescales with rapid technology refresh capabilities.	25.000	-	-
Title: Hallmark ***Description:*** The Hallmark program demonstrated a space Battle Management Command and Control (BMC2) development capability to provide U.S. senior leadership the tools needed to effectively manage space assets in real time. The program enabled the rapid development of command and control decision support tools for the full-spectrum of space operations, management, and control, from peace to potential conflict. Hallmark demonstrated the ability to increase space threat awareness via use of multi-data fusion and to protect against threats by using modeling and simulation tools to develop courses of action for both natural events and adversary actions. The program employed artificial intelligence (AI) and machine learning (ML) technologies to increase commander and operator awareness, thereby transforming information to knowledge and effectively communicating and facilitating time-critical decision making. The Hallmark BMC2 layer was underpinned by an innovative, flexible infrastructure that enables the agile development and integration of tools in an accelerated, operationally relevant time fame, in	12.450	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
order to respond to shifting adversary Tactics, Techniques, and Procedures (TTPs). Elements of the program have transitioned to an Intelligence Community partner, with additional transitions to Intelligence Community partners and the Air Force in progress.			
Accomplishments/Planned Programs Subtotals	256.181	190.306	158.439

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	100.042	123.616	95.864	-	95.864	142.412	154.559	154.510	163.496	-	-
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	51.871	58.279	36.131	-	36.131	75.512	102.559	102.510	111.496	-	-
MT-16: *BEYOND SCALING ADVANCED TECHNOLOGIES*	-	48.171	65.337	59.733	-	59.733	66.900	52.000	52.000	52.000	-	-

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; (2) integrated photonic-electronic components for positioning, navigation and timing in GPS-denied environments; (3) flexible, software-defined cameras that enable real-time image analysis of complex scenes to provide more actionable information; and (4) 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 2021 Defense Advanced Research Projects Agency	Date: February 2020
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B. Program Change Summary ($ in Millions)	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	111.099	128.616	196.405	-	196.405
Current President's Budget	100.042	123.616	95.864	-	95.864
Total Adjustments	-11.057	-5.000	-100.541	-	-100.541
• Congressional General Reductions	0.000	-5.000			
• 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	-7.321	0.000			
• SBIR/STTR Transfer	-3.736	0.000			
• TotalOtherAdjustments	-	-	-100.541	-	-100.541

Change Summary Explanation

FY 2019: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2020: Decrease reflects congressional action.
FY 2021: Decrease reflects completion of various Mixed Technology Integration programs in FY 2020.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	51.871	58.279	36.131	-	36.131	75.512	102.559	102.510	111.496	-	-

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; (2) integrated photonic-electronic components for positioning, navigation and timing in GPS-denied environments; (3) flexible, software-defined cameras that enable real-time image analysis of complex scenes to provide more actionable information; and (4) 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 2019	FY 2020	FY 2021
Title: Reconfigurable Imaging (ReImagine)	22.738	21.000	9.960

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 the 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 2020 Plans:
- Demonstrate the ReImagine reconfigurable sensing system concept using the Gen-1 reconfigurable ROIC.
- Complete the Gen-2 ROIC tier 1 design and submit to the foundry for manufacturing.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Begin designing a multi-functional digital ROIC camera prototype system integrating multiple tier 3D implementations and the Gen-2 reconfigurable ROIC. ***FY 2021 Plans:*** - Complete functional verification testing of Gen-2 ROIC tier 1. - Complete the design and build of the Gen-2 prototype camera that integrates the Gen-2 ROIC. - Fully demonstrate the updated ReImagine reconfigurable sensing system concept. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 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)	-	14.500	17.000
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, electronic warfare (EW) communications deception, 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 featureless 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 2020 Plans:*** - Complete system study of transceiver architecture for ultra-broadband, secure communication links. - Perform initial studies of antenna, integrated circuits, and waveform to implement ultra-broadband communications. - Simulate and optimize the transceiver architecture design. ***FY 2021 Plans:*** - Integrate the 1st-generation brassboard prototype transceiver. - Prepare testing environment for secured radio prototype in laboratory. - Perform laboratory testing of secured radio prototype in laboratory environment. - Prepare to implement 2nd generation secured transceiver prototype. ***FY 2020 to FY 2021 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
The FY 2021 increase reflects the program shifting from developing and fabricating components of the 1st-generation of transceivers to implementing a 2nd generation secured transceiver prototype.			
Title: Portable Optical Integrated Network Transceivers (POINT) ***Description:*** To enable advanced communications and improve network resiliency, the Portable Optical Integrated Network Transceivers (POINT) program aims to develop low size, weight, and power (SWaP) photonic transceivers and demonstrate them in free-space optical (FSO) links for micro-satellites and small mobile platforms. The high-SWaP of existing optical terminals with gimbals and telescopes are incompatible with micro-satellite payload capacity and mission requirements. POINT will leverage recent development of optical phased array based transmitter technology combined with wide field of view, dual-mode, high-speed imaging receivers. The integrated optical transceivers will have no moving parts, resulting in a radical reduction in SWaP, enabling advanced and resilient communications for small Low-Earth Orbit (LEO) satellites and other mobile platforms. The program will develop and demonstrate an FSO link applicable to LEO-LEO or LEO-Ground missions, providing high bandwidth, efficient, and secure communication links for resilient command, control, communications, computer, intelligence, surveillance, and reconnaissance operations in space. Other terrestrial uses of the technology include interference-free operation in denied environments and low probability of intercept/low probability of detection tactical links. Technologies developed under the POINT program are planned for transition to the Services. ***FY 2021 Plans:*** - Develop and mature chip-scale photonic transmitters and receivers with sufficient bandwidth, range, and field of regard to acquire and maintain robust FSO links up to 1 Gbps at 200 km. - Develop gimbal-free FSO terminals with form-factor and SWaP compatible with deployment on micro-satellites and small mobile platforms. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.	-	-	9.171
Title: Precise Robust Inertial Guidance for Munitions (PRIGM) ***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 focusing on two areas: (1) By 2020, it aims to develop and transition a Navigation-Grade Inertial Measurement Unit (NGIMU), a state-of-the-art MEMS device, to DoD platforms; and (2) By 2030, it aims to develop Advanced Inertial MEMS Sensors that can	12.600	12.000	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
provide gun-hard, high-bandwidth, high dynamic range navigation for GPS-free munitions. These advances will enable navigation applications, such as smart munitions, that require low-cost, size, weight, and power (SWaP) inertial sensors with high bandwidth, precision and shock tolerance. PRIGM will advance state-of-the-art MEMS gyros from TRL-3 devices to a TRL-6 transition platform, eventually enabling the Service laboratories to perform TRL-7 field demonstrations. 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 basic research efforts funded in PE 0601101E, Project ES-01 and applied research efforts funded in PE 0602716E, Project ELT-01. ***FY 2020 Plans:*** - Deliver two MEMS-based, navigation-grade, integrated IMU prototypes for government evaluation. - Evaluate MEMS-based, navigation-grade, integrated IMU prototypes (non-gun hardened) in laboratory environment. - Evaluate MEMS-based, navigation-grade, integrated IMU prototypes (non-gun hardened) in operational environment. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: Rapid Array Development (RAD) ***Description:*** The Rapid Array Development (RAD) program is building an immersive electromagnetic environment for use by the warfighter to understand the effects of electronic maneuvers and developing new electronic maneuver warfare (EMW) techniques. The program is leveraging recent 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 radically change the development and deployment cycle for EMW techniques. Currently, the development cycle for EMW algorithms is long and costly. However, they must be able to evolve rapidly in order to adapt to new modes of operation and changing operating parameters associated with modern military threats. The programmable RAD testbeds will ultimately train warfighters on how to deal with legacy and emerging threats in the RF spectrum through maneuvers, signal jamming tactics, signal intelligence gathering, and other missions. The outcome of RAD will be better tactics, techniques, and procedures for handling EMW as well as the identification of new technology assets for deploying EMW capabilities. Technologies developed under the RAD program are planned for transition to the Services. ***FY 2020 Plans:*** - Explore development of a processing platform capable of executing EMW algorithms, array configuration, data flow, and end-user interactions. - Design a software framework for rapidly developing new EMW applications.	11.533	10.779	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Initiate development of a full EMW mission control system to include electromagnetic spectrum monitoring and management. - Initiate plans for a testbed installation at a military base or radar test range and begin electromagnetic spectrum monitoring. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: Efficient Ultra-Compact Laser-Integrated Diodes (EUCLID) ***Description:*** The Efficient Ultra-Compact Laser-Integrated Diodes (EUCLID) program aimed to significantly reduce the size of laser diode pump modules (DPMs) while increasing their electrical-to-optical efficiency. EUCLID leveraged advances in thermal management components to design, build, test, and demonstrate densely packageable, prototype DPMs that are less than half the size of their commercial counterparts. The program pursued improved optical components that can more efficiently focus light from individual laser diodes. The resulting EUCLID DPMs will be available for procurement and integration into ultra-low size, weight, and power fiber-laser array weapons systems, enabling integration into a variety of Air Force, Navy, Army, and Missile Defense Agency platforms.	5.000	-	-
Accomplishments/Planned Programs Subtotals	51.871	58.279	36.131

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
MT-16: *BEYOND SCALING ADVANCED TECHNOLOGIES*	-	48.171	65.337	59.733	-	59.733	66.900	52.000	52.000	52.000	-	-

A. Mission Description and Budget Item Justification

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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Beyond Scaling - Access	30.200	25.137	18.733

Description: The Beyond Scaling - Access program will demonstrate the design and fabrication of advanced electronics through collaborations with leading industry players. It accomplishes complementary goals of working in a commercial environment for innovation beyond-SOTA to develop electronics for military capabilities, while simultaneously strengthening our domestic ecosystem and ensuring that the DoD has enduring access to SOTA technologies. Although the United States has led the development of advanced electronics since its inception 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 has led to a cost barrier in meeting its future technology needs. This program will forge forward-looking collaborations among the commercial electronics community, defense industrial base, university researchers, and the DoD. Activities include establishing design capabilities for advanced digital logic in SOTA foundries, developing new architectures for field programmable gate arrays (FPGAs) using commercial manufacturing flows, and lowering the technical hurdles for ubiquitous heterogeneous integration by revolutionizing back end compound semiconductor processes. Technologies from this program are intended for transition to the Services.

FY 2020 Plans:
- Demonstrate fabrication of DoD microelectronic designs in a leading-edge commercial foundry.
- Develop architectures and design tools for advanced, high-bandwidth FPGAs.
- Establish initial architecture specifications for potential commercially manufactured devices with DoD relevance.

FY 2021 Plans:
- Demonstrate application of Electronics Resurgence Initiative technologies in DoD-relevant applications.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Develop process flows for scaled transistor and interconnect technology for more complex (>10,000 device) III-V circuits. - Demonstrate fabrication of advanced FPGAs to achieve breakthrough high-bandwidth dataflow for DoD applications such as communications/radar beamforming, or synthetic aperture radar. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects demonstration of multiple technologies fabricated through various commercial process flows.			
Title: Millimeter Wave Digital Arrays (MIDAS)	17.971	19.200	12.000
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 GHz 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, the program will develop a common digital phased array tile that can be used to build large arrays from this common block. The program will be executed in two primary technical areas. First, advanced complementary metal oxide semiconductor (CMOS) technology will be 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 will be 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 2020 Plans:*** - Fabricate and test millimeter wave frequency low-power, 16-element, element-level digital phased arrays in advanced silicon CMOS. - Begin designs of millimeter wave 64-element digital phased arrays in advanced CMOS co-integrated with compound semiconductor power amplifiers and wideband apertures. - Continue demonstrating advancements in the fundamental technologies relevant to millimeter wave digital arrays in the areas of converters, filters, oscillators, and broadband apertures. ***FY 2021 Plans:*** - Finalize designs of millimeter wave 64-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 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Begin finalizing advancements in the fundamental technologies relevant to millimeter wave digital arrays in the areas of converters, filters, oscillators, and broadband apertures. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the program shifting from demonstrating to finalizing advancements in the fundamental technologies relevant to the millimeter wave digital arrays.			
Title: Photonics in the Package for Extreme Scalability (PIPES)*	-	7.000	13.000
Description: *Previously part of Beyond Scaling - Access 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 FPGAs, widely used in advanced DoD sensors and RF systems. The goal of the program is improving I/O bandwidth density, efficiency, and reach by >100x 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 2020 Plans:*** - Design and begin fabrication of silicon photonics and electronic drive circuitry to enable package-level photonic interconnects for state-of-the-art (SoA) FPGAs, targeting 10x improvements to link energy and bandwidth over current SoA performance. - Develop and demonstrate innovative component technologies for next-generation photonic interconnects, targeting concepts for 100x improvement to link energy and bandwidth over current SoA performance. ***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.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Integrate innovative component technologies and characterize link performance of next-generation photonic interconnect capabilities. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects the program shifting from designing to integrating silicon photonics and electronic drive circuitry, and characterizing the packaged photonic interconnect demonstrator's performance to enable FPGAs with photonic interfaces.			
Title: Technologies for Mixed-mode Ultra Scaled Integrated Circuits (T-MUSIC)*	-	14.000	16.000
Description: *Previously part of Beyond Scaling - Access The Technologies for Mixed-mode Ultra Scaled Integrated Circuits (T-MUSIC) program will develop 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. The mixed-mode circuits take signals from the physical world (analog, RF) and transform them to be processed in computing systems (digital). As defense and commercial wireless applications move to higher frequencies to carry faster data traffic, integrating the broadband mixed-mode circuitries with high speed digital processing logics onto one integrated chip is needed to attain the performance required for future systems. 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. The goal of T-MUSIC technology is to enable wireless operations beyond 100 GHz with very wide bandwidth with low noise and high dynamic range. In parallel, T-MUSIC aims to develop the next-generation terahertz (THz) 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 2020 Plans:*** - Develop 350 GHz high speed mixed-mode device technology leveraging domestic foundry fabrication processes and facilities. - Define device topology and advanced fabrication techniques through simulation and experiments in foundries. - Explore advanced materials, device structures, and integration processes for THz devices in a domestic CMOS process platform. ***FY 2021 Plans:*** - Fabricate and demonstrate foundational mixed-mode analog/digital circuit building blocks in domestic foundries. - Identify the development specification for next-generation 400 GHz high speed mixed-mode device technology. - Demonstrate advanced materials, THz device structures, and integration process based on domestic CMOS process platform. ***FY 2020 to FY 2021 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
The FY 2021 increase reflects the program shifting from developing to fabricating foundational mixed-mode analog/digital building blocks in domestic foundries.			
Accomplishments/Planned Programs Subtotals	48.171	65.337	59.733

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	178.074	229.134	221.724	-	221.724	283.864	269.986	245.909	226.491	-	-
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	99.823	130.539	110.555	-	110.555	204.112	226.992	222.109	226.491	-	-
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	78.251	98.595	111.169	-	111.169	79.752	42.994	23.800	0.000	-	-

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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	185.984	232.134	188.881	-	188.881
Current President's Budget	178.074	229.134	221.724	-	221.724
Total Adjustments	-7.910	-3.000	32.843	-	32.843
• Congressional General Reductions	0.000	-10.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	7.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	3.176	0.000			
• SBIR/STTR Transfer	-11.086	0.000			
• TotalOtherAdjustments	-	-	32.843	-	32.843

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	**Date:** February 2020
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*

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

	FY 2019	FY 2020
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 2019: Decrease reflects SBIR/STTR transfer, offset by reprogrammings.
FY 2020: Decrease reflects congressional adjustments.
FY 2021: Increase reflects initiation of several Information Integration Systems programs and expansion of classified programs in FY 2021.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	99.823	130.539	110.555	-	110.555	204.112	226.992	222.109	226.491	-	-

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 2019	FY 2020	FY 2021
Title: Secure Handhelds on Assured Resilient networks at the tactical Edge (SHARE)	23.503	24.963	10.655

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 2020 Plans:

- Conduct research and experimentation using SHARE software prototype that further supports creation of automated network configuration software. Experiments will test compatibility with existing operationally deployed handheld devices.
- Conduct research and begin integrating SHARE security and networking capabilities into operational airborne and ground networks that support larger DoD command & control (C2) enterprise systems in addition to tactical handhelds.
- Conduct field experimentation during multiple DoD-sponsored coalition exercises to validate SHARE system security and performance.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Begin co-development of SHARE software with DoD partners for follow-on software configuration management. ***FY 2021 Plans:*** - 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 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from research and experimentation to system integration and transition.			
Title: Dynamic Network Adaptation for Mission Optimization (DyNAMO)	20.965	15.330	4.989
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 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 2020 Plans:*** - Conduct ground test of integrated system. - Conduct field test of integrated system with instantiations of inter-network coordination, mission-based control, and real-time optimization to show the quantitative and qualitative value of DyNAMO for a variety of military missions. - Integrate program software into tactical radio hardware. - Demonstrate Army, Navy, Marine, and Air Force inter-network scenarios. ***FY 2021 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
- Integrate advanced security elements into DyNAMO in order to operate over multiple security enclaves that exist when using multiple radio platforms and networks. - Demonstrate the integrated system of DyNAMO to service partners, illustrating the usefulness of DyNAMO in a tactical environment with multiple security enclaves. - Provide DyNAMO software in government controlled repository for use by the Military Services. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from testing and initial integration to final demonstrations and further refinement of the system.			
Title: Geospatial Cloud Analytics (GCA) ***Description:*** The Geospatial Cloud Analytics (GCA) program will develop 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 Services and DoD Agencies. ***FY 2020 Plans:*** - Complete a multi-source, multi-modality platform with global-scale analytics. - Demonstrate ability for DoD users to use the analytics services in an operationally relevant environment. - Refine the analytics services based on feedback from end users ***FY 2021 Plans:*** - Begin development of additional future advanced analytics services based on feedback from end users. - Transition analytics services to additional DoD military users and other Government entities. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from platform and software development into testing of the analytics services in operationally relevant environments.	21.965	19.993	7.889
Title: Network Universal Persistence (Network UP)	12.377	23.934	9.829

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** - Demonstrate a communication system that provides reliable communications in the presence of jamming. - Demonstrate physical communications channel divided into two separate functions and radio frequency bands. - Complete design of radio architectures and build and test prototypes. - Complete design of network architectures and build and test prototypes. - Demonstrate radio architectures in highly mobile scenarios with large amounts of environmental attenuation. ***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. - 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from system development to testing.			
Title: Protected Forward Communications (PFC) ***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	12.593	20.924	11.069

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
(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 2020 Plans:*** - Conduct simulation and modeling of systems in representative operating environments to assess resistance to geolocation and jamming. - Conduct system engineering reviews to ensure design readiness for further development. - Conduct experimental validation of key design elements. - Develop size, weight, and power estimates for complete prototype and complete system. - Develop bread board implementations of communications technologies. ***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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects transitioning from design and prototyping activities to experimentation and assessment activities.			
Title: Composable Logistics and Information Omniscience (LogX) ***Description:*** The Composable Logistics and Information Omniscience (LogX) program will develop and demonstrate 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).	-	18.395	25.552

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
FY 2020 Plans: - Initiate development and demonstration of the technology and the underlying enabling capabilities. - Demonstrate diagnostic and prognostic capabilities enabling situational awareness. - Begin integration of test environment with limited complexity logistics data set. ***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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects additional effort required to conduct demonstrations and prepare systems for deployment in operational settings.			
Title: Multi-Domain Analytics (MDA) ***Description:*** The Multi-Domain Analytics (MDA) program will develop network and data management tools for automating the establishment of cross-domain networks in support of data analytics and decision making tools. The tools will manage information flow to support data correlation and fusion across multiple, isolated databases and networks. Technology advances are making it possible to pass messages across heterogeneous waveforms and networks, but there are no technologies today that can determine if it is the data that is most important to end users and systems. Building upon technologies developed in the Secure Handhelds on Assured Resilient networks at the tactical edge (SHARE) program (budgeted in this PE/Project), MDA will combine network management with data analytics, information exploitation and fusion technology to route information in an understandable context, based upon information need and value. MDA also seeks to address multi-level security configuration issues that often add delays and limit interoperability. The MDA program will enable automated data analysis across different networks without manually moving impracticably large amounts of data. Technology developed by this program will transition to the Services. ***FY 2021 Plans:*** - Create initial machine learning, artificial intelligence (AI), and other techniques for understanding context and information value at user, system, and mission level. - Begin development of algorithmic techniques for determining global information relevance and importance and converting it to local context. - Create initial Course of Action Analyses for tactical level decision making using information from multiple security levels. ***FY 2020 to FY 2021 Increase/Decrease Statement:***	-	-	7.232

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
The increase in FY 2021 reflects program initiation.			
Title: Dynamic Airspace Control	-	-	13.693
Description: The Dynamic Airspace Control program will develop and demonstrate alternate means of creating the local airspace picture and dynamically managing the local airspace without requiring high power radars or communications. This capability will support the simultaneous operations and airspace deconfliction of a wide array of airborne systems, such as manned and unmanned weapons systems and non-combatant aircraft. Based on technologies developed in the Systems of Systems-Enhanced Small Units (SESU) program (budgeted in PE 0603766E/Project NET-01), Dynamic Airspace Control will consist of an artificial intelligence engine and a mix of traditional and non-traditional sensors to create the air picture. It will also leverage legacy Airspace management tools to take advantage of prior investments in technologies, such as human-machine interfaces, and to minimize the impact on training. The artificial intelligence engine will generate a real-world model enabling automated airspace deconfliction for a variety of simultaneous missions (e.g., helicopter search and rescue, fires, and surveillance with unmanned airborne vehicles). The program will use traditional and non-traditional sensors, such as flight plans, air platform self-reporting, and passive sensing in order to confirm flight plans or to detect unidentified air platforms in the airspace. Technologies from this program will transition to the Air Force. ***FY 2021 Plans:*** - Develop representative airspace vignettes and identify performance metrics. - Design and develop the software architecture, development environment (DEVOPS), and interface specifications to host the artificial intelligence engine algorithms and interoperate with legacy airspace management tools. - Define required training data sets. - Identify non-traditional sensor options and develop models. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Resilient Networked Distributed Multi-Transceiver Communications (RNDMC)	-	-	7.365
Description: Resilient Networked Distributed Multi-Transceiver 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 repeaters 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 repeaters and tactical radios to enhance desired signals and reject intentional and unintentional interference. Based on technologies developed in the Protected Forward Communications (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 repeater			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
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 CEWEC configurations. - Begin development of specifications for tactical terminals and repeater nodes. - Verify designs using modeling and simulation in ground and air vignettes. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Multi-Network Exploitation (MNE) ***Description:*** Multi-Network Exploitation (MNE) will create an end-to-end logical network to enable tactical network resilience and assurance to ensure critical information is exchanged between systems and their users. This will include the research and development of a common underlying (physical or virtual) infrastructure that permits the transfer of information across multiple paths and between multiple systems. Based on technologies developed in the Secure Handhelds on Assured Resilient Networks at the Tactical Edge (SHARE) program (budgeted in this PE/Project), the MNE program will develop networking systems that are sensitive to the tradeoffs of delivery of both timely and precise information. MNE will investigate innovations to layers in the network stack to offer new opportunities for ensuring critical systems and user information are delivered in virtual slices across multiple networking paths, including combinations of tactical and commercial networks, even when the underlying physical networks are not designed to operate with each other. MNE will demonstrate improved access, quality of service, and data rates with reduced latency on scaled networks to ease application to enterprise and tactical networks. Technology developed by the MNE program will transition to the Services. ***FY 2021 Plans:*** - Identify technologies that contribute to overall end-to-end system design. - Conduct individual sub-system laboratory testing to validate technology performance and suitability for overall MNE system design. - Select and initiate development of multi-network test site for at-scale evaluation. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.	-	-	5.942
Title: Trusted Networks (TNets)	-	-	6.340

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
Description: The Trusted Networks (TNets) program will create technology that allows any underlying network path to be used for command and control, enables automated command and control functions to be distributed using trusted platforms (e.g. trusted Distributed Computing), and supports distributed network forensics and continuous verification. Based on technologies developed in the Secure Handhelds on Assured Resilient Networks at the Tactical Edge (SHARE) program (budgeted in this PE/Project), TNets will build architectural redundancy and trust at multiple levels with trusted hardware, software-defined radio and networking protocols, and network-level integrity using novel, distributed security. TNets will also develop a trusted network appliance and networking design principles that enable resilient and secure tactical and strategic communications regardless of the underlying physical infrastructure. This will provide mission-adaptive military connectivity, while minimizing network logistics and interoperability burdens. Technologies developed under this program will transition to the Services. ***FY 2021 Plans:*** - Initiate research into hardware and networking component technologies. - Begin hardware research and laboratory analysis to verify system building block capabilities. - Conduct operating system and application research and laboratory analysis to determine network architectures. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY2021 increase reflects program initiation.			
Title: Spectrum Efficiency and Access ***Description:*** The Federal Government is working to transition large swaths of spectrum (up to 500 MHz) from Federal (DoD is the primary contributor) to civilian use for broadband telecommunications. The DoD will need more highly integrated and networked sensor and data capacity over the next decades and will therefore need new technology that requires less spectrum to operate. The objective of the Spectrum Efficiency and Access program was to investigate improvements in spectral reuse, such as spectrum sharing of sensor and radar bands with communication systems. The program leveraged technologies originally developed for radar anti-jam and interference mitigation that could enable spectrum sharing by allowing overlay of communications within the same spectral footprint. The approach included exploring real-time control data links between radars and communications systems and developing the advanced waveforms and components to enable radars and communication networks to operate in close proximity. The ultimate goal was to turn the DoD spectrum loss into a net gain of up to hundreds of MHz in capacity. Technology from this program transitioned to the Army.	5.987	-	-
Title: 100 Gb/s RF Backbone ***Description:*** The proliferation of video, voice, chat, and other important data-streams on the battlefield has driven a need for higher capacity, reliable, assured, and all-weather communications that are deployable on a wide range of air, ground, and maritime platforms. The goal of this High-Capacity Links technologies program was to demonstrate a 100 Gigabit-per-second	2.433	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
(Gb/s) radio frequency (RF) backbone that could meet the anticipated mid-term (within 3-10 years) wireless networking capacity needs of deployed military forces. The primary focus of the program was a millimeter-wave (mmW) solution to provide high capacity and all-weather resiliency. The program developed the constituent subsystems (waveform generation, efficient power amplifiers, and receivers) and spatial multiplexing architectures to construct an all-weather mmW 100 Gb/s backbone at half the SWaP consumption of the current Optical RF Communications Adjunct (ORCA) system. Technology developed under this program transitioned to the Air Force.			
Accomplishments/Planned Programs Subtotals	99.823	123.539	110.555

	FY 2019	FY 2020
Congressional Add: Satellite Antenna Technology ***FY 2020 Plans:*** - Conduct research in technology for satellite antennas.	-	7.000
Congressional Adds Subtotals	-	7.000

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	78.251	98.595	111.169	-	111.169	79.752	42.994	23.800	0.000	-	-

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 2019	FY 2020	FY 2021
Title: Classified DARPA Program	78.251	98.595	111.169
Description: This project funds Classified DARPA Programs. Details of this submission are classified.			
FY 2020 Plans: Details will be provided under separate cover.			
FY 2021 Plans: Details will be provided under separate cover.			
FY 2020 to FY 2021 Increase/Decrease Statement: Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	78.251	98.595	111.169

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 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	413.948	507.424	661.158	-	661.158	647.113	545.081	475.012	437.982	-	-
NET-01: *JOINT WARFARE SYSTEMS*	-	100.528	99.487	148.199	-	148.199	130.697	151.941	168.992	197.352	-	-
NET-02: *MARITIME SYSTEMS*	-	79.808	127.484	148.459	-	148.459	224.082	220.946	239.020	240.630	-	-
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	233.612	280.453	364.500	-	364.500	292.334	172.194	67.000	0.000	-	-

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.

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 2021 Defense Advanced Research Projects Agency	Date: February 2020
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*

B. Program Change Summary ($ in Millions)	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	434.069	512.424	447.162	-	447.162
Current President's Budget	413.948	507.424	661.158	-	661.158
Total Adjustments	-20.121	-5.000	213.996	-	213.996
• Congressional General Reductions	0.000	-5.000			
• 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	-5.525	0.000			
• SBIR/STTR Transfer	-14.596	0.000			
• TotalOtherAdjustments	-	-	213.996	-	213.996

Change Summary Explanation

FY 2019: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2020: Decrease reflects congressional reduction.
FY 2021: Increase reflects expansion of experimentation programs, maritime efforts and classified programs.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
NET-01: *JOINT WARFARE SYSTEMS*	-	100.528	99.487	148.199	-	148.199	130.697	151.941	168.992	197.352	-	-

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 2019	FY 2020	FY 2021
Title: System of Systems Integration Technology and Experimentation (SoSITE)	29.159	18.159	13.625
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 2020 Plans:*** - Deploy SoSITE integration technologies, called STITCHES (System of Systems Technology Integration Tool Chain for Heterogeneous Electronic Systems), to a DoD-accredited cloud hosted repository.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Implement upgrades to toolchain required by transition partners, including technology to allow full backwards and forwards compatibility of all versions of the toolchain. - Perform live flight experiments of system of systems architectures. - Design coalition system of systems architectures and plan international integration events with U.S. foreign partners. ***FY 2021 Plans:*** - Perform live flight experiments for USAF and USN partners. - Create and deploy STITCHES training software. - Establish transition team to migrate the SoSITE STITCHES toolchain to the USAF and USN. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the transfer of the SoSITE technology and transition team to the responsibility of the USAF and USN.			
Title: Prototype Resilient Operations Testbed for Expeditionary Urban Systems of Systems (PROTEUS)	20.285	15.960	14.136
Description: The Prototype Resilient Operations Testbed for Expeditionary Urban Systems of Systems (PROTEUS) program will demonstrate 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 provide the tools and automation to enable small tactical units to compose force packages optimized to specific urban combat objectives and challenges. These tools will support planning and force composition for all missions relevant to the urban environment: command & control, fires, maneuver, logistics, intelligence, force protection, and medical. 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 2020 Plans:*** - Begin development of planning and force composition tools for spectrum and intelligence operations. - Demonstrate integration of the virtual testbed and composition tool using multi-resolution scenarios with increased complexity. - Demonstrate enhanced adaptive composition capability with Service participants. ***FY 2021 Plans:*** - Expand development of planning and force composition tools for information 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 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Demonstrate system integration with Service participants executing multi-echelon operations. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from initial testing and refinement to demonstration and documentation.			
Title: Systems of Systems-Enhanced Small Units (SESU)	14.815	23.185	20.487
Description: The System-of-Systems-Enhanced Small Unit (SESU) program will develop and demonstrate 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 and combat systems. Technologies to accomplish this include command & 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 2020 Plans:*** - Integrate modeling and simulation environment and evaluate baseline and advanced architecture performances based on selected scenarios. - Demonstrate impact of advanced technology suites. - Down select from designs based on performance and begin development of prototypes with distributed C2, sensors, and effectors. - Develop plan for live field experimentation for CoL. - Finalize architectures and designs for C2, sensors, and effectors and provide documentation for government modeling and simulation efforts. ***FY 2021 Plans:*** - 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. - Demonstrate architecture flexibility by incorporating government furnished third party sensors, effectors, and autonomous platforms.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Conduct live, virtual, constructive experiments for a government provided mission to demonstrate the ability of the system to support new missions and transition. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from development to testing.			
Title: Assault Breaker II (ABII)	24.400	28.000	71.350
Description: Assault Breaker II (ABII) seeks to change the current warfighting paradigm of reliance on Service-specific, platform centric force executing prescribed kill chains to a highly adaptable, capability-based force operating as a disaggregated kill web able to execute rapidly composable, joint, all domain kill chains. Building upon technologies developed in the Cross Domain Maritime Surveillance and Targeting (CDMaST) program, budgeted in this PE and 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 and simulation (M&S), and experimentation to inform research and development and program of record recommendations, and 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 with physical nodes that will enable the transition of ABII technologies, concepts and architectures to transition to the Services. ***FY 2020 Plans:*** - Complete initial kill web analysis studies and deliver updated advanced kill web technologies program recommendation report. - Initiate second round of kill web analysis studies to support kill web architecture refinement. - Execute contracts for the modeling and simulation architectures. - Complete M&S testbed development. - Complete preliminary design of multi-domain, multi-level security environment. - Complete preliminary experimentation plan. - Perform baseline experiments to serve as a proof of concept for the final experimentation environment. - Complete preliminary design of the Vanguard Force DevOps Environment (VFDE). - Initiate contracting of relevant parties to execute DevOps architectures and software modules. ***FY 2021 Plans:*** - Initiate detailed design of multi-domain, multi-level security environment. - Demonstrate completed modules and simulation environment compatibility. - Demonstrated completed modules and scenarios for VFDE and related facilities. - Complete studies for finalization of kill web architecture and effects. - Begin experimentation efforts within the Distributed Experimentation Environment (DE2). - Complete stand up of the VFDE.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Demonstrate completed modules and battle management capabilities of the VFDE. - Complete early user evaluations and field trial of technologies matured through ABII. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY2021 increase reflects the additional scope of the VFDE, as well as the software and modules required to execute.			
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 2020 Plans:*** - Develop AI dogfight algorithms and test in M&S environment against simulated red air adversaries. - Develop initial empirically-based trust measurement model. - Design and develop the Human Machine Interfaces (HMIs) for M&S assessment, and provide detailed designs of the HMIs for use with the sub-scale and full-scale platforms. - Begin development of extension of combat autonomy algorithms to large force exercise data analytics. ***FY 2021 Plans:*** - Refine and implement WVR algorithms onto sub-scale commercial UAV aircraft and test in a live experiment. - Develop 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program shift from initial development to multiple live flight testing events.	-	12.838	28.601
Title: Resilient Synchronized Planning and Assessment for the Contested Environment (RSPACE)	11.869	1.345	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
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 will develop 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 will develop tools supporting a mixed initiative planning approach, maximizing automation according to operator's choice, and enabling human-in-the-loop intervention and modification. RSPACE will also develop 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 will provide lifecycle tracking of targeting and information needs and support assessment of progress towards achieving the commander's intent. The tools will dynamically respond as directed to ad hoc requests and significant plan deviations via a real-time dynamic re-planning capability and easily adapt to technology refreshes. RSPACE tools will transition to the Air Force and the Navy. ***FY 2020 Plans:*** - Complete software development in support of transition of select RSPACE software components to Air Force Program of Record. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Accomplishments/Planned Programs Subtotals	100.528	99.487	148.199

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
NET-02: *MARITIME SYSTEMS*	-	79.808	127.484	148.459	-	148.459	224.082	220.946	239.020	240.630	-	-

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 2019	FY 2020	FY 2021
Title: Cross Domain Maritime Surveillance and Targeting (CDMaST)	25.892	22.897	11.326

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 2020 Plans:
- Complete system integration.
- Complete software-in-the-loop system testing.
- Complete CDMaST testbed.
- Conduct two at-sea demonstrations of the CDMaST architecture.

FY 2021 Plans:
- Document results of at-sea demonstrations and deliver test results report.
- Perform analysis of results and develop final experimentation plan.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Execute final CDMaST experimentation event. - Prepare documentation to support capability transition to the Navy. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a decline in major experimentation efforts.			
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 2020 Plans:*** - Complete fabrication of carriage system. - Develop full Hunter system and information assurance implementation test plan. - Perform stand-alone in-water test of full Hunter payload delivery carriage. - Commence carriage integration with the XLUUV. ***FY 2021 Plans:*** - Continue 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. - Complete coordinated in-water systems-of-systems testing. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the transition from system development to integration and test.	24.496	22.742	11.863
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	11.499	25.933	13.011

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
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 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 2020 Plans:*** - Develop advanced platform design. - Research active sensor behaviors for potential inclusion into advanced system design. - Demonstrate and test advanced sensors through large-scale ocean float deployment. - Develop government data cloud and architecture, model ocean inputs, and apply initial machine learning applications. - Develop visualization of machine learning results for military application. - Evaluate test data to determine performance and coverage in the ocean. ***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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the shift from hardware development to cloud deployment of software analytics.			
Title: Timely Information for Maritime Engagements (TIMEly)* ***Description:*** *Formerly Heterogeneous Under-Water Communications (HUWC) 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 will create a heterogeneous underwater network architecture that will span the ocean and bridge to other operating domains. Building upon technologies learned in the Tactical Underwater Network Architecture and Positioning System for Deep Ocean Navigation (POSYDON) programs, 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	-	11.778	20.259

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
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 2020 Plans:*** - Conduct modeling and simulation to support architecture design trade studies. - Begin development of heterogeneous network architectures comprised of acoustic and non-acoustic elements. - Begin development of algorithms to adapt networks to mission and environment. - Commence operational and mission analysis to identify sample program missions and performance metrics. ***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. - 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects an increase in testing, hardware procurement, and integration.			
Title: Disaggregated Strike Group - Manta Ray* ***Description:*** *Previously part of Maritime Missileer The Disaggregated Strike Group - Manta Ray (DSG - 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 DSG - 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, long duration energy management techniques, biofouling reduction technologies, and long duration navigational enablers. The anticipated transition partner is the Navy. ***FY 2020 Plans:*** - Develop concept of operations and identify critical technologies.	-	11.415	22.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Develop system requirements. - Develop representative platform concept designs. ***FY 2021 Plans:*** - Conduct preliminary design review. - Develop platform subsystems. - Demonstrate and test subsystems in a controlled maritime environment. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects transition from initial concept development to systems development.			
Title: No Manning Required Ship (NOMARS)* ***Description:*** *Previously part of Maritime Missileer, formerly called Disaggregated Strike Group - Surface 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 seaframe (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 2020 Plans:*** - Begin evaluation of design trade space and initial concept development. - Begin technology exploration activities related to self-health autonomy and other critical subsystem technologies. ***FY 2021 Plans:*** - Complete Conceptual Design Review (CoDR). - Identify critical technology risks areas and develop risk reduction strategies. - Initiate formation of specific ship/maintenance concepts. - Conduct system preliminary design.	-	13.000	24.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Complete preliminary recurring unit cost analysis. - Complete initial mission analysis study. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program continued ramp up from initial trade space analysis to risk reduction and design.			
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 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 also has a companion applied research effort budgeted in PE 0602702E, Project TT-03. The anticipated transition is to the Navy. ***FY 2020 Plans:*** - Begin systems engineering and design of prototype architecture for autonomous, undersea manipulation operations. - Complete Conceptual Design Review (CoDR). - Conduct Preliminary Design Review (PDR). - Test robot subsystems in laboratory or simulation environments. ***FY 2021 Plans:*** - Conduct Critical Design Reviews (CDR). - Develop fully integrated robot system prototypes. - Demonstrate and test robot prototypes in a representative maritime environment. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects system platform design and integration and initial testing of prototypes.	-	15.000	26.000
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.	-	-	20.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
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:*** - Conduct exploratory trade studies to establish feasibility of technical approaches. - Perform Conceptual Design Review of the Objective System. - Conduct Systems Requirements Review of the Phase 1 Demonstration System. - Perform subsystem integration and test. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
Title: Positioning System for Deep Ocean Navigation (POSYDON) ***Description:*** The Positioning System for Deep Ocean Navigation (POSYDON) program will provide 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 will distribute a small number of acoustic sources, analogous to GPS satellites, around an ocean basin at known locations. A submarine or AUV will be equipped with an acoustic receiver and appropriate software in order to obtain and maintain 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 can determine its range from each source and thus calculate its position. Technologies developed under this program will transition to the Navy. ***FY 2020 Plans:*** - Transition POSYDON hardware to Navy undersea test bed. - Demonstrate mission planning tool to guide system employment. - Conduct modeling and simulation to demonstrate concept of operations for deep and littoral mission. ***FY 2020 to FY 2021 Increase/Decrease Statement:***	13.580	4.719	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
The FY 2021 decrease reflects program completion.			
Title: Mobile Offboard Command, Control and Attack (MOCCA) ***Description:*** The Mobile Offboard Command, Control and Attack (MOCCA) program sought to counter the fourth-generation submarine signature quieting technology that has significantly degraded passive anti-submarine warfare (ASW) sonar detection range and targeting performance. The MOCCA program aimed to nullify submarine signature reduction trends with active sonar projectors deployed from a mobile unmanned undersea vehicle (UUV) and cooperatively processed with onboard submarine acoustic receive sonar systems. The off-board UUV sonar projector was planned to operate under positive control at a significant distance from the cooperative submarine using communication links. The program achieved breakthrough capability for novel low probability of intercept/low probability of detection (LPI/LPD) communication signaling. The MOCCA communication system was integrated into submarine onboard sonar systems. Communication technologies from this program transitioned to the Navy.	1.889	-	-
Title: Tactical Undersea Network Architecture ***Description:*** Systems fighting as a network are vulnerable to a loss of connectivity in a contested environment. This connectivity is important for synchronizing forces, establishing and maintaining situation awareness, and control of remotely operated vehicles and systems. Additionally, undersea systems are challenged to maintain connectivity and must carry their own energy and operate over their design lifetime with little to no maintenance and repair. These factors inhibit their use in collaborative networks and prevent the full exploitation of the potential of undersea systems. The Tactical Undersea Network Architectures program sought to overcome these limitations by developing the technologies necessary for autonomous, reliable, and secure undersea data transfers; true plug, play, and operate standards; and rapid, cost-effective deployment technologies. The program developed and demonstrated novel technology options and designs to restore connectivity temporarily for existing tactical data networks in contested environments using small-diameter optical fiber and buoy relay nodes. The program focused on innovative system architecture designs, lightweight optical fiber technologies, and rapidly deployable buoy node designs and component technologies. The Tactical Undersea Network Architecture program emphasized early risk reduction with scaled at-sea integrated demonstrations of increasing complexity. Program technologies transitioned to the Navy.	1.220	-	-
Title: Tactical Exploitation of the Acoustic Channel (TEAC) ***Description:*** The Tactical Exploitation of the Acoustic Channel (TEAC) program provided the capability to coherently combine acoustic energy from a distributed network of underwater acoustic sources to improve signal transmission in an undersea environment. The ability to cohere multiple underwater sensors is showing an impact for a number of compelling applications including surveillance, communications, and vehicle positioning. For all of these applications, sensor gain had been achieved by deploying large, costly, and cumbersome cabled arrays. The TEAC program created the opportunity to deploy groups of low unit-cost sources that work cooperatively to focus energy undersea. This provided an extensible, affordable, and flexible method to	1.232	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
harness the rapid development of undersea vehicles and new acoustic source technologies. Technologies developed under this program have transitioned to the Navy.			
Accomplishments/Planned Programs Subtotals	79.808	127.484	148.459

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	233.612	280.453	364.500	-	364.500	292.334	172.194	67.000	0.000	-	-

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 2019	FY 2020	FY 2021
Title: Classified DARPA Program	233.612	280.453	364.500
Description: This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2020 Plans:*** Details will be provided under separate cover. ***FY 2021 Plans:*** Details will be provided under separate cover. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	233.612	280.453	364.500

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	174.094	158.903	200.220	-	200.220	189.258	220.596	254.964	264.233	-	-
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	37.926	37.766	33.281	-	33.281	19.401	8.401	8.401	8.401	-	-
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	60.436	67.237	64.414	-	64.414	78.014	153.831	235.563	255.832	-	-
SEN-06: *SENSOR TECHNOLOGY*	-	75.732	53.900	102.525	-	102.525	91.843	58.364	11.000	0.000	-	-

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 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	183.101	163.903	269.619	-	269.619
Current President's Budget	174.094	158.903	200.220	-	200.220
Total Adjustments	-9.007	-5.000	-69.399	-	-69.399
• Congressional General Reductions	0.000	-5.000			
• 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	-2.850	0.000			
• SBIR/STTR Transfer	-6.157	0.000			
• TotalOtherAdjustments	-	-	-69.399	-	-69.399

Change Summary Explanation

FY 2019: Decrease reflects the reprogrammings and the SBIR/STTR transfer.
FY 2020: Decrease reflects congressional reduction.
FY 2021: Decrease reflects rephasing of several programs in the Surveillance and Countermeasures Technology and Sensors and Processing Systems projects.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	37.926	37.766	33.281	-	33.281	19.401	8.401	8.401	8.401	-	-

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 2019	FY 2020	FY 2021
Title: Aerial Dragnet	17.508	11.071	4.356

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 sensors mounted on distributed 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. This program focuses on the development of payloads to be hosted on unmanned aerial platforms, comprising 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 Homeland Security.

FY 2020 Plans:
- Demonstrate multiple UAS detection and tracking in a dense, multi-neighborhood-sized urban area.
- Improve classification algorithms to reduce false alarms.
- Develop autonomy algorithms to allow platforms to adapt to urban terrain.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Engage transition partners to adopt developed systems. ***FY 2021 Plans:*** - Demonstrate persistent UAS detection, classification, and tracking in a dense, city-sized urban area. - Evaluate system performance in defense against a scripted, multi-UAS attack on an urban area. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the transition from system development to test and evaluation.			
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. ***FY 2020 Plans:*** - Complete HF transmit system integration. - Conduct over-the-air field tests to assess propagation and backscatter characteristics. - Confirm physical modeling and analysis using measured experimental data. - Compare performance of distributed geometries through modeling and experimentation. ***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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects a shift from development and integration of the technologies to demonstrations.	12.144	10.625	9.855
Title: All Source Combat Operations and Targeting (ASCOT) ***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 sensor and local platform sensors. The program builds upon technology developed as a part of the Resilient Synchronized Planning & Assessment Contested Environment (RSPACE) program, budgeted in PE 0603766E/Project NET-01. Key attributes	8.274	16.070	19.070

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
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 2020 Plans:*** - Conduct testing of sensor fusion and data analysis tools in simulation and test environment. - Analyze collected data to identify system performance and examine robustness. - Conduct lab testing of payload designs. - Initiate the development of adaptive combat control techniques. ***FY 2021 Plans:*** - Conduct localization field testing with 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects a shift from system design and development to architecture-level integration and field testing of payload.			
Accomplishments/Planned Programs Subtotals	37.926	37.766	33.281

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	60.436	67.237	64.414	-	64.414	78.014	153.831	235.563	255.832	-	-

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 2019	FY 2020	FY 2021
Title: Dynamically Composed RF Systems	11.864	13.972	11.758

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 2020 Plans:
- Complete initial version of objective system SSRM software and payload interfaces.
- Integrate SSRM software onto two third-party payloads and conduct integration testing to validate ability of SSRM to control the third-party payloads.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Develop upgraded version of SSRM software and conduct acceptance testing. ***FY 2021 Plans:*** - Conduct laboratory testing of the SSRM installed on the two third-party payloads to demonstrate the SSRM's ability to control the two payloads in concert. - Conduct flight tests of the SSRM controlling third-party payloads and demonstrate ability to control those payloads in flight. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects the transition from initial development of the SSRM software and integration onto third-party payloads to a focus on testing.			
Title: Military Tactical Means (MTM)*	-	13.806	26.524
Description: *formerly Cross-Domain Multi-Modality Sensing & Targeting The Military Tactical Means (MTM) program will develop 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. Building upon technologies from the Automatic Target Recognition (ATR) program, budgeted in this PE/Project, 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 with possibly 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 2020 Plans:*** - Begin development of exploitation algorithms suitable for abstracted target characterization to enable consistent chain of custody. - Begin development of multi-mode sensor modules. - Begin modeling of processing algorithms with emulated and real data. - Begin development of measures of performance (MOP) and measures of effectiveness (MOE). ***FY 2021 Plans:*** - Continue multi-mode sensor module design based on size, weight, power, and modality requirements.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Conduct preliminary and critical design reviews of the senor modules to determine viability of the designs. - Begin building sensor modules and begin integration efforts into the host platform. - Continue development of exploitation algorithms to further refine the effectiveness of the modalities. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects the shift from component-level research to system integration.			
Title: Military Tactical Means (MTM) Demo ***Description:*** The MTM Demo program will develop sensors and software automation capable of supporting future tactical Intelligence, Surveillance, and Reconnaissance (ISR) operations. This scalable multi-modal ISR approach will allow tactical users to rapidly characterize, quantify and report battlespace environments and conditions. Based on technologies developed in the Military Tactical Means (MTM) program (also budgeted in this PE/Project), MTM Demo will demonstrate rapid signature discovery options for improving target discrimination and tracking while also providing key foundational information to support both rural and complex urban Military Stability Operations (MSO). MTM Demo aims to rapidly develop and demonstrate a prototype system, the data from which will be used to optimize both Automated Target Recognition (ATRs) and MSO algorithms. Technology developed by this program will transition to the Services and other government agencies. ***FY 2021 Plans:*** - Develop MSO concepts of operation with military partners. - Conduct system requirements review (SRR) and preliminary design review (PDR). - Develop demonstrations plans for tactical scenarios. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.	-	-	9.447
Title: Non-Kinetic Effects (NKE) ***Description:*** The Non-Kinetic Effects (NKE) program will develop new systems for signal attack, sensing and protection. Electronic warfare (EW) covers these three aspects when the signals are electromagnetic in nature. The NKE program will include EW innovation as a subset of NKE's broader objectives where signal includes electromagnetics and other non-kinetic modes of operation. A new paradigm will be employed in NKE focused on offensive measures, as opposed to the traditional approach that concentrates on protection with attacks that are typically defensive and/or responsive in nature. NKE will develop new technologies as required, but will primarily focus at the system level, where multi-system architectures will be developed. System management and non-kinetic battle assessment technologies will be required to support the multi-mode NKE mission. The NKE systems are applicable to force-on-force conflict, but will also provide new options for conducting hybrid operations at all scales of conflict. Technologies will be transferred to the Services.	-	-	7.527

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
FY 2021 Plans: - Begin development of offensive non-kinetic engagement techniques and phenomenologies. - Begin development of single- and multi-system techniques management and effectiveness assessment. - Identify options to modify existing systems for coordinated techniques to enable novel non-kinetic effects. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.			
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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects program initiation.	-	-	9.158
Title: Seeker Cost Transformation (SECTR) ***Description:*** The Seeker Cost Transformation (SECTR) program will develop 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 will be small size, weight and power (SWaP), low recurring cost, and be applicable to a wide range of weapons and missions, such as small unit lethality, suppression	4.210	3.626	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
of enemy air defenses, precision strike, and strike of time-sensitive targets. Hardware technology will leverage 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 will also develop a Government-owned open system architecture for the seeker with standardized interfaces between components (both hardware and software). The technical approach to target recognition will start from "deep learning" and machine vision algorithms pioneered for facial recognition and the identification of critical image features. Technologies developed under this program will transition to the Services. ***FY 2020 Plans:*** - Conduct additional free-flight tests of SECTR prototype seeker. - Assess seeker performance and update hardware-in-the-loop (HWIL) models and assumptions as needed. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: Small Satellite Sensors ***Description:*** The Small Satellite Sensors program will develop and space-qualify Electro-Optical Infrared (EO/IR) sensor and inter-satellite communications technologies and establish feasibility for new DoD tactical capabilities to be implemented on small (< 100 kg) satellites. Experimental payloads will be flown on small satellites, and data will be 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 seeks to leverage 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 will focus 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 will transition to the Services. ***FY 2020 Plans:*** - Continue space-based data collections. - Continue user demonstration and field activities. - Develop models and reports which quantify effectiveness of the sensor technology and the suite of processing algorithms. - Transition key results and technologies to military users for use in operational constellations. - Complete on-orbit operations, user demonstration, and field activities with satellites.	16.156	14.848	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
- Initiate design activities for next-generation prototypes designed for transition to a potential operational constellation. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: All-Signal Tactical Real-Time Analyzer (ASTRAL) ***Description:*** The All-Signal Tactical Real-time Analyzer (ASTRAL) program will develop and demonstrate a system for radio frequency and optical electromagnetic signal surveillance and environment understanding. Building on technologies explored under the Dynamically Composed RF Systems program, also budgeted in this PE/Project, the objective of ASTRAL is to provide a factor of at least 1,000 times improvement over current signal awareness processing speed over broad spectral coverage. The program will use technology that supports a development path leading to a mobile, tactical capability. The development objectives of the ASTRAL program are 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 that may be 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 will transition to the Navy. ***FY 2020 Plans:*** - Begin hybrid processor architecture development, identifying risks and risk mitigation approaches. - Demonstrate execution of algorithms suitable for tactical applications with brassboard system in the laboratory environment. - Define concept of operations plans for tactical applications of the hybrid processor architectures. - Complete hybrid processor architecture development. - Transition the ASTRAL technology to the Navy's Future Naval Capability effort. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.	12.368	11.832	-
Title: Collection and Monitoring via Planning for Active Situational Scenarios (COMPASS) ***Description:*** The Collection and Monitoring via Planning for Active Situational Scenarios (COMPASS) program will 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 & Assessment Contested Environment (RSPACE) program, budgeted in PE 0603766E, Project NET-01, the purpose of the COMPASS program is 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. The tools produced by COMPASS will automate	10.158	9.153	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
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 will employ active sensing and recommend actions that U.S. Forces and allied partners can take to stimulate the environment and reveal any hostile strategies. To achieve this goal, COMPASS will build and demonstrate tools to: 1) develop a dynamic model of hostile activities in a gray zone environment, 2) assess the decision space to recommend which actions may provide the highest value information, and 3) monitor execution of these actions to assess incremental progress toward reducing the ambiguity of the operating environment and suggest adjustments. COMPASS will transition to the Services. ***FY 2020 Plans:*** - Increase complexity of the gray zone environment and improve the effectiveness of the algorithms for action generation. - Expand situational awareness to include social activities such as economic, political, and influence campaigns. - Improve the functionality of the tool to account for adversaries that adapt their behavior. - Conduct experiments and demonstrations for operational users to assess utility and explore transition. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 decrease reflects program completion.			
Title: Spatial, Temporal and Orientation Information for Contested Environments (STOIC) ***Description:*** The Spatial, Temporal and Orientation Information for Contested Environments (STOIC) program enabled precision cooperative effects by developing global time transfer and synchronization systems independent of GPS. As a corollary to time synchronization, this program also enabled GPS-independent positioning to maintain precise time synchronization between collaborating mobile users. Key attributes of this program are global availability, minimal and low cost infrastructure, anti-jamming capability, and performance equal to or better than GPS, achieved through recent advances in optical clocks and time transfer. Demonstrations on relevant platforms in relevant environments were used to validate the technology. Technologies from this program transitioned to the Navy.	4.056	-	-
Title: Automatic Target Recognition (ATR) Technology ***Description:*** Automatic Target Recognition (ATR) systems provide the capability to detect, identify, and track high value targets from collected sensor data. ATRs have typically been designed for specific sensors and provide only limited, static mission support due to pre-programmed target lists and operating modes. Extending ATR technology to accommodate sensor upgrades or include new emerging targets has been costly and time-consuming. The objective of the ATR Technology program was to develop technologies that reduce operational limitations while also providing significant performance improvements, dramatically reduced development times, and reduced life-cycle maintenance costs. Breakthroughs in deep learning algorithms and embedded computing systems promised dramatic improvements in ATR utility. The program focused on three core areas:	1.624	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency		Date: February 2020
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 2019	FY 2020	FY 2021
(1) development of on-line adaptive algorithms that enabled performance-driven sensing and ATR utility; (2) algorithm training technology that enabled rapid incorporation of new targets; and (3) technologies that dramatically reduced required data rates, processing times, and the overall hardware and software demands of ATR systems. ATR technology developed under the program transitioned to multiple agencies within the Department of Defense.			
Accomplishments/Planned Programs Subtotals	60.436	67.237	64.414

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Defense Advanced Research Projects Agency			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
SEN-06: *SENSOR TECHNOLOGY*	-	75.732	53.900	102.525	-	102.525	91.843	58.364	11.000	0.000	-	-

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 2019	FY 2020	FY 2021
Title: Classified DARPA Program	75.732	53.900	102.525
Description: This project funds Classified DARPA Programs. Details of this submission are classified.			
FY 2020 Plans: Details will be provided under separate cover.			
FY 2021 Plans: Details will be provided under separate cover.			
FY 2020 to FY 2021 Increase/Decrease Statement: Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	75.732	53.900	102.525

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	67.850	68.498	74.334	-	74.334	74.770	75.702	76.652	77.624	-	-
MST-01: *MISSION SUPPORT*	-	67.850	68.498	74.334	-	74.334	74.770	75.702	76.652	77.624	-	-
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	65.646	68.498	69.318	-	69.318
Current President's Budget	67.850	68.498	74.334	-	74.334
Total Adjustments	2.204	0.000	5.016	-	5.016
• 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	2.204	0.000			
• SBIR/STTR Transfer	0.000	0.000			
• TotalOtherAdjustments	-	-	5.016	-	5.016

Change Summary Explanation

FY 2019: Increase reflects reprogramming for increase in mission support activities.
FY 2020: N/A
FY 2021: Increase reflects salaries and benefits for additional civilian personnel, offset by Defense Wide Review (DWR) Pentagon Force Protection Agency (PFPA) support reduction.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Mission Support	67.850	68.498	74.334
Description: Mission Support			

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021
FY 2020 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 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 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects increased costs associated with rent, security, infrastructure support, and civilian personnel costs.			
Accomplishments/Planned Programs Subtotals	67.850	68.498	74.334

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	112.579	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
SB-01: *SMALL BUSINESS INNOVATION RESEARCH*	-	112.579	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

In accordance with Public Law No: 116-120 (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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	0.000	0.000	0.000	-	0.000
Current President's Budget	112.579	0.000	0.000	-	0.000
Total Adjustments	112.579	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	112.579	0.000			
• SBIR/STTR Transfer	0.000	0.000			

Change Summary Explanation

FY 2019: Increase reflects transfer to establish the SBIR/STTR program.
FY 2020: N/A
FY 2021: N/A

C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Small Business Innovation Research	112.579	-	-
Description: The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are			

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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 2019	FY 2020	FY 2021
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.			
Accomplishments/Planned Programs Subtotals	112.579	-	-

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	**Date:** February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
Total Program Element	-	13.663	13.208	13.434	-	13.434	13.488	13.487	13.567	13.569	-	-
MH-01: *MANAGEMENT HQ - R&D*	-	13.663	13.208	13.434	-	13.434	13.488	13.487	13.567	13.569	-	-
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	13.643	13.208	13.268	-	13.268
Current President's Budget	13.663	13.208	13.434	-	13.434
Total Adjustments	0.020	0.000	0.166	-	0.166
• 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	0.020	0.000			
• SBIR/STTR Transfer	0.000	0.000			
• TotalOtherAdjustments	-	-	0.166	-	0.166

Change Summary Explanation

FY 2019: Increase reflects minor reprogramming.
FY 2020: N/A
FY 2021: Increase reflects minor repricing of civilian personnel costs.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Management Headquarters	13.663	13.208	13.434
Description: Management Headquarters			

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Defense Advanced Research Projects Agency	Date: February 2020
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*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
FY 2020 Plans: - Fund management headquarters civilian salaries, benefits, travel and support contract costs. ***FY 2021 Plans:*** - Fund management headquarters civilian salaries, benefits, travel and support contract costs. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** The FY 2021 increase reflects minor repricing.			
Accomplishments/Planned Programs Subtotals	13.663	13.208	13.434

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A