Exhibit R-2, RDT&E Budget Item Justification: PB 2025 Defense Advanced Research Projects Agency	Date: March 2024
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 2023	FY 2024	FY 2025 Base	FY 2025 OCO	FY 2025 Total	FY 2026	FY 2027	FY 2028	FY 2029	Cost To Complete	Total Cost
Total Program Element	-	376.978	311.531	303.830	-	303.830	332.425	373.016	393.308	403.331	-	-
CCS-02: *MATH AND COMPUTER SCIENCES*	-	214.936	179.433	188.187	-	188.187	214.925	241.874	255.727	264.831	-	-
ES-01: *ELECTRONIC SCIENCES*	-	4.696	12.854	4.768	-	4.768	5.445	6.128	6.479	6.710	-	-
ES-02: *BEYOND SCALING SCIENCES*	-	68.868	52.004	55.350	-	55.350	48.641	53.649	55.649	53.651	-	-
MS-01: *MATERIALS SCIENCES*	-	60.474	62.934	55.525	-	55.525	63.414	71.365	75.453	78.139	-	-
TRS-01: *TRANSFORMATIVE SCIENCES*	-	28.004	4.306	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

The efforts described in this Program Element (PE) address the Basic Research associated with the Defense Research Sciences Program that 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. This PE supports the scientific study and experimentation that is the basis for more advanced knowledge and understanding in information, electronic, mathematical, computer, and materials sciences. This PE also supports innovation and robust transition planning in the technology cycle by working with entrepreneurs to increase the likelihood that DARPA funded technologies take root in the U.S. and provide new capabilities for national defense.

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

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 advancement in microelectronics innovation that has characterized the last few decades, the project will provide DoD with new, improved, or potentially revolutionary device options for accomplishing these critical functions. The resulting technologies will 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, and new approaches to nanometer-scale structures, molecules, and devices.

The Beyond Scaling Sciences project supports investigations into materials, devices, and architectures to provide disruptive improvements in electronics performance that can be realized by techniques other than transistor scaling. Examples include circuit specialization, non-volatile memory devices that combine computation and memory, and new automated design tools using machine learning. Additionally, new design and manufacturing advances for three-dimensional microelectronics integration will underpin continued performance improvements as silicon transistor scaling plateaus.

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 life sciences, data sciences, and manufacturing. Innovative technologies developed in this project will address multiple DoD challenges such as identification of and adaptation to emerging threats, access to DoD relevant critical materials for manufacturing and warfighter readiness. Successful programs in this project will integrate diverse disciplines and engineer complex biological systems to detect novel threat agents, accelerate warfighter injury recover, accelerate recovery of DoD natural resources following natural disaster, and develop new platform materials and manufacturing processes.

B. Program Change Summary ($ in Millions)	FY 2023	FY 2024	FY 2025 Base	FY 2025 OCO	FY 2025 Total
Previous President's Budget	404.370	311.531	358.978	-	358.978
Current President's Budget	376.978	311.531	303.830	-	303.830
Total Adjustments	-27.392	0.000	-55.148	-	-55.148
• 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	-4.000	0.000			
• Reprogrammings	-9.831	0.000			
• SBIR/STTR Transfer	-13.561	0.000			
• TotalOtherAdjustments	-	-	-55.148	-	-55.148

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2023	FY 2024
Project: CCS-02: *MATH AND COMPUTER SCIENCES*		
Congressional Add: *University Partnerships for AI Development - Congressional Add*	9.000	-
Congressional Add Subtotals for Project: CCS-02	9.000	-

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Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2023	FY 2024
Congressional Add Totals for all Projects	9.000	-

Change Summary Explanation

FY 2023: Decrease reflects SBIR/STTR transfer, transfer of the 'Advanced Predictive Analytics for Supply Chain Risk Management' Congressional Add to the Air Force and reprogrammings.

FY 2024: N/A

FY 2025: Decrease reflects completion of several basic research programs in FY 2024 including Alternative Computing, Artificial Social Intelligence for Successful Teams (ASIST), Guaranteeing AI Robustness against Deception (GARD), Human Social Systems, Machine Common Sense (MCS) and Pipelined Reasoning of Verifiers Enabling Robust Systems (PROVERS), Atomic-Photonic Integration (A-PhI) and Rapid Healing for Warfighter Injuries as well as a shift from component development and integration to system demonstration and refinement in the Fundamental Limits program.

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency			Date: March 2024
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 2023	FY 2024	FY 2025 Base	FY 2025 OCO	FY 2025 Total	FY 2026	FY 2027	FY 2028	FY 2029	Cost To Complete	Total Cost
CCS-02: *MATH AND COMPUTER SCIENCES*	-	214.936	179.433	188.187	-	188.187	214.925	241.874	255.727	264.831	-	-

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 and information domain, put military systems, critical infrastructure, and the civilian economy at risk. This project aims to magnify these opportunities and mitigate these threats by leveraging emerging mathematical and computational capabilities, including artificial intelligence (AI), computational social science, machine learning and reasoning, data science, quantum science, complex systems modeling and simulation, and theories of computation and programming. The basic research conducted under the Math and Computer Sciences project will produce breakthroughs that enable new capabilities for national and homeland security.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
Title: Foundational Artificial Intelligence (AI) Science	40.400	43.771	46.370
Description: The Foundational Artificial Intelligence (AI) Science thrust is developing a fundamental scientific basis for understanding and quantifying performance expectations and limits of AI technologies. Current AI technologies are challenged in handling uncertainty and incompleteness of training protocols and data. This has prevented the successful integration of AI technology into many transformative DoD applications. To address these limitations, the Foundational AI Science thrust focuses on the development of new learning architectures that enhance AI systems' ability to handle uncertainty, reduce vulnerabilities, and improve robustness for Department of Defense AI systems. One focus area of this thrust is the ability to detect and accommodate novelty - i.e., violations of implicit or explicit assumptions - in AI applications. 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, accommodating novelty, and other DoD relevant applications. ***FY 2024 Plans:*** - Build baseline algorithmic decision makers that are able to be aligned with decision-making attributes of a reference group of human decision makers and computational approaches for quantifying the alignment of the algorithmic decision maker with the human reference group.			

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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 2023	FY 2024	FY 2025
- Develop techniques to evaluate algorithmic decision maker's ability to align with a reference group of human decision makers and validate baseline computational approaches for quantifying the measurement of alignment and the impact of alignment on trust of algorithmic decision makers. - Evaluate the performance of machine learning algorithms in combination with a variety of new data modalities to predict mental states self-reported by users. - Investigate technologies and methodologies to partially automate knowledge curation in a human / machine collaboration. - Formulate AI architectures, learning, and reasoning strategies for an autonomous scientist that can use scientific reasoning to acquire knowledge, develop creative hypotheses, and make decisions with its own knowledge in order to enable scientific discovery at speed and scale. - Explore methods to increase accountability and avoid over-trust through human-AI dialogue-based friction that reveals implicit assumptions and reflective reasoning that prompts critical analysis. - Continue to develop foundational AI science, advance the state of the art in AI engineering, and create human-machine teaming approaches that support trustworthy AI for mission- and safety-critical domains. ***FY 2025 Plans:*** - Evaluate algorithmic decision maker's ability to align with a reference group of human decision makers. - Validate baseline computational approaches for quantifying the measurement of alignment, and measure impact of alignment on trust of algorithmic decision makers. - Design baseline computational approaches for quantifying the alignment of an algorithmic decision maker with a single human decision maker. - Develop and demonstrate a rudimentary autonomous AI-based scientist that is simultaneously creative in its generation of scientific hypotheses and skeptical in its examination of scientific hypotheses. - Demonstrate accountability gains through the use of dialogue-based friction between AI-systems and humans, and evaluate the technique on DoD workflows associated with strategic planning and intelligence analysis. - Continue to develop foundational AI science, advance the state of the art in AI engineering, and create human-machine teaming approaches that support trustworthy AI for mission- and safety-critical domains. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 increase reflects a shift from technique development to algorithm validation and verification.			
Title: Young Faculty Award (YFA)	17.000	17.000	17.000
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			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
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 2024 Plans:*** - Award FY 2024 grants for new two-year research efforts across YFA topic areas, establishing a new set of scientific approaches to solve current DoD challenges. - Continue FY 2023 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 2022 participants to refine technology further and align to DoD needs. ***FY 2025 Plans:*** - Award FY 2025 grants for new two-year research efforts across YFA topic areas, establishing a new set of scientific approaches to solve current DoD challenges. - Continue FY 2024 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 2023 participants to refine technology further and align to DoD needs.			
Title: Perceptually-Enabled Task Guidance (PTG)	18.092	18.500	15.817
Description: The Perceptually-Enabled Task Guidance (PTG) program is developing artificial intelligence (AI) technology that guides users in the performance of a wide range of cognitively challenging physical tasks. PTG leverages recent advances in machine perception, automated reasoning, and augmented reality. The program connects perception to reasoning and reasoning to augmented reality (AR) so as to create personalized, real-time feedback and contextualized assistance. To connect perception and reasoning, PTG develops AI technologies for (1) perceptual grounding, to create a shared vocabulary for perception and reasoning, and (2) perceptual attention, to select important information from large volumes of perceptual data. To connect reasoning with AR, PTG develops AI technologies for (3) knowledge transfer, to derive task models from instructions intended for humans, and (4) user modeling, to determine if, when, and how to best convey task information to the user. Together, PTG technologies will lay the foundation for perceptually-enabled guidance and a qualitatively new type of AI device that enables mechanics, medics, and other military specialists to perform physical tasks within and beyond their skillsets with greater accuracy and efficiency.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
FY 2024 Plans: - Integrate perceptual, reasoning, and augmented reality technology with technologies for knowledge transfer, perceptual grounding, and perceptual attention and develop interactive demonstration scenarios involving answering questions for users performing tasks. - Develop user modeling technologies applicable to individuals performing tasks in multiple military use cases. - Perform assessments of task completion and user acceptance of the integrated technologies in the completion of tasks from application domains defined in collaboration with military stakeholders. ***FY 2025 Plans:*** - Develop and demonstrate capability for systems to answer questions and engage in task-related dialog while monitoring task progress and providing active guidance. - Test ability of systems to follow task steps, identify objects, and track actions while actively guiding military users through multiple tasks simultaneously. - Evaluate integrated system performance against military use case-related tasks in terms of speed of task completion, accuracy, and user acceptance. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects ramping down of development and integration of perceptually enabled intelligent agents, and emphasis shifting to demonstration and assessment of the technology on military task use cases.			
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 Artificial Intelligence (AI) techniques to establish a framework for knowledge analysis and causal reasoning, and developing automation tools that effectively elicit and impart acquired knowledge via user friendly interfaces. ***FY 2024 Plans:*** - Evaluate novel AI knowledge management tools for use in domains of potential military interest. - Incorporate personal sensor input modality into novel AI tools.	17.300	17.000	5.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
- Extend novel AI knowledge management tools to scale to individuals in organizations. - Explore use of large pre-trained models for organizational knowledge management. ***FY 2025 Plans:*** - Compare novel knowledge management tools to large pre-trained models through real-world experimentation in domains of potential military interest. - Transition novel knowledge management tools to military organizations and measure operational effectiveness in stakeholder defined experiments. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects a shift from technology development to final testing and transition activities.			
Title: Environment-driven Conceptual Learning (ECOLE) ***Description:*** The Environment-driven Conceptual Learning (ECOLE) program is creating AI agents capable of continually learning from linguistic and visual input to enable human-machine collaborative analysis of image, video, and multimedia documents during time-sensitive, mission-critical DoD analytic tasks, where reliability and robustness are essential. ECOLE aims to transform current machine learning approaches by developing algorithms that can identify, represent, and ground the attributes that form the symbolic and contextual model for a particular object or activity through interactive learning with a human analyst. Knowledge of attributes and affordances, learned dynamically from data encountered within an analytic workflow, will enable joint reasoning with a human partner. This acquired knowledge will also enable the machine to recognize when an observed object or activity is novel, rather than misclassifying the newly observed object or action as a member of a previously-learned class, and to readily learn a new symbolic representation through interaction with its human partner. ***FY 2024 Plans:*** - Formulate AI agents capable of continually learning from language and vision to enable human-machine collaborative analysis of image, video, and multimedia documents. - Develop algorithms that identify, represent, and ground novel attributes that form the symbolic and contextual model for a particular object or activity through interactive learning with a human analyst. - Initiate development of a suite of collaborative human-machine image analysis challenge problems based on inputs from potential transition partners in the defense and intelligence communities. ***FY 2025 Plans:*** - Refine algorithms that identify, represent, and ground novel attributes that form the symbolic and contextual model for a particular object or activity through interactive learning with a human analyst using increasingly expansive, realistic curricula. - Utilize the AI agents' capabilities of continually learning from language and vision to enable human-machine collaborative analysis of image, video, and multimedia documents.	10.000	15.500	21.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
- Perform initial assessments of collaborative human-machine image and language analysis capabilities on challenge problems of interest to potential transition partners in the defense and intelligence communities. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 increase reflects ramping up of efforts to create techniques for human-machine collaborative analysis and initiation of work to assess capabilities on a suite of analytic challenge problems of interest to the defense and intelligence communities.			
Title: Alternative Computing ***Description:*** The Alternative Computing thrust is exploring and developing new computational primitives for modeling and simulating complex systems. Despite decades of rapid advancement in electronic computing, there remain important national security relevant challenge problems that do not lend themselves to achieving tractable solutions under size, weight, and power (SWaP) constrained conditions. For example, simulation of complex nonlinear phenomena such as turbulence, fluid flow, and plasma dynamics can be challenging even using currently available high-power computing resources. Building on technologies developed under the Advanced Tools for Modeling and Simulation thrust, also in this PE/Project, the goal of the Alternative Computing thrust is to develop novel architectural and algorithmic approaches to enable fast and accurate simulations for problems that are practically intractable using electronic computers. Approaches considered under this thrust include the following: (1) analog computing substrates for efficiently simulating systems governed by complex non-linear phenomena; (2) multi-functional spin-based devices for scalable, efficient neuromorphic computing; (3) computing approaches that exploit the capacity of nonlinear systems to simulate nonlinear dynamical systems; and (4) quantum enabled optimization of complex systems. ***FY 2024 Plans:*** - Create predictive and scalable benchmarks for quantifying the utility of quantum computers. - Calculate the hardware resources necessary to achieve key utility thresholds using quantum computers to solve transformational problems. - Perform benchmarking of quantum optimization algorithms against the best classical method to demonstrate and quantify quantum advantage. ***FY 2025 Plans:*** - Investigate mathematical approaches for transforming complex systems into solvable representations. - Initiate the development of methods to simplify computation.	18.020	9.000	9.000
Title: Intrinsic Cognitive Security (ICS) ***Description:*** The Intrinsic Cognitive Security (ICS) program, building on technologies developed in the Pipelined Reasoning of Verifiers Enabling Robust Systems (PROVERS) program (PE 0601101E, Project CCS-02), will extend computational formal	-	5.000	14.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
methods with cognitive guarantees and models to protect mixed reality users from cognitive attack. Mixed reality (MR) integrates virtual and real worlds in real time and will be ubiquitous in future military missions, including missions involving dismounted soldiers. Currently, users of MR systems are vulnerable to a wide variety of adversary attacks that exploit the intimate connection between users and MR equipment. Formal methods are rigorous, mathematics-based approaches to provide guarantees about computer-based systems, for example, to guarantee the absence of exploitable weaknesses. Cognitive models represent aspects of human perception, action, memory, and reasoning. The ICS program will extend formal methods by explicitly creating and analyzing cognitive models as part of MR system development to protect the user from adversary attacks. To accomplish this task, ICS will create cognitive guarantees that address mixed reality vulnerabilities and are expressed in languages suitable for proofs from models; build cognitive models for reasoning about users of mixed reality systems with sufficient fidelity relative to human behaviors; and evaluate model, proof, and guarantee validity using automated reasoning tools and prototype implementations of proved guarantees. The cognitive protections to be developed under ICS are needed to prevent exploitation of MR systems by adversaries. ***FY 2024 Plans:*** - Formulate approaches for combining computational formal methods with cognitive guarantees and models to protect mixed reality (MR) users from cognitive attack. ***FY 2025 Plans:*** - Create cognitive guarantees that address mixed reality vulnerabilities and are expressed in languages suitable for proofs from models. - Build cognitive models for reasoning about users of mixed reality systems with sufficient fidelity relative to human behaviors. - Evaluate model, proof, and guarantee validity using automated reasoning tools and initial prototype implementations of proved guarantees. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 increase reflects ramping up of development and evaluation of techniques to combine computational formal methods with cognitive guarantees and models to protect mixed reality (MR) users from cognitive attack.			
Title: Enhanced SBOM for Optimized Software Sustainment (E-BOSS)	-	5.000	11.000
Description: The Enhanced SBOM for Optimized Software Sustainment (E-BOSS) program is creating enhanced software bill of materials (eSBOM) technologies with new types of rich metadata and developing cyber reasoning algorithms and tools that leverage eSBOMs to defend against potential flaws during the software development process, as well as to triage and remediate flaws found in operation. The global impacts of flawed software deployed at scale (such as the Log4Shell vulnerability found in Log4j cloud and web app deployments, where mitigations took from one week to months, and are not yet completed for a large percentage of systems) motivated the new SBOM requirements in Executive Order 14028. However, SBOMs alone			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
cannot enable identification and mitigation of the flow of hostile data to the flaws in the code. E-BOSS will develop software technologies integrated with modern software build chains to enable rapid triage and remediation of vulnerabilities at the scale of national computing infrastructure. The enhanced metadata incorporated in the eSBOMs will enable trace back of discovered flaw evidence, starting from a crash and walking back through complex inter-component interactions, transfers, and transformations to derive the vulnerability triggers. If successful, E-BOSS technologies will enable cyber-reasoning for improved remediation and sustainment of large-scale software systems. The E-BOSS program is funded in PE 0601101E, Project CCS-02 and PE 0602303E, Project IT-03. ***FY 2024 Plans:*** - Develop enhanced software bill of materials (eSBOM) formats that incorporate new types of rich metadata and initiate development of cyber reasoning algorithms and tools that leverage eSBOMs to defend against potential flaws during software development. - Conceptualize approaches for trace back of discovered flaws, starting from a crash and walking back through complex inter-component interactions, transfers, and transformations to derive the triggers and to identify how and where to apply fixes. ***FY 2025 Plans:*** - Develop enhanced SBOM (eSBOM) with new types of metadata that provides fine-grained data about control and data flows and inter-component interactions. - Develop algorithms in modern build chains and compiler extensions for unifying program analysis techniques and cyber reasoning tools to enable rapid remediation of vulnerabilities at scale. - Establish a concept of operations (CONOPS) and design use cases that are relevant to both open-source communities as well as to DoD software factories and initiate development of a test and evaluation range architecture extensible to millions of simulated nodes. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 increase reflects ramping up of development of enhanced SBOM technologies and of use cases and a test range to demonstrate and evaluate security and sustainment benefits on large scale software systems.			
Title: Scientific Feasibility (SciFy) ***Description:*** The Scientific Feasibility (SciFy) program, addressing challenges encountered in the Advanced Tools for Modeling and Simulation program (PE 0601101E, Project CCS-02), will develop computational methods to measure the feasibility of claims to enable accurate assessments of scientific content. Automated scientific content generation, via rapidly improving large pre-trained models, has the potential to disrupt the U.S. technology base in times of crisis and to distort the global race for technological dominance in key areas. Similarly, false capability claims can have significant negative implications for national security and international relations. To address these threats, SciFy will focus on methods for assessing the scientific feasibility	-	3.000	10.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
of claims using automated reasoning to decompose claims into constituent, verifiable parts. Assessing each component will involve referencing existing technological advancements, foundational scientific principles, data, software, models, simulation results, and industry standards or benchmarks. SciFy will create methods that go beyond automated fact-checking by also addressing complex component interactions and operational constraints, and evaluating logical consistency, system integration, and compatibility considerations. If successful, SciFy will enable the U.S. to reliably determine whether claimed scientific and technological capabilities, even when theoretically possible in parts, are practical and realistic when considered as a whole. ***FY 2024 Plans:*** - Formulate approaches to automatically reason, verify, and evaluate scientific, technological, and capability claims, especially in sensitive areas surrounding national security and defense. ***FY 2025 Plans:*** - Develop methods to decompose scientific, technological, and capability claims into constituent, verifiable parts amenable to automated feasibility assessment. - Develop techniques for automatically assessing component feasibility by referencing existing technological advancements, foundational scientific principles, data, software, models, simulation results, and industry standards or benchmarks. - Extend and integrate approaches to address high priority scientific feasibility assessment use cases in collaboration with potential transition partners. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 increase reflects shift from initial analysis activities to development of methods and techniques.			
Title: Emerging Opportunities in Math and Computer Sciences	-	-	39.000
Description: The grounds for strategic surprise are often realized through the discovery of unifying principles, novel fundamental limits, and unexpected connections between nominally disparate fields. This thrust explores emergent capabilities and universal themes at the interface of quantum science, mathematics, nanoscience, and materials science to develop novel approaches to critical national security needs. Emerging opportunities in this thrust will explore and analyze new scientific and technological ideas, seeking answers to high-risk/high-reward what if? questions, and assess the impact of further investment on problems of importance to national security. Understanding the complex interplay between DoD systems and their environment is critical in developing new platforms and in determining the limitations of current platforms. Current mathematical tools cannot capture the nonlinear, multiscale, high dimensional dynamics of the coupled/multiscale physics that describe these complex physical systems. ***FY 2025 Plans:*** - Investigate the potential of AI language processing to enable abstract reasoning. - Initiate the development of capabilities for generalizable knowledge representation and reasoning.			

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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 2023	FY 2024	FY 2025
- Initiate development of techniques to enable transparent and logical communications between humans and AI models. - Use machine learning algorithms to discover unknown transformations that are difficult to write down and/or discover. - Begin exploring methods for tracking the evolution of large-scale machine learning models. - Initiate efforts to expand data science techniques for socioeconomic systems. - Start to explore the fundamental questions surrounding quantum technologies, sensing, measurement, computation and/or processing. - Explore fundamental questions surrounding math and computer science. - Explore methods for personalized instruction. - Formulate programming languages for optical computing. - Explore formal methods for high-quality software. - Explore techniques for information integrity assessment. - Formulate guided compilers for heterogeneous systems. - Initiate approaches for grounding LPTMs to physical tasks for which training data may be sparse and/or costly. - Adapt techniques from data-driven neural networks to classical optimization problems where there is no training data. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 increase reflects program initiation.			
Title: Artificial Social Intelligence for Successful Teams (ASIST) ***Description:*** The Artificial Social Intelligence for Successful Teams (ASIST) program is developing intelligent software agents that can create shared mental models to enable effective teaming with humans. Theory of mind and the ability to create shared mental models are key elements of human social intelligence. Together these capabilities enable human collaboration and teamwork at all scales, whether the setting is a playing field or a military mission. The ASIST program aims to develop technologies to enable machines to exhibit similar capabilities for collaboration and teamwork with humans, capabilities which can be termed artificial social intelligence. These include the capability to infer the goals and situational knowledge of human partners, to predict what human partners will need, and to formulate context-aware actions having high value to team outcomes. ASIST aims to provide the basis for machines that can participate effectively with humans on tasks where teamwork is required. ***FY 2024 Plans:*** - Demonstrate socially intelligent agents capable of partnering with complex teams comprising individuals with specialized skills in support of a selected use case. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects program completion.	12.800	4.162	-
Title: Guaranteeing AI Robustness against Deception (GARD)	18.000	10.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency		Date: March 2024
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 2023	FY 2024	FY 2025
Description: The Guaranteeing AI Robustness against Deception (GARD) program is developing techniques to defend against deception and other adversarial attacks on machine learning (ML) and artificial intelligence (AI) systems. GARD addresses the need to defend against deception attacks, whereby an adversary inputs engineered data into an ML system intending to cause the system to produce erroneous results. Deception attacks can enable adversaries to take control of autonomous systems, alter conclusions of ML-based decision support applications, and compromise tools and systems that rely on ML and AI technologies. Current techniques for defending ML and AI have proven brittle due to a focus on individual attack methods and weak methods for testing and evaluation. The GARD program is developing techniques that address the current limitations of defenses and produce ML and AI systems suitable for use in adversarial environments. The GARD program is also developing theory regarding potential fundamental limits on achievable ML robustness. ***FY 2024 Plans:*** - Extend adversarial AI techniques to federated learning systems. - Explore the potential of physically realizable attacks in domains relevant to DoD and U.S. Government transition partners. - Demonstrate and transition AI/ML defense technology to DoD and U.S. Government transition partners. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects program completion.			
Title: Human Social Systems ***Description:*** The social and behavioral sciences provide essential theories and models that can enable deeper understanding of human social/behavioral systems relevant to national security such as mental health, 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/behavioral systems; (2) identifying methods to better characterize and quantify properties, dynamics, and behaviors of different social/behavioral systems to enable better and more confident forecasting of changes in such systems, particularly when under stress; (3) developing an understanding of the complex effect of context and incorporating these effects into 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/behavioral 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.	11.000	7.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency		Date: March 2024
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 2023	FY 2024	FY 2025
FY 2024 Plans: - Test the accuracy of causal models of regional socioeconomic systems derived from collective local understandings for predicting event outcomes compared to the current state of practice in new locations to test generalizability of methods. - Evaluate the efficiency of methodologies for developing causal models of regional socioeconomic systems derived from collective local understanding compared to the current state of practice in new locations to test generalizability of methods. - Continue to demonstrate that mechanisms developed for engaging local populations are compatible with local infrastructure and generate sufficient quality data to generate predictive causal models in new locations to test generalizability of methods. - Design mechanistic models for targeting brain stimulation to enhance rapid eye movement (REM) sleep and improve sleep-deprived stress and trauma adaptation. - Develop hardware for the targeted modulation of REM sleep mechanisms. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects program completion.			
Title: Machine Common Sense (MCS) ***Description:*** The Machine Common Sense (MCS) program is exploring approaches to enable common-sense reasoning by machines. Recent advances in machine learning have resulted in new artificial intelligence (AI) capabilities in areas such as image recognition, task-focused natural language processing, and strategy games such as Chess, Go, and Poker. In all of these application domains, the machine reasoning is narrow and highly specialized, and the machine must be carefully trained or programmed for every situation. This program addresses the challenge of general machine reasoning on par with common sense human cognition. MCS develops computational models that mimic core systems of human cognitive development that are grounded in perceptual, motor, and memory modalities; a simulated interaction and learning environment to support machine manipulation of grounded concept models; and common-sense knowledge repositories to support AI system development. AI systems that are capable of human-like reasoning will be able to behave more appropriately in unforeseen situations and to learn with reduced requirements for training data. ***FY 2024 Plans:*** - Use the simulation environment to assess machine common sense capabilities on benchmark common sense challenge problem suites in environments exhibiting high complexity, noise, and novelty. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects program completion.	18.000	5.000	-
Title: Pipelined Reasoning of Verifiers Enabling Robust Systems (PROVERS)	8.000	19.500	-

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency		Date: March 2024
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 2023	FY 2024	FY 2025
Description: The Pipelined Reasoning of Verifiers Enabling Robust Systems (PROVERS) program is creating the science and technology needed for continuous reasoning about complex systems that can support software development pipelines. These mathematically based techniques, or formal methods, enable rigorous modeling, reasoning, and proving diverse properties of software code or design models, for example, the absence of a specific type of defect or security vulnerability. PROVERS integrates formal methods into a modern incremental and iterative development process by running tools at each code commit and delivering results to developers when they can most effectively remediate discovered issues. To achieve this, PROVERS is focusing on creating and sustaining a body of evidence that can co-evolve with the system under change to support continuous assessment and ensure that the system remains free of identified categories of defects and security vulnerabilities through its lifetime. Key PROVERS objectives include enabling proof maintenance and repair capabilities at a cost that is proportionate to code change; integration of formal methods with code, properties, and proofs in a single workflow that reduces human involvement; providing improved explanations to facilitate proof repair; and automating formal methods-based software analysis to support software developers that are not formal methods experts. PROVERS science and technology will facilitate the agile development and continuous improvement of mission-critical software systems that meet the high security and quality standards required by the DoD. Beginning in FY 2025, this program is funded in PE 0602303E, Project IT-03. ***FY 2024 Plans:*** - Develop and demonstrate formal methods approaches, tools, and data management techniques integrated in pipelined software development processes and quantify the costs related to adding formal methods-based assurances in development workflows. - Implement mathematical approaches for proof engineering at scale and demonstrate efficiency and quality of outputs within existing and modified workflows. - Collaborate with DoD stakeholders on controlled formal-methods-based experiments on selected mission-critical software systems to quantify the improvements in development productivity and system security. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects focus shifting from basic research to applied research with FY 2025 funding provided in PE 0602303E, Project IT-03.			
Title: Advanced Tools for Modeling and Simulation	3.000	-	-
Description: The Advanced Tools for Modeling and Simulation thrust developed 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 was developing a unified mathematical framework to enable better visualization and analysis of massive, complex data sets. Rigorous mathematical theories were also 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 were well beyond the scope of capabilities that existed			

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency		Date: March 2024
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 2023	FY 2024	FY 2025
at the time. Other work in this thrust focused 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 improved the speed and accuracy of modeling and simulation, as well as enabled management of complexity across DoD devices, parts, and systems. Another focus area of this thrust was multi-physics models for predicting behavior and non-intuitive failure pathways for complex, dynamic physical systems.			
Title: Safe Documents (SafeDocs) ***Description:*** The Safe Documents (SafeDocs) program developed software technologies that constrain syntactic complexity in data exchange formats and improve the capability to reject invalid and maliciously crafted data in electronic documents and streaming data. The high complexity and unmanaged evolution of electronic document formats and streaming data protocols greatly increase the computational attack surface. The SafeDocs program rationalized existing data exchange formats significant to the defense mission with attention to compatibility, and advanced the state of the art in the security of document and data format parsers. SafeDocs advances enable automated code verification, assure that the conditions of data validity are enforced, and secure documents and streaming data.	8.000	-	-
Title: Learning with Less Labeling (LwLL) ***Description:*** The Learning with Less Labeling (LwLL) program developed 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, particularly for national security applications. LwLL addressed this problem by creating ML algorithms that learn and adapt more efficiently than current ML approaches, formally deriving the limits of machine learning and adaptation, and training with a combination of labeled and unlabeled data. LwLL created ML systems that are easier to train for use in variable, unpredictable, real-world environments where training data is costly or sparse.	6.324	-	-
Accomplishments/Planned Programs Subtotals	205.936	179.433	188.187

	FY 2023	FY 2024
Congressional Add: University Partnerships for AI Development - Congressional Add	9.000	-
FY 2023 Accomplishments: - Initiated University Partnerships for AI Development.		
Congressional Adds Subtotals	9.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency		Date: March 2024
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*

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency			Date: March 2024
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 2023	FY 2024	FY 2025 Base	FY 2025 OCO	FY 2025 Total	FY 2026	FY 2027	FY 2028	FY 2029	Cost To Complete	Total Cost
ES-01: *ELECTRONIC SCIENCES*	-	4.696	12.854	4.768	-	4.768	5.445	6.128	6.479	6.710	-	-

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 advancement in microelectronics innovation that has characterized the last few decades, the project will provide DoD with new, improved, or potentially revolutionary device options for accomplishing these critical functions. The resulting technologies will help maintain knowledge of the adversary, 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, and new approaches to nanometer-scale structures, molecules, and devices.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
Title: Emerging Opportunities in Electronic Sciences	-	-	4.768
Description: Studies conducted under this thrust will examine and evaluate emerging opportunities in electronic sciences that could lead to dramatic advances for the DoD and domestic industry. This includes novel technologies in electronic materials, devices, and circuits, as well as associated software algorithms to optimize electronic system performance. Topics include: materials growth and characterization, device architecture and scaling, circuit design and simulation, and algorithm development and integration. ***FY 2025 Plans:*** - Investigate new approaches to decrease time from ideation to realization of new materials and devices. - Investigate approaches to increase yield of new capability during design phase. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 increase reflects program initiation.			
Title: Atomic-Photonic Integration (A-PhI)	4.696	12.854	-
Description: The Atomic-Photonic Integration (A-PhI) program is reducing the size, weight, and power of atomic clocks and gyroscopes for position, navigation, and timing (PNT) applications through the development of integrated photonics. Specifically, A-PhI will demonstrate that a compact photonic integrated chip can replace the optical assembly for trapped atomic gyroscopes and clocks without degrading the performance of the device. PNT is a critical resource for all DoD missions such as communications, navigation, reconnaissance, and electronic warfare. While PNT needs usually are met by using the global positioning system (GPS), GPS signals are vulnerable to disruption and a fallback from GPS is essential. In the absence of GPS,			

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency		Date: March 2024
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
tactical-grade clocks and tactical/navigation grade inertial measurement units (IMUs) currently can provide GPS-like accuracy only for the short term, and longer-term GPS-independent strategies are highly desirable. A-PhI will enable long-term GPS independence and enable better-than-GPS PNT accuracy for short durations. ***FY 2024 Plans:*** - Test first highly-accurate transportable optical atomic clock by referencing to civilian and military time standards. - Demonstrate a trapped atom gyroscope with single measurement angle rate resolution and scale factor exceeding commercial gyroscopes. - Demonstrate stability and dynamic control over trapped atoms, including separating them at resolutions smaller than the wavelength of the trapping light. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects program completion.			
Accomplishments/Planned Programs Subtotals	4.696	12.854	4.768

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency			Date: March 2024
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 2023	FY 2024	FY 2025 Base	FY 2025 OCO	FY 2025 Total	FY 2026	FY 2027	FY 2028	FY 2029	Cost To Complete	Total Cost
ES-02: *BEYOND SCALING SCIENCES*	-	68.868	52.004	55.350	-	55.350	48.641	53.649	55.649	53.651	-	-

A. Mission Description and Budget Item Justification

The Beyond Scaling Sciences project supports investigations into materials, devices, and architectures to provide disruptive improvements in electronics performance that can be realized by techniques other than transistor scaling. Examples include circuit specialization, non-volatile memory devices that combine computation and memory, and new automated design tools using machine learning. Additionally, new design and manufacturing advances for three-dimensional microelectronics integration will underpin continued performance improvements as silicon transistor scaling plateaus.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
Title: Joint University Microelectronics Program 2.0 (JUMP 2.0)	26.000	26.000	26.000
Description: The Joint University Microelectronics Program 2.0 (JUMP 2.0) program is developing and demonstrating innovative next-generation microelectronics technologies through a public-private consortium with universities, the defense industrial base, and the semiconductor industry. The JUMP 2.0 program addresses the grand technical challenges of our increasingly connected world that must be overcome including: the need for innovation in analog hardware, increasing demand for more memory and data storage, the imbalance between data generation and communication capacity, the emerging security vulnerabilities in highly-interconnected Artificial Intelligence systems, and the unsustainable growth in energy demands for computing. Therefore, the JUMP 2.0 program sponsors academic research teams focused on related key technology areas that will not only impact future defense and national security capabilities but also strengthen U.S. leadership in information and communication technology. The JUMP 2.0 program will push fundamental technology research themes in cognition, communications, sensing to action, computing and processing, memory and storage, integration and packaging, and high-performance energy efficient devices to enable key disruptive advances in microelectronic technology.			
FY 2024 Plans: - Develop emerging materials, devices, and integration and packaging technologies for future microsystems. - Establish concepts for next-generation artificial intelligence, efficient communication, intelligent storage, novel sensing-to-action, and distributed computing architectures.			
FY 2025 Plans: - Benchmark newly-developed materials, devices, and integration and packaging technologies. - Demonstrate components for building next-generation artificial intelligence, efficient communication, intelligent storage, novel sensing-to-action, and distributed computing architectures prototypes.			

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency		Date: March 2024
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 2023	FY 2024	FY 2025
- Identify new research directions and amend new projects to the JUMP 2.0 university research portfolio.			
Title: Low Temperature Logic Technology (LTLT) ***Description:*** The Low Temperature Logic Technology (LTLT) program will exploit the unique device and material performance characteristics of state-of-the-art silicon transistors at cryogenic temperatures. Current silicon transistors are performance and power limited when operating at room temperature or higher. This program removes these limitations through modifying the design of existing silicon transistors to optimize their performance at cryogenic temperatures. These devices will be compatible with current complementary metal-oxide-semiconductor (CMOS) fabrication process flows and will offer significant increases in performance and power efficiency over room temperature devices. This program has applied research efforts funded in PE 0602716E, Project ELT-02. ***FY 2024 Plans:*** - Fabricate optimized transistors and generate compact device models. - Demonstrate compact, low power memory cells and experimentally show their performance at low temperature. ***FY 2025 Plans:*** - Optimize high speed, low power switching devices and experimentally verify their performance advantage at low temperature. - Optimize compact, high speed, low power static memory cells and experimentally verify their performance advantages at low temperature. - Demonstrate 45X improvement in performance relative to power of low temperature central processing compared to processing at room temperature. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects a shift from initial design to demonstration of low power memory cells.	13.188	7.004	3.500
Title: Compartmentalization and Privilege Management (CPM) ***Description:*** The Compartmentalization and Privilege Management (CPM) program is developing new system frameworks, architectures, and tooling to provide fine grained, least privileged, compartmentalization that enables prevention and containment of cyber attacks. Today's information systems are structured around a monolithic core (the kernel) that operates within a single protection domain at a single high privilege level. This monolithic kernel contains many separate components, but because there are no protection boundaries between these components, a single compromise anywhere in the system allows attackers effectively unlimited access through an extended sequence of exploits and steps of privilege escalation and lateral motion. CPM is developing technologies and tools to automatically compartmentalize large legacy software systems and designing processor architectures and system software to enforce a compartment and privilege-level regime. CPM tools and architectures will prevent initial penetrations from propagating into successful cyber attacks.	-	10.000	16.000

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency		Date: March 2024
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 2023	FY 2024	FY 2025
FY 2024 Plans: - Formulate approaches and initiate development of a suite of tools to automatically compartmentalize legacy code and manage privilege levels. - Initiate development of processor architectures and system software to enforce a compartment and privilege-level regime with low overhead. - Initiate development of a library of attack campaign test cases for quantifying compartmentalization effectiveness and overhead, and select DoD systems on which to demonstrate attack containment. ***FY 2025 Plans:*** - Produce initial processor designs and refined processor performance models for compartmentalized codes. - Incorporate refined processor performance models in initial implementations of compartmentalization and privilege management tools. - Develop attack campaign test cases for operating systems and legacy applications and conduct initial experiments to measure effectiveness and overhead of compartmentalization and privilege management techniques. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 increase reflects continued development of techniques, tools processor architectures, and system software to automatically compartmentalize legacy code and manage privilege levels, and initiation of efforts to measure the effectiveness of the technology.			
Title: Emerging Opportunities in Electronic Sciences ***Description:*** The Emerging Opportunities in Electronic Sciences thrust is investing in fundamental technologies to take advantage of novel microscale phenomena. This includes on-chip photonics and optics for high bandwidth interconnects, improved materials for high power and high efficiency devices, advanced computing architectures, novel fabrication and packaging techniques, innovative magnetics, and energy efficient, high performance computing. This thrust aims to set the foundation for future programs by taking on the risk associated with fundamental technologies and ultimately enabling disruptive capabilities for the warfighter. ***FY 2025 Plans:*** - Perform initial exploration of advanced material fabrication techniques for photonic, optical, and magnetic applications. - Develop novel architectures for efficient, high performance computing of complex datasets. - Investigate new materials and devices for high power and high efficiency devices and circuits. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 increase reflects program initiation.	-	-	9.850
Title: Next Generation Microelectronics - Advanced Manufacturing Science	18.680	9.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency		Date: March 2024
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 2023	FY 2024	FY 2025
Description: Next Generation Microelectronics - Advanced Manufacturing Science addresses the fundamental science of advanced design, fabrication, packaging, assembly, and testing for complex microsystems. This area also addresses leveraging the underlying device physics of novel material systems to enable electronics that operate in extreme environments, such as environments with high voltage, high current, high temperature, low temperature, and radiation exposure. This effort will build upon a fundamental understanding of the materials, interconnects, and device technologies to enable the design, assembly, testing, and digital emulation of three-dimensional heterogeneous integration (3DHI) in microsystems, and their use in both standard and extreme environments. The physics of interfaces between similar and dissimilar materials and the ability to characterize and reduce defect densities will be critical to the future of 3DHI approaches. In addition, the physics of electron transport, photon transport, and heat dissipation are key areas of study. Materials advances and metrology that improve the reliability of heterogeneously integrated microsystems will be addressed, including those that enable high current density for power delivery. Applied research related to this effort is funded within PE 0602716E, Project ELT-02. ***FY 2024 Plans:*** - Evaluate candidate electrical characterization techniques and metrology for representative three-dimensionally interconnected microsystems and thermally-hardened microsystems. - Perform initial experiments to create precisely aligned, high-density interconnects for digital components. - Characterize candidate novel materials and material systems to extend temperature operation range and to improve thermal interfaces, leveraging artificial intelligence (AI) and additive manufacturing. - Evaluate advanced additive manufacturing techniques including aerosol ink jet printing, nano-composite materials, and selective etching for use in 3DHI electronics. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects program completion.			
Title: Guaranteed Architectures for Physical Security (GAPS) ***Description:*** The Guaranteed Architectures for Physical Security (GAPS) program developed hardware security and software architectures with provable security interfaces. These interfaces physically isolate high-risk transactions during both system design and system build, and will ensure that such protections are enforced at run-time. GAPS reduced the inherent complexity through the development of hardware and software that is open, extendible, and compatible with size, weight, and power-constrained environments to enable security across DoD and commercial systems. The program substantially lowered the barrier to safely enabling high-risk transactions, thus allowing for fast computer-to-computer transactions, physical spatial isolation reducing the need for unreliable software partitioning solutions, and more complex missions without putting sensitive data at risk. This program has applied research efforts funded in PE 0602716E, Project ELT-02.	11.000	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency		Date: March 2024
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 2023	FY 2024	FY 2025
Accomplishments/Planned Programs Subtotals	68.868	52.004	55.350

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency			Date: March 2024
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 2023	FY 2024	FY 2025 Base	FY 2025 OCO	FY 2025 Total	FY 2026	FY 2027	FY 2028	FY 2029	Cost To Complete	Total Cost
MS-01: *MATERIALS SCIENCES*	-	60.474	62.934	55.525	-	55.525	63.414	71.365	75.453	78.139	-	-

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 2023	FY 2024	FY 2025
Title: Fundamental Limits	30.773	38.140	14.134
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, 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 2024 Plans:*** - Initial demonstration of compact, highly-sensitive atomic vapor-based electric and magnetic field sensor devices. - Initial demonstration of compact vapor-based quantum device with high atom-photon interaction strength and quantum coherence. - Perform an engineering analysis of atomic vapor benchtop devices to provide a blueprint for future fieldable systems tailored to DoD applications. - Complete initial modeling of high energy particle accelerator structures and particle source targets; continue evaluation of laser driver technical approaches for accelerator structures. - Define system requirements for compact and directional particle sources. - Develop the theoretical framework for transport of spin polarized electrons. - Initiate efforts to develop techniques to control chemical reaction pathways for the synthesis and separation of chiral molecules. - Perform experiments to characterize and demonstrate persistence and transport of spin-polarized electrons in chiral and achiral molecules. - Demonstrate yield improvements for synthesis and separation of chiral and achiral molecules. - Investigate the fundamental properties that inhibit and enable adhesion in aqueous environments. - Develop methodologies for forming fuels efficiently from readily-available sources directly at the point of need - Develop models and device designs for correlated multiphoton sources for sensing, communication, and imaging. - Design and simulate cavity-enhanced quantum control and readout schemes for atomic and molecular qubits.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
- Validate novel approaches to the scalable creation, autonomous error correction, and control of entangled and topologically protected qubits to enable new capabilities in quantum information processing. - Initiate exploration of novel sensor architectures to simultaneously levitate a heavy mass with high confinement bandwidth in a compact form factor. ***FY 2025 Plans:*** - Complete initial studies of two technical approaches for laser driver and particle accelerator concepts; procure long-lead equipment. - Demonstrate and characterize compact, highly-sensitive atomic vapor-based electric and magnetic field sensor devices. - Demonstrate and characterize compact vapor-based quantum device with high atom-photon interaction strength and quantum coherence. - Perform experiments to characterize and demonstrate persistence and transport of spin-polarized electrons in chiral and achiral molecules. - Demonstrate yield improvements for synthesis and separation of chiral and achiral molecules. - Demonstrate and characterize correlated multiphoton sources for sensing, communication, and imaging. - Continue exploration of novel sensor architectures to simultaneously levitate a heavy mass with high confinement bandwidth in a compact form factor. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects a shift from component development and integration to system demonstration and refinement.			
Title: Molecular Systems and Materials Assembly	29.701	24.794	25.359
Description: The Molecular Systems and Materials Assembly thrust is exploring new approaches for the synthesis, assembly, characterization and application of molecules and materials for a variety of DoD applications from the atomic to the product scale. Ultimately, materials and methods developed in this thrust will support a wide range of DoD applications that will leverage novel materials to extend the range, duration, and capabilities of DoD systems and the warfighter. Through control of the arrangement, interactions, and assembly of atoms and molecules, new materials and manufacturing processes are being developed to address long-standing challenges in supply chains, logistics, and sustainment while simultaneously enhancing the warfighter's capabilities on the battlefield. Efforts in this thrust range from fundamental science to better understand the chemistry and physics related to each application, to developing means to utilize such capabilities in future test systems and prototype devices. ***FY 2024 Plans:*** - Predict evolution of morphology and local gradients in electrochemical interfaces. - Demonstrate persistence improvements in solid-state laboratory scale battery test samples due to solid/solid morphogenic interfaces.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
- Demonstrate higher fatigue strength of test samples with morphogenic solid/liquid and solid/vapor interfaces in a corrosive environment. - Achieve simultaneous production of four human macronutrients in microbial food and initiate efforts to produce macro- and micro- nutrients in desired ratios. - Demonstrate in a laboratory environment each of the essential processes required to produce microbial food in the field and initiate efforts to reduce system size, weight, and power (SWaP). - Demonstrate ability to flavor microbial food and initiate efforts to produce multiple flavors and formats. - Leverage data-driven approaches to material discovery to identify candidate tunable optical materials that can lead to disruptive DoD technologies. - Initiate design of CO2 reduction reactors and CO2 capture and release materials. - Model fundamental boundary layer flows to optimize drag reducing geometries in water. ***FY 2025 Plans:*** - Demonstrate regulation of morphology and local gradients in electrochemical interfaces. - Fabricate solid-state battery test samples to demonstrate the utility of persistence in solid/solid morphogenic interfaces. - Fabricate tensile test samples to demonstrate morphogenic solid/liquid and solid/vapor interfaces in a corrosive environment. - Produce microbial foodstuffs that meet the DoD Nutritional Standards for Restricted Rations in accepted food formats, and initiate research to meet the DoD Nutritional Standards for Operational Rations. - Demonstrate a system capable of producing sufficient foodstuffs for multiple people over a two-week period while excluding food-borne pathogens. - Begin growing material candidates to understand their physical and optical properties, multi-state operation and failure mechanisms. - Initiate development of carbon dioxide reactors to address mass and energy transport-based rate limitations in CO2 reduction. - Initiate synthesis and characterization of hybrid reactive/adsorptive materials for evaluating the presence of possible synergistic effects between reaction energy and stability. - Demonstrate drag reduction on surfaces with complex curvatures. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 increase reflects minor program repricing.			
Title: Emerging Opportunities in Materials Sciences	-	-	16.032
Description: The grounds for strategic surprise are often realized through the discovery of unifying principles, novel fundamental limits, and unexpected connections between nominally disparate fields. Examples include new fundamental limits of sensing and information gathering capabilities enabled by multimodal sensor networks and new avenues to high performance information processing by encoding information within dynamical physical or biological systems. This thrust explores emergent capabilities			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
and universal themes at the interface of quantum science, mathematics, nanoscience, and materials science to develop novel approaches to critical national security needs. Focus areas include harnessing the universal principles of turbulence from new forms of simulation for high complexity physical systems; systemic discovery of materials with desired properties; the analysis of new scientific and technological ideas of importance to national security. ***FY 2025 Plans:*** - Develop predictive models of broad classes of turbulent dynamics. - Explore quantum simulations for modelling complex physical systems. - Develop adaptive discovery methods for the discovery of new optical materials. - Leverage high-throughput computational and experimental screening methods for thin film materials to rapidly build data sets that drive discovery. - Explore fundamental questions surrounding novel materials and structures. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 increase reflects program initiation.			
Accomplishments/Planned Programs Subtotals	60.474	62.934	55.525

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2025 Defense Advanced Research Projects Agency			Date: March 2024
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COST ($ in Millions)	Prior Years	FY 2023	FY 2024	FY 2025 Base	FY 2025 OCO	FY 2025 Total	FY 2026	FY 2027	FY 2028	FY 2029	Cost To Complete	Total Cost
TRS-01: *TRANSFORMATIVE SCIENCES*	-	28.004	4.306	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

The Transformative Sciences project focuses on research and analysis that leverages converging technological forces and transformational trends in information-intensive subareas of life sciences, data sciences, and manufacturing. Innovative technologies developed in this project will address multiple DoD challenges such as identification of and adaptation to emerging threats, access to DoD relevant critical materials for manufacturing, and warfighter readiness. Successful programs in this project will integrate diverse disciplines and engineer complex biological systems to detect novel threat agents, accelerate warfighter injury recovery, accelerate recovery of DoD natural resources following natural disaster, and develop new platform materials and manufacturing processes.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
Title: Rapid Healing for Warfighter Injuries	19.421	2.970	-
Description: The Rapid Healing for Warfighter Injuries effort is addressing the DoD need for improving warfighter recovery from injury by developing technologies that can accelerate the restoration and repair of complex wounds. This program is developing 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 2024 Plans:*** - Integrate sensors and actuators for all required physiological processes into a single platform. - Demonstrate that the integrated system can fully heal wounds in half the time relative to current state of art or reduce deleterious effects of normal healing in vivo. - Demonstrate that the algorithmic model predicts the wound stage with at least 90% accuracy. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects program completion.			
Title: Engineering Functional Materials with Biology	4.309	1.336	-
Description: The Engineering Functional Materials with Biology program is pursuing new approaches to engineer complex biological systems for enhanced capabilities and functional materials to improve military infrastructure design and logistics,			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2023	FY 2024	FY 2025
sensors, and platforms. Complex biological materials and systems have unique properties (e.g., controlled porosity, high strength-to-weight ratios, tunable magnetic and optical properties, etc.) not only because of the inherent biological components but also because of how those components are assembled together from microscopic to macroscopic scales. Engineering biology tools and techniques are now at a stage to improve the production, organization, and function of biomaterial systems for a variety of expanded capabilities, including those that can help DoD address supply chain challenges. This program is conducting research to enable information-driven assembly of hierarchical biological systems for materials as well as alternate approaches for the production of critical molecules and materials. Advances in this program will impact: next-generation material design for optical and electronic applications; military approaches to infrastructure design in austere environments; and established methods for the manufacture and maintenance of military platforms. ***FY 2024 Plans:*** - Characterize biological manufacturing approaches for increased performance of microbes in austere environments. - Refine models to predict the feasibility, logistics, and economics of biomanufacturing in austere environments based on experimental biological data. - Develop reproducible high-throughput methods to hypothesize and verify biological mode of action and gene function. ***FY 2024 to FY 2025 Increase/Decrease Statement:*** The FY 2025 decrease reflects program completion.			
Title: Biology for Security (BIOSEC) ***Description:*** The Biology for Security (BIOSEC) program investigated novel approaches to address the DoD need for rapid detection of unknown and/or emerging biological threats. This program investigated 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 handles scenarios involving engineered or undiscovered bacterial pathogens that do not have known hallmarks. Advances in this area have produced completely new capabilities to assess the emergence of pathogens and to detect pathogens that evade detection by traditional methods. Resulting systems can now 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.	4.274	-	-
Accomplishments/Planned Programs Subtotals	28.004	4.306	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

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D. Acquisition Strategy

N/A