Exhibit R-2, RDT&E Budget Item Justification: PB 2023 Army	**Date:** April 2022
Appropriation/Budget Activity 2040: *Research, Development, Test & Evaluation, Army* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
Total Program Element	-	344.031	368.751	279.328	-	279.328	283.521	289.022	291.270	291.296	0.000	2,147.219
AA1: *ILIR - AMC*	-	10.780	10.884	11.532	-	11.532	11.706	12.003	12.006	12.003	0.000	80.914
AA2: *ILIR - SMDC*	-	0.965	0.979	1.039	-	1.039	1.057	1.082	1.057	1.056	0.000	7.235
AA3: *Single Investigator Basic Research*	-	100.773	89.760	97.211	-	97.211	99.126	100.196	101.687	101.660	0.000	690.413
AA4: *Training and Human Science Research*	-	21.322	21.644	22.180	-	22.180	22.414	22.393	22.334	22.329	0.000	154.616
AA5: *Biotechnology and Systems Biology*	-	6.042	6.063	6.421	-	6.421	6.518	6.577	6.579	6.577	0.000	44.777
AA6: *Robotics and Mobile Energy*	-	22.353	20.616	21.854	-	21.854	22.173	24.323	24.331	24.324	0.000	159.974
AA7: *Mechanics and Ballistics*	-	35.368	33.331	35.234	-	35.234	35.760	36.184	36.195	36.186	0.000	248.258
AA8: *Sensing and Electromagnetics*	-	9.006	13.589	13.619	-	13.619	13.499	14.160	14.840	14.940	0.000	93.653
AA9: *Information and Networking*	-	40.376	40.435	42.839	-	42.839	43.480	43.875	43.889	43.877	0.000	298.771
AB1: *Basic Res in infect Dis, Oper Med and Combat Care*	-	31.957	36.910	4.405	-	4.405	4.465	4.607	4.580	4.578	0.000	91.502
AB2: *Protection, Maneuver, Geospatial, Natural Sciences*	-	17.089	17.967	19.201	-	19.201	19.478	19.749	19.897	19.892	0.000	133.273
CH9: *Advancing Concepts and Technology Forecasting*	-	-	3.573	3.793	-	3.793	3.845	3.873	3.875	3.874	0.000	22.833
T14: *BASIC RESEARCH INITIATIVES - AMC (CA)*	-	48.000	73.000	-	-	-	-	-	-	-	0.000	121.000

A. Mission Description and Budget Item Justification

This Program Element (PE) builds fundamental scientific knowledge contributing to the sustainment of United States (US) Army scientific and technological superiority in land warfighting capability and to solving military problems related to long-term national security needs, investigates new concepts and technologies for the Army's future force, and provides the means to exploit scientific breakthroughs and avoid technological surprises. This PE fosters innovation in Army niche areas (e.g., lightweight armor, energetic materials, and night vision capability) and areas where there is no commercial investment due to limited markets (e.g., vaccines for tropical diseases).

It also focuses university single investigator research on areas of high interest to the Army (e.g., high-density compact power and novel sensor phenomenology). The in-house portion of the program capitalizes on the Army's scientific talent and specialized facilities to transition knowledge and technology into appropriate developmental activities. The extramural program leverages the research efforts of other government agencies, academia, and industry. This PE also supports basic research at the Army laboratories through the In-House Laboratory Independent Research (ILIR) program. The ILIR program serves as a catalyst for major technology breakthroughs by providing laboratory directors flexibility in implementing novel research ideas, by nurturing promising young scientists and engineers, and is used to attract and retain top doctoral degreed scientists and engineers. The ILIR program also provides a source of competitive funds for peer reviewed efforts at Army laboratories to stimulate high quality, innovative research with significant opportunity for payoff to Army warfighting capability. This PE also identifies emerging and disruptive basic scientific research outcomes in order to translate, integrate, and ingrain research outcomes with Army Warfighting Concepts which describe how the Army will fight in the far-term future.

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas and the Army Modernization Strategy.

B. Program Change Summary ($ in Millions)	**FY 2021**	**FY 2022**	**FY 2023 Base**	**FY 2023 OCO**	**FY 2023 Total**
Previous President's Budget	344.031	297.241	0.000	-	0.000
Current President's Budget	344.031	368.751	279.328	-	279.328
Total Adjustments	0.000	71.510	279.328	-	279.328
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	73.000			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-	-			
• SBIR/STTR Transfer	-	-			
• Adjustments to Budget Years	-	-	279.328	-	279.328
• FFRDC Transfer	-	-1.490	-	-	-

Congressional Add Details ($ in Millions, and Includes General Reductions)	**FY 2021**	**FY 2022**
Project: T14: *BASIC RESEARCH INITIATIVES - AMC (CA)*		
Congressional Add: *Multi-fuel ignition, chemistry and control strategies for unmanned aircraft systems hybrid propulsion*	15.000	-
Congressional Add: *Program increase*	10.000	25.000
Congressional Add: *Program increase - explosives and opiods dual-use UV detection*	3.000	5.000
Congressional Add: *Program increase: Artificial intelligence complex multi?material composites processing*	10.000	-
Congressional Add: *Program Increase: Cell-Free Expression for Biomanufacturing*	10.000	10.000
Congressional Add: *Digital Thread for Advanced Manufacturing*	-	5.000

Exhibit R-2, **RDT&E Budget Item Justification:** PB 2023 Army	**Date:** April 2022
Appropriation/Budget Activity 2040: *Research, Development, Test & Evaluation, Army* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*

Congressional Add Details ($ in Millions, and Includes General Reductions)	**FY 2021**	**FY 2022**
Congressional Add: *Joint Research Labratories*	-	20.000
Congressional Add: *Lightweight High Entropy Metallic Alloy Discovery*	-	3.000
Congressional Add: *Unmanned Aerial Systems Propulsion*	-	5.000
Congressional Add Subtotals for Project: T14	48.000	73.000
Congressional Add Totals for all Projects	48.000	73.000

Change Summary Explanation

Fiscal Year 2023 (FY23) funding increase reflects the fact that the FY22 President's Budget request did not include out-year funding.

Exhibit R-2A, **RDT&E Project Justification:** PB 2023 Army			**Date:** April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA1 / *ILIR - AMC*	

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
AA1: *ILIR - AMC*	-	10.780	10.884	11.532	-	11.532	11.706	12.003	12.006	12.003	0.000	80.914

A. Mission Description and Budget Item Justification

Work in this Project supports basic research at the Army Futures Command through the In-House Laboratory Independent Research (ILIR) program. Basic research lays the foundation for future developmental efforts by identifying fundamental principles governing various phenomena and appropriate pathways to exploit this knowledge. The ILIR program serves as a catalyst for major technology breakthroughs by providing laboratory directors flexibility in implementing novel research ideas, by nurturing promising young scientists and engineers, and is used to attract and retain top doctoral degreed scientists and engineers. The ILIR program also provides a source of competitive funds for peer reviewed efforts at Army laboratories to stimulate high quality, innovative research with significant opportunity for payoff to Army warfighting capability.

Work in this Project is performed by the United States Army Futures Command (AFC).

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas and the Army Modernization Strategy.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Edgewood Chemical Biological Center (ECBC)	1.001	0.968	1.085
Description: Basic research in chemistry, biology, biotechnology, toxicology, material science, and aerosols for creating the science base needed for countering improvised explosive devices (IEDs), explosives forensics, obscurants, sensing, advanced materials, and defeating targets. ***FY 2022 Plans:*** Will conduct basic research that informs Department of Defense Research Priorities and Army Modernization Priorities, focused on the areas of synthetic biology, machine learning for threat detection, novel physical and biological materials for future application of obscuration, protection, and detection, and expanded modeling and simulation in chemical and biological adsorption and deposition. ***FY 2023 Plans:*** Will conduct novel basic science research on the phenomenology of principal components in chemical and biological sciences, focused on the utilization of materials by design concepts (modeling, synthesis, and characterization) of synthetic biology for the development of novel physical/biological materials, new sensing materials, threat detection and characterization. Will employ Artificial intelligence, machine learning and predictive modeling for the identification of emerging threats, enhancement of performance and/or truncation of the development cycle. ***FY 2022 to FY 2023 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA1 / *ILIR - AMC*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Funding change reflects planned lifecycle of this effort.			
Title: Armaments Research, Development and Engineering Center (ARDEC) ***Description:*** Funds basic research in weapons component physics, explosives synthesis/detection, and the fundamental science base of area denial. ***FY 2022 Plans:*** Will conduct basic research investigations of airy beams, factors affecting and mechanisms of tube memory, rate constants for gas-phase energetic material decomposition, non-destructive methods for detecting hydrogen embrittlement in steels using plasmonic nanoparticles, thermally induced crack formation mechanisms, new and powerful insensitive explosives with enhanced performance, and novel composite structural materials for light weight armament systems. ***FY 2023 Plans:*** Will conduct research on methods to simulate breakup, ablation, and component connectivity change on novel composite structural materials for light weight armament systems. Will conduct research on methods to directly model surface texture and its modification to alter mechanical response. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.446	1.426	1.570
Title: Tank Automotive Research, Development and Engineering Center (TARDEC) ***Description:*** This effort funds basic research in ground vehicle technologies that include power, mobility, autonomous systems, materials and manufacturing. ***FY 2022 Plans:*** Will competitively select in-house basic research topic areas to advance fundamental scientific understanding to support ground vehicle systems in: control systems for vehicles, optimal path planning for autonomous systems, advanced coatings, lightweight and composite materials, additive manufacturing, multi-physics battery modeling, hydrodynamic modeling, and internal combustion engine modeling. ***FY 2023 Plans:*** Will conduct competitively-selected, basic, in-house research to improve the fundamental understanding of ground vehicles and establish the underlying physics in such areas as semi- and fully autonomous vehicles; soft soil mobility modeling; active protection and signature management; advanced combustion engine thermal control; multi-physics battery modeling and simulation; lightweight materials and additive manufacturing; corrosion modeling; cognitive loading and crew station design; vehicle control systems; and cybersecurity threat detection. ***FY 2022 to FY 2023 Increase/Decrease Statement:***	1.235	1.189	1.320

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Funding change reflects planned lifecycle of this effort.			
Title: Natick Soldier Research, Development and Engineering Center (NSRDEC) ***Description:*** This effort funds basic research in food sciences, textiles, and lightweight materials with potential for individual protection. ***FY 2022 Plans:*** Will explore techniques for tuning reconfigurability of metamaterials to control activation of multifunctional material properties and inform advancement of high-frequency rectifier materials platforms. Will produce knowledge to support improvements in antenna, communication, data storage, and electromagnetic interference (EMI) shielding technologies. ***FY 2023 Plans:*** Will examine the effects of diverse food forms (e.g. varied compression and lipid levels) on human systems and perception to understand the impact of condensing and altering combat ration components in support of improved Soldier performance and sustainment. Will characterize optoelectronic and electronic properties of two-dimensional materials (MXenes) and investigate molecular structure-function relationships. Will interpret results to advance understanding related to the use of unique two-dimensional materials for controlling conductivity and EMI shielding efficiency. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.126	1.112	1.238
Title: Aviation and Missile Research, Development and Engineering Center: Missile Efforts (AMRDEC-MI) ***Description:*** This effort funds the underlying fundamental science of Lethality and Protection Superiority for guided missile and rocket systems, directed energy weapons, unmanned vehicles, and related components. ***FY 2022 Plans:*** Will develop an experimental system using unclocked Boolean circuits to enable exploration of the fundamental nature of complex dynamics in networks of coupled identical oscillators for secure communications and device protection; will explore compressive sensing techniques based on deep learning methods to augment existing sensor suites and maximize information collected from sensor hardware while reducing size, weight, power, and cost (SWAP-C); will investigate, simulate, and fabricate new proof-of-principle designer devices and artificial materials to enable disruptive opto-electro-plasmonic systems for sensors and devices for sensor protection and masking; will develop proof-of-concept experiments for entanglement generation on a quantum integrated circuit with investigations into quadrature methods for detection to enable quantum radar operation below classical noise limits. ***FY 2023 Plans:*** Will explore the fundamental nature of complex dynamics in networks of coupled identical oscillators using the experimental unclocked Boolean circuit for secure communications and device protection; continue to explore and begin experimentation with	2.394	2.310	2.509

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
compressive sensing techniques based on deep learning methods to augment existing sensor suites and maximize information collected from sensor hardware while reducing size, weight, power, and cost (SWAP-C); continue basic research into advanced modeling techniques to investigate, simulate, and fabricate new proof-of-principle designer devices and artificial materials to enable disruptive opto-electro-plasmonic systems for sensors and devices for sensor protection and masking; study the role of temperature on noise and entangled photon generation in a Josephson junction based quantum integrated circuit; investigate the fundamental models that could enable the use of machine learning techniques to predict new materials and the provide direction for their synthesis. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Aviation and Missile Research, Development and Engineering Center: Aviation Efforts (AMRDEC-AV) ***Description:*** This effort funds basic research for aviation enabling technologies in the areas of aerodynamics, structural dynamics, and material science. ***FY 2022 Plans:*** Will continue basic aerodynamic science research in the areas of vorticity dynamics, bluff body flow separation, and wake interactions; investigate advanced boundary layer flow control phenomenon including fluidic oscillators in the context of hub flows; will develop an uncertainty quantification and sensitivity analysis framework for rotorcraft aeromechanics simulations; will improve automation for setup and execution of rotorcraft aeromechanics simulation; develop high-fidelity surrogate models for rotorcraft aeromechanics simulations in order to dramatically reduce computational run times for these simulations. ***FY 2023 Plans:*** Will develop a permeable-surface acoustics formulation that will accurately capture the acoustic scattering and shielding effects due to impingement of pressure waves on solid surfaces prevalent in emerging configurations with multiple rotors/propulsors and lifting surfaces; will conduct experimental tests to better understand fundamental behavior of single and coaxial propeller over a range of configurations and operating conditions. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.344	1.327	1.466
Title: Communications Electronics Research and Engineering Directorate (CERDEC) ***Description:*** Funds basic research for communication and network enabling technologies in the areas of antenna design, network management, power generation and storage, and sensors. ***FY 2022 Plans:***	2.234	2.154	2.344

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army			Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA1 / *ILIR - AMC*	

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Will conduct research in structural excitation based conformal antenna design concepts; will study incoherent Fourier Ptychographic Photography (FPP) optimized with deep neural networks to Army imaging applications including Aided Target Recognition (AiTR) and target identification; will investigate the material properties of vanadium oxide (VOx) for Long-Wavelength Infrared (LWIR) sensor material; will investigate the incorporation and diffusion of Zinc into semiconductor alloys grown by molecular beam epitaxy (MBE); will investigate the reduction of interfacial resistance between cathode and solid electrolyte through conducting glass for solid state lithium ion batteries; will investigate safe polymer electrolytes for use with high voltage electrode materials in lithium-ion batteries. ***FY 2023 Plans:*** Will research unconventional vision-aided landmark navigation using spectral signature beacons; will investigate methods for wireless power transfer; will study thermal runaway inhibitors to reduce cell charge transfer at elevated temperatures in lithium-ion batteries; will investigate algorithms to fuse different aspects of Lidar and Radar data for improve target tracking; will characterize and analyze material inhomogeneity in type-II superlattice materials for infrared detectors; will investigate the use of electron channeling contrast imaging (ECCI) to identify and characterize crystalline defects in epitaxial materials grown for infrared detectors; will investigate atmospheric properties of the intraThermal Infrared (intraTIR) spectral band (4.5 ? 8.5 um). ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: FY2022 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	0.398	-
Accomplishments/Planned Programs Subtotals	10.780	10.884	11.532

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army			**Date:** April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA2 / *ILIR - SMDC*	

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
AA2: *ILIR - SMDC*	-	0.965	0.979	1.039	-	1.039	1.057	1.082	1.057	1.056	0.000	7.235

A. Mission Description and Budget Item Justification

Work in this Project supports basic research at the United States Army Space and Missile Defense Command - Technical Center (USASMDC-TC) through the In-House Laboratory Independent Research (ILIR) program. Basic research lays the foundation for future developmental efforts by identifying fundamental principles governing various phenomena and appropriate pathways to exploit this knowledge. The ILIR program serves as a catalyst for major technology breakthroughs by providing laboratory directors flexibility in implementing novel research ideas, by nurturing promising young scientists and engineers, and is used to attract and retain top doctoral level scientists and engineers. The ILIR program also provides a source of competitive funds for peer reviewed efforts at Army laboratories to stimulate high quality, innovative research with significant opportunity for payoff to Army warfighting capability.

Work in the Project provides a foundation for applied research initiatives at the Army laboratories and research, development, and engineering centers.

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas and the Army Modernization Strategy.

Work in this Project is related to, and fully coordinated with efforts in PE 0602150A Air and Missile Defense Technology / AD2 (High Energy Laser (HEL) Enabling and Support Technologies.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: SMDC In-house Laboratory Independent Research (ILIR) ***Description:*** This effort provides ILIR at USASMDC-TC. This basic research on lasers and directed energy lays the foundation for future developmental efforts on high energy lasers and directed energy systems by identifying the fundamental principles governing various directed energy phenomena with the goal of developing technologies that will significantly reduce size, weight and power requirements for laser systems. ***FY 2022 Plans:*** Will collect data using the advanced optical turbulence sensor developed in this effort. Will design a lab experiment and implement control algorithms for advanced atmospheric turbulence compensation techniques. Will design and conduct lab experiments for next generation laser technology. ***FY 2023 Plans:*** Will expand atmospheric propagation data collection to include slant and vertical path to investigate the boundary layer as a function of time of day, weather conditions, solar loading, and terrain parameters. Will expand models to better match	0.965	0.957	1.039

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA2 / *ILIR - SMDC*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
data. Will collect data using the Ultra Short Pulsed Lasers (USPL) lab capability to investigate propagation and filamentation phenomenology and material interaction. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: SBIR/STTR Tax ***Description:*** ?Funding transferred in accordance with Title 15 USC ?638? ***FY 2022 Plans:*** ?Funding transferred in accordance with Title 15 USC ?638? ***FY 2022 to FY 2023 Increase/Decrease Statement:*** ?Funding transferred in accordance with Title 15 USC ?638?	-	0.022	-
Accomplishments/Planned Programs Subtotals	0.965	0.979	1.039

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) AA3 / *Single Investigator Basic Research*

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
AA3: *Single Investigator Basic Research*	-	100.773	89.760	97.211	-	97.211	99.126	100.196	101.687	101.660	0.000	690.413

A. Mission Description and Budget Item Justification

This Project fosters extramural basic research to create and exploit new scientific discoveries and technology breakthroughs, primarily from universities, that will improve the Army's transformational capabilities. The Army Futures Command maintains a strong peer-reviewed scientific research program through which leap-ahead technological solutions may be discovered, matured, and transitioned to overcome the technological barriers associated with next generation capabilities. Included are research efforts for increasing knowledge and understanding in fields related to long-term future force needs in the physical sciences (i.e., physics, chemistry, life sciences, and social sciences), the engineering sciences (i.e., mechanical sciences, electronics, materials sciences, and environmental science), and information sciences (i.e., mathematical sciences, computing sciences, and network sciences). Targeted research programs in nanotechnology, training and simulation, smart structures, multifunctional and micro-miniature sensors, intelligent systems, countermine, compact power, and other mission-driven areas will lead to a future force that is more strategically deployable, more agile, more lethal, and more survivable. The breadth of this basic research program covers approximately 800 active, ongoing research grants and contracts with leading academic researchers and approximately 1,600 graduate students yearly, supporting research at nearly 210 institutions in 50 states.

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas and the Army Modernization Strategy.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Basic Research in Life Sciences ***Description:*** This effort fosters fundamental discoveries in life sciences with the ultimate goal of facilitating the development of novel biomaterials to greatly enhance Soldier protection and performance. More specifically, i) molecular genetics research that pursues fundamental studies in molecular and systems biology, and genetics, ii) neurosciences research to investigate the physiology underlying perception, neuro-motor output, and potential methods of monitoring cognitive states during activity, iii) biochemistry research focused on studies in structural and cell biology, metabolic processes, and biophysics, iv) research in microbiology that pursues studies in microbial physiology, ecology, and evolution, v) social science research that aims to elucidate the social, cultural, and other influences to human actions, and vi) auditory and signal processing research that maps the cognitive implications of multisensory information integration. ***FY 2022 Plans:*** Will identity the biological molecules and mechanisms involved in the selective sequestration of strontium ions from seawater and the control over the single crystal growth of the mineral celestine that if successful, will be a key step toward designing biotechnological approaches to remove toxins to protect the Soldier, and for the use of synthetic biology to assemble structures with non-natural elements, thereby expanding the periodic table accessible to biology; will identify the regulatory mechanisms mediating expression variation in key genes involved in maintaining hydrogen sulfide homeostasis in tolerant and non-tolerant	12.102	10.115	11.235

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
eukaryotic populations that if successful, may lead to new therapeutic methods for combat casualty care and the treatment of traumatic injuries; will employ a machine learning approach wherein a computer vision algorithm is trained to identify bacteria in public-domain images of brain tissue to examine preliminary findings that the brain is not a sterile environment as traditionally thought, which if successful would validate initial findings that brain tissue co-exists with various bacterial species and would fundamentally change the scientific understanding of detecting and treating neurodegenerative diseases and mood disorders that may affect the active and retired Soldier; will conduct systems-level molecular studies on the physiology of slow growth with methanogenic Archaea using anaerobic chemostats with growth rates limited by either catabolic or anabolic substrates, to determine how cellular energy and ribosomal activity is allocated during slow growth, that if completed will provide new routes to harness microorganisms for the synthesis of future compounds of interest ranging from therapeutics to enzymes for inactivating toxic chemicals or warfare agents. ***FY 2023 Plans:*** Will dissect and characterize the L-form phenotype in specific prokaryotes to be able to induce it temporarily or permanently as a key step forward for bioengineering, as L-form prokaryotes induce less or no host response and are anticipated to be able to better release their payload, that if successful may enable the Army to produce new types of materiel and to enable new systems for better warfighter protection; attach nickel catalysts and photocatalysts to a variety of specific bioconjugation sites within different cross-linked protein crystals and characterize the structures and catalytic properties of the resulting hybrid materials that if successful, will be a key step toward using porous protein frameworks as scaffolds to organize dual abiotic catalysts to enable new-to-nature chemical transformations for the synthesis of Army-relevant materials including energetic materials, precursors to energetic materials, polymers, and composites; measure the native growth activity of microbial communities in cold region ecosystems and provide the foundation for establishing how microbial activity in these cold environments responds to environmental change which, if successful, will contribute to the Army?s strategy in regaining Arctic dominance by providing the Soldier with new tools to assess the impact of warming in Arctic environments on the integrity of infrastructure assets in these regions; measure changes in brain oxygenation with a genetically encoded bioluminescence reporter in rodents, that if completed will offer a precise tool to determine whether sleep deprivation affects oxygen tension under operationally-relevant functional tasks and pave a path to link overall brain metabolism with Soldier cognitive performance and the impacts of brain aging on resilience to disease or sleep deprivation. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Basic Research in Chemical Sciences ***Description:*** This effort fosters basic research to achieve advanced energy control, improved threat detection, and novel responsive materials for Soldier protection. Research efforts will lead to: light-weight, reliable, compact power sources, more effective, lower vulnerability propellants and explosives for tailored precision strikes with minimum collateral damage, new approaches for shielding the Soldier and Army platforms from ballistic, chemical, and biological threats, and reducing signatures	14.664	10.950	10.607

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) AA3 / *Single Investigator Basic Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
for identification by the enemy, and advance warning of explosive, chemical, and biological weapons and dangerous industrial chemicals. ***FY 2022 Plans:*** Will assess a new hypothesis for how to design new classes of depolymerizable polymers that are capable of rapid depolymerization in the context of solid materials that if successful, will enable future protective layers for electronics devices and smart coatings for self-healing materials or the controlled release of specialized material layers to protect the Soldier and materiel; design, synthesize, and validate transient, responsive functional nanomaterials that autonomously respond to specific chemical stimuli that if successful will enable new classes of functional materials that can autonomously transform into a different functional configuration according to a preset schedule or stimuli, such as to resist or inactivate a toxic industrial chemical; perform parametric experimental studies as a function of the chemical functionality present at cation-exchange/anion-exchange membranes, coupled with multiscale modeling on length scales from nanometers to hundreds of microns to determine the transport and interfacial effects in bipolar membranes that if successful, will enable the next generation of polymer electrolyte fuel cells to reduce soldier-borne weight; determine the photochemical fate of saxitoxin (which can be from natural or synthetic sources) and its analogues in surface waters by assessing the degradation kinetics and pathways and identifying the major transformation products, that if successful will provide novel tracking and remediation practices to protect the Soldier and Army materiel. ***FY 2023 Plans:*** Will identify the physical limitations to the rate of water dissociation in bipolar membranes and how they can be used to pass ionic current commensurate with currents observed in practical reversible fuel cells that if successful, will potentially enable the next generation of polymer electrolyte fuel cells with the goal of reducing soldier-borne weight associated with power generation; develop a quantitative model that links the molecular structures, adsorption strengths, and oxidation kinetics of organics in the aqueous phase of complex environmental matrices that if successful, will be a key step towards designing novel waste stream remediation technologies or reducing corrosion rates and surface film formation to protect the Soldier and materiel; integrate polymer science and biostatistical sequence analysis to better understand the fundamental design rules needed to rationally design polymeric materials to effectively interface with biological proteins that if successful, may lead to new functional hybrid biomaterials with enhanced stability and activity of proteins in non-biological environments, enabling new technologies for energy harvesting and conversion, catalysis, sensing, and bioremediation. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort			
Title: Basic Research in Physics ***Description:*** This effort fosters research in many subfields of physics, including condensed matter physics, optical physics, atomic and molecular physics, and quantum information, with an emphasis on discovering new realms of quantum and optical	11.607	11.522	12.784

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
phenomena. Pursuit of fundamental physics in these subfields provides new opportunities for future developments in superior optics, ultra-sensitive sensors, and novel electronic architectures for classical and quantum computing. ***FY 2022 Plans:*** Will perform two-photon electron bridge spectroscopy of the 229Th3+ nuclear isomer transition that if successful is expected to enable compact, fieldable, atomic clocks with significantly reduced environmental sensitivity to provide new capabilities in positioning, navigation, and timing; elucidate the nature of magnetic coupling across interfaces between topological materials and magnetic materials to the degree that device concepts based on those couplings can be pursued, that if successful will provide a foundation for new energy efficient electronic technologies that will enable Soldiers and small systems to extend mission length and reduce dependence on extensive portable power systems; will generate and preserve multi-quantum bit entangled states via dynamically-corrected gate operations in silicon spin quantum bits that, if successful, should have a transformative impact on silicon based quantum computing by enabling the implementation of future quantum information processors that will provide new capabilities in command, control, computers, communications, cyber, intelligence, surveillance and reconnaissance; utilize non-Hermitian interaction coupled with quantum gauge theory for active control of chiral light with quantized orbital angular momentum that if successful would provide on-chip information processing and high-powered semiconductor microlaser sources for secure high-speed optical communications. ***FY 2023 Plans:*** Will devise new theoretical approaches for analyzing quantum systems using light-matter coupling through the tuning of material properties via strong coherent coupling to vacuum fluctuations of terahertz (Thz) metamaterials and analyze properties of electrons in mono- and twisted bilayer two-dimensional materials embedded in terahertz cavities that if successful will enable the creation of materials with new functionalities for sensing, information storage, and processing; advance recent demonstrations of second-order nonlinear interactions in Aluminum Nitride (AlN) optical parametric oscillators (OPO) by utilizing chip-based coherent sources of light in the visible (VIS) and near-infrared (NIR) to construct broadband, self-referencing optical frequency combs that if successful, will enable fieldable light sources able to provide precise frequency standards for inertial sensors with increased sensitivity; identify challenges associated with the nature of fundamental structural and electronic microwave properties of superconductor-semiconductor interfaces to work toward optimal interfaces for qubits that if successful, will possess properties ideal for quantum computation platforms that are amenable for scaling up to the number of qubits necessary to carry out computations of Army relevance such as those related to optimization, logistics, and advanced material simulation. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Basic Research in Electronics and Photonics	10.449	8.453	9.545

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Description: This effort fosters discoveries in electronic sensing, optoelectronics, solid state and high frequency science, electromagnetics, microwaves, and power electronics for situational awareness, communications, information processing, electro-magnetic warfare, and power efficiency. ***FY 2022 Plans:*** Will develop bioelectric field imaging techniques and electronic material and device-based interfaces with single cells; will map the relationship between genetic responses and bioelectric networks within cell communities; will develop a hierarchy of simulation tools to analyze wave-propagation effects and electron-transport physics in active electromagnetic structures including the complex coupling of physical equations describing the nonlinear active phenomena with full-wave electromagnetic-wave modelling that captures interactions; will utilize two dimensional materials embedded in microcavities to induce band splitting with optical fields; will assess non-reciprocal effects that may be used in integrated photonic platforms; will explore large refractive index changes in inverted bandgap superlattices for long wavelength infrared optoelectronics including modulation and beam steering. ***FY 2023 Plans:*** Will study the fundamental structure/property relationship between metasurface geometries and Silicon Germanium Oxide (SixGeyO1-x-y) sensing layers for uncooled microbolometers that if successful, will enable improved sensitivity and resolution in night vision imaging systems; investigate ultrafast dynamics and coherent control on the surfaces of Weyl semimetals using a novel terahertz scanning tunneling microscope technique that if successful, may lead to new electronic device concepts capable of operating at THz frequencies supporting next generation high bandwidth communication systems; study extracellular bioelectrical stimulation and theoretical modeling with other published technologies to understand the impact of extracellular bioelectric fields on the structures and functions of intracellular liquid condensates that if successful, may lead to new insights and therapies for traumatic brain injury; investigate silicon nitride on lithium niobate as an optoelectronics materials platform along with the necessary design, fabrication, and characterization processes to validate the material?s unique capabilities for realizing modulator architectures with unprecedented performance that if successful, will enable high performance computing hardware for artificial intelligence (AI) applications such as target recognition or natural language processing; study the nature of magnetic coupling across interfaces between topological materials and magnetic materials that if successful, will provide a foundation for new energy efficient electronic technologies that will enable Soldiers and small systems to extend mission length and reduce dependence on extensive portable power systems. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Basic Research in Materials Sciences ***Description:*** Research that provides innovations in materials design and process through the elucidation of fundamental relationships linking composition, microstructure, defect structure, processing and properties of materials. Revolutionary materials	11.760	10.809	13.631

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023

provide support for the Army in firepower, mobility, communications, personnel protection, infrastructure and installations, and will directly affect virtually all mission areas.

FY 2022 Plans:
Will investigate novel driving forces that influence equilibrium and non-equilibrium self-assembly, including turbulence, light, mechanical stress, or chemical gradients, and use these forces to design self-assembling and reconfigurable soft materials that adapt to their environment and/or serve as artificial neural networks; develop the necessary computational, theoretical, and machine learning methods to enable new data-driven forward and inverse design paradigms for creating self-assembling and reconfigurable soft matter; investigate hetero-epitaxial thin-film growth methods to synthesize a new class of ternary transition metal perovskite chalcogenide in thin film form to understand the influence of strain and dimensionality on the physical properties of these materials; systematically investigate innovative synthesis routes and fundamental physical properties (electronic, optical, magnetic, superconducting as well as topological insulator behavior) of a novel class of crystalline two-dimensional metal-organic frameworks; will develop a computational method for calculating the ideal processing parameters for metallic additive manufacturing (AM) to address the challenges in formulating qualification procedures for AM parts; will explore new material phases in extreme mechanical and thermomechanical environments, to determine if they can actively respond to extreme events by becoming harder and tougher; design robust metamaterials capable of steering mechanical stress waves around critical areas within structures, which could eventually lead to lighter armor for Soldier and vehicle protection.

FY 2023 Plans:
Will investigate the ability of polystyrene sulfonate and polyacrylic acid microgels to selectively sequester and release colistin and polypeptide-based anti-microbials using optical microscopy, electron microscopy, and computer simulations that could be used to tune these chemical interactions so that the microgels release their cargo in response to biologically and environmentally relevant changes in pH and ionic strength that if successful, could enable self-disinfecting surfaces, advanced surgical treatments, or systems for chemical-biological defense; identify thermodynamic, electronic, magnetic, and piezoelectric properties of twodimensional transition metal silicates and calculate oxidation states of the transition metals that if successful, will enable low power, more resilient electronics; identify phase transformation mechanisms of two dimensional materials under pressure and transition to structures with extraordinary mechanical properties that if successful, could enable Soldier protection systems which actively increase stiffness and strength in response to extreme events like blast and impact; conduct experiments to characterize the local heating stages of an ultrasonic consolidation method that is expected to enable safer processing of energetic materials in order to understand the relationships between the processing conditions and the resulting material's microstructure and properties; develop supramolecular, nano-porous peptide materials that undergo localized reconfiguration upon selectively binding of target molecules that if successful, may lead to sensitive sensor platforms for Army needs in chemical and biological warfare agent detection.

FY 2022 to FY 2023 Increase/Decrease Statement:

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2021**	**FY 2022**	**FY 2023**
Funding change reflects planned lifecycle of this effort.			
Title: Basic Research in Mechanical Sciences ***Description:*** This effort focuses on improved understanding of propulsion and combustion for improved efficiency and fuel flexibility, energetics initiation for insensitive munitions, fluid dynamics for rotorcraft, complex dynamic systems for novel sensors, energy generation and multi-dimensional systems, and solid mechanics especially at high strain rates in composite materials for novel armor and protection systems. ***FY 2022 Plans:*** Will develop information-theoretic control across different spatio-temporal scales and generalize uncertainties by combining tools from information theory with advances in nonequilibrium statistical mechanics and apply them to the problem of nonlinear stochastic optimal control; will explore the possibility that turbulent fluctuations can be harnessed to de-mix particles and assemble structures; will extend proof-of-concept work in the development of the Ultra-Short Pulse Off-Axis Digital Holography (USPODH) technique for imaging high pressure fuel sprays in the dense spray region; will determine the mechanisms which give rise to nonlinearity in geomaterials, will determine the influence of different periodic arrangements of the microstructures found in geomaterials on wave propagation, and will design meta-materials with controlled wave-propagation based on these microstructural features; will elucidate the role that surface roughness (topography) plays in modulating the spatial and temporal variability of wind, temperature, and passive gases inside the canopy/roughness layer, between and just above the buildings in urban terrain. ***FY 2023 Plans:*** Will derive precursors for the prediction of flow instabilities leading to separation around airfoils using partially observed states and validate a rigorous framework for the prediction of extreme events for specified quantities of interest, using partially observed states that if successful, will improve the control and maneuverability of rotorcraft; study how thermodynamic forces and information processing drive adaptive, emergent, and intrinsic computation in intelligent systems that if successful, could yield self-adapting autonomous systems; investigate high-pressure deformation mechanisms and constitutive behavior at grain boundaries, intermetallic inclusions, and nanoscale precipitates in aluminum 7075 that if successful, could enable lighter weight vehicle armor; assess the hypothesis that crystallographic orientation and particle morphology are major contributors to fracture behavior of single and multiple silica sand particles during high strain rate loading and if successful, has the potential to improve the ground penetration of projectiles. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	11.188	8.421	9.340
Title: Basic Research in Computing Sciences	8.648	6.342	7.532

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Description: This effort provides the backbone for performing complex, multi-system analysis, modeling, and simulation for understanding information systems. Advancements in computer sciences have a direct impact on enhancing the Warfighters' decision-making and situation awareness. ***FY 2022 Plans:*** Will develop new decentralized planning and learning methods for coordinating multiple agents in uncertain, unstructured domains that address three issues: planning in large continuous spaces, asynchronous learning, and adaptability. This will potentially enable efficient planning and learning methods to accomplish missions such as reconnaissance or resupply; investigate the robustness of existing machine learning systems and the ability to inject adaptively to the associated general methodologies in resource-limited scenarios with potential time-critical contexts, impacting areas such as Intelligence, Surveillance, Reconnaissance (ISR) and robotic perception; build a fully unified framework for Tractable Deep Probabilistic Models (TDPM) which will provided greater efficiency and interpretability compared to current deep neural network approach, benefitting future Army systems that will employ deep neural networks; explore understanding human behavior to be able to create generators and classifiers at the right level of fidelity in a virtual environment; better understand Generative Adversarial Networks (GANs) for data generation, compression, domain transfer, and security, resulting in the ability to design more robust implementations of secure, reliable, and efficient deep neural network artificial intelligence solutions. ***FY 2023 Plans:*** Will explore the theoretical underpinnings of vulnerabilities of deep learning and create robust methodology to defend against potentially backdoored Deep Neural Networks that if successful, will enable the detection of the presence of adversarial triggers (backdoors) and to accurately recover the correct output label even when presented with a poisoned/adversarial input; develop a dynamic learning framework that effectively extracts Activity-Based Intelligence in highly complex and plausible military operations, specifically, Dynamic Scene Graphs over large-scale multimodal time series data may be such a candidate for representation learning; determine how systems that serve as the backbone of modern computing infrastructure can exploit heterogeneous storage to achieve faster performance at a lower cost by incorporating heterogeneous storage into databases, which are a core system of any computing application in any environment; investigate how meta-learning and multi-task learning methods can adapt to both changes in the environment and changes in specific tasks by developing online meta-learning methods that can use past experiences of adapting to changes in the environment and task and by distilling this past experience into a compositional and modular multi-task representation. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Basic Research In Network Sciences ***Description:*** This effort focuses on gaining an understanding of the fundamental aspects of how networks develop, function, and adapt to the environment and the rate of information flow in man-made and naturally occurring networks. This understanding	10.807	10.453	11.742

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
will have a direct impact on net-centric force operations, such as better communication system design and operations, and more efficient logistics or communications support. ***FY 2022 Plans:*** Will develop theory and system of network-wide radio context attestation that is capable of capturing the continuous dynamic change of radio contexts of individual devices while protecting the confidentiality of the operational parameters of those devices against untrusted network components, leading to the next generation of remote verification properties for military radios; develop a unified framework for geometric factorization for community mining, with particular focus on the challenges faced by homeland security and military intelligence operations such as network scenarios with many hidden links, small-footprint outliers, and outlying communities, that will address the current challenges associated with modeling the complexity of social networks; will develop an efficient computational method for the synthesis of optimal distributed controllers, particularly a new mathematical foundation for the design of optimal decentralized/distributed controllers that can be deployed for a wide range of real-world applications such as communication networks, electrical power systems, aerospace systems, large-space flexible structures, traffic systems, wireless sensor networks, and various multi-agent systems; will explore the use of online reinforcement learning across multiple concurrent agents to enable cross-layer optimization in tactical networks to support more efficient usage of resources in a dynamic and resource constrained environment. ***FY 2023 Plans:*** Will develop wireless networking algorithms for ultra-reliable-low-latency communications with various constraints, such as strict deadline constraints and age of information constraints, facilitated by network function virtualization, starting with single hop contention based network and working towards multi-hop wireless; develop multi-Agent Reinforcement Learning algorithms in networked autonomous systems that operate in dynamic, uncertain, and possibly adversarial environments to support autonomous behavior of agents working in concert to accomplish a mission, including transfer learning for agents from each other, as well as learning the objectives of other agents from their actions and identify agents whose objectives might diverge from the mission goals; explore control methodologies to reduce the error rates of qubits in quantum systems to enable scalable quantum computers and efficient quantum communication systems; investigate quantum error correction codes to ensure that they can produce useful virtual qubits from a practically realizable number of physical qubits; assess human-agent teaming to reduce errors associated with knowledge handoffs during human shift changes in complex intelligence activities, with specific focus on reduction in the risk inherent in human processing of intelligence, particularly in settings where the body of information is so complex it requires a team of analysts to execute the mission; investigate the use of interactive agents to assess the impact on communication and coordination problems such as blind spots, biases, and human-introduced inaccuracies during shift handovers of intelligence work; develop a method to use Neural Networks to identify events, given that identification of events depends on contextual information, and how to bring the context into Deep Neural Networks while processing text. ***FY 2022 to FY 2023 Increase/Decrease Statement:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Funding change reflects planned lifecycle of this effort.			
Title: Basic Research in Mathematical Sciences ***Description:*** This effort fosters the creation of new mathematical tools and methods for performing complex, multi-system analysis and modeling to enhance Soldier and weapon-system performance. More specifically, the focus is on creating mathematical principles and practical algorithms for stochastic analysis and control, analysis and control of biological systems, numerical computation of infinite-dimensional systems, and modeling of irregular geometric and social phenomena. ***FY 2022 Plans:*** Will investigate and develop the increasing mathematical network of interlocking analogies between physics, topology, logic, and computer science, and their common overlap as the possible beginnings of a new science in the general science of mathematical systems and processes bringing together mathematical ideas within the context of Category theory, including in the contexts of algorithms, complexity, and error correction, such as are present in quantum information; gain an understanding of how electrical stimulation affects the behavior of active neuronal networks, focusing on creating and implementing new modeling techniques for simulations of large-scale biologically realistic cortical networks subjected to electrical stimulation, potentially leading to significantly improve the efficacy of existing electrical stimulation therapies across multiple domains and will be useful for future device/therapy design for neural dysfunctions such as movement disorders, tinnitus, traumatic brain injury, and pain and could potentially be used for restoration of motor function or sensation as well as for improvements in memory performance; will construct better optimization algorithms by uncovering the geometric structure of the model's landscape as a function of its parameters to better enable the fitting of statistical and probability models (i.e., finding good parameter values) which will lead to knowing the landscape's geometry aiding in finding a collection of nearly optimal points to allow analysts to see which features they agree (giving us more confidence in the inference) or disagree (giving us less confidence). This could enable more accurate modeling and simulation of future Army systems; develop an entirely new approach to Topological Data Analysis (TDA), bridging the important gap between traditional TDA output and practical applications of it using statistical inference and machine learning, and developing TDA output that is more stable with respect to initial data than the standard TDA output (e.g. persistence diagrams) which could enable the development of tools to search very large sets of data for anomalies and threats and to provide visualizations that may be used by humans to obtain actionable intelligence. ***FY 2023 Plans:*** Will develop new methods for manipulating and synthesizing large amounts of noisy data to characterize in a more mathematically structured form, and therefore a form that may be ultimately more useful in applications; investigate the foundations of mathematics based on type theory in order to develop a fusion of logic and computation that is capable of developing scale-bridging mathematical modeling methodologies; will solve some of the key difficulties in heterogeneous data analysis like the individual difficulties of identifying what portions of the data are related and which are not, and then developing principled methods to partition, while also identifying key relationships between partitions; investigate the homotopical certification of algorithms to be used in complex data analysis, which have shown potential in areas such as self-assembly of micro or nano-structures,	9.548	7.011	8.055

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
where structural evolution and energy release are mapped out so as to cooperatively construct useful structures in situ, such as for material healing or in-body drug assembly/activation; explore homotopy methods for hierarchical control in the previously mentioned contexts; explore homotopy methods in other multiscale applications of Army interest, such as in characterizing the dynamical and state properties of complex biological systems. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: HBCU/MI Single Investigator ***Description:*** This effort supports extramural basic research to create and exploit new scientific discoveries from Historically Black Colleges and Universities and Minority Institutions (HBCU/MI) that will improve the Army's transformational capabilities. Areas of interest include chemical sciences, computing sciences, electronics and photonics, life sciences, material sciences, mathematical sciences, mechanical sciences, network sciences, and physics. ***FY 2022 Plans:*** Will identify and support competitively-selected extramural research conducted at HBCU/MI institutions to provide increased knowledge and understanding in fields related to long-term future force needs; support faculty immersion program where HBCU/MI faculty are aligned with Research 1 (R-1) universities and Army research laboratories in order to contribute research in support of long-term Army modernization priority needs. ***FY 2023 Plans:*** Will continue to identify and support competitively-selected extramural research conducted at HBCU/MI institutions to provide increased knowledge and understanding in fields related to long-term future force needs; will support faculty immersion program where HBCU/ MI faculty are aligned with R-1 universities and Army research laboratories in order to grow organic research capabilities at the HBCU/MI institutions and contribute to the long-term Army modernization priority needs. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	-	2.388	2.740
Title: FY2022 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 to FY 2023 Increase/Decrease Statement:***	-	3.296	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Funding transferred in accordance with Title 15 USC ?638			
Accomplishments/Planned Programs Subtotals	100.773	89.760	97.211

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 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
AA4: *Training and Human Science Research*	-	21.322	21.644	22.180	-	22.180	22.414	22.393	22.334	22.329	0.000	154.616

A. Mission Description and Budget Item Justification

This Project focuses on research that improves Soldier-system performance in future force environments by looking at key phenomena underlying Soldier integration with intelligent technologies and autonomous agents. This Project researches optimal methods for information exchange between Soldiers and intelligent technologies including 1) human performance in automated, mixed-initiative (human control-machine control) environments; 2) visual scanning and target detection; 3) performance-related Soldier state changes; 4) integration across multiple sensory modalities; and 5) collaborative (team) and independent multi-task, multi-modal, multi-echelon Soldier-system performance - all cast against the influx of emerging intelligent technologies and autonomous systems. Technical solutions are being pursued in the areas of data generation and algorithm development in these emerging environments in order to update and improve our understanding of performance boundaries and requirements. These solutions include multi-disciplinary partnerships, metrics, simulation capabilities, and modeling tools for characterizing Soldier-system performance, and provide a shared conceptual and operational framework for militarily relevant research on critical aspects of human-agent teaming.

In the area of translational neuroscience, research is carried out to examine leading edge methodologies and technologies to improve the measurement and classification of neural states and behavior in operationally-relevant environments; to examine the potential for application of neuroscience theories to autonomous systems to improve Soldier-system interactions; to model the relationship between brain structure and cognitive performance for understanding individual differences and injury; and to assess how neural pathways implicated in functional processing can be enhanced through dynamic system interface technologies for improving in-theatre performance and training.

In the area of cybernetics, which is a scientific discipline that bridges the fields of control theory and communication theory for the study and modeling of behavior in complex systems, research is carried out to examine the complex human-system-environment relationships that define, constrain, and influence the interactions between Soldier and system. Research efforts are pursued to advance theory, models, and methodological approaches that capture the dynamic and multidimensional nature of human behavior, including the temporal dependencies inherent to human behavior, through an integrated program of research efforts focused on: novel cybernetic models of human multisensory integration and human-system communication; neuro-inspired, bio-inspired, and engineering approaches to computational algorithms for multisensory integration and multi-sensor fusion to enable enhanced and augmented Soldier perception in human-system interactions; new methodological approaches for the design of multisensory displays and human-system communications; and multisensory test bed platforms for examining experimental hypotheses driven by model predictions and proof-of-principle applications of identified algorithms and methods.

This Project also investigates innovative theories, models, and methods to improve personnel assessment, training, and leader development, as well as provide a better understanding of individual, unit, and organizational behavior and performance within the context of complex organizational and operational environments. The research within these domains will enable advances in psychometrics to support the development of the next generation of psychological assessments for selection, classification, and assignment. The research also will target how to improve the assessment of difficult-to-measure skills and enable theoretical advances to inform and support the

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accelerated development of complex cognitive and social skills. This research lays the foundation for future applications that address the behavioral and organizational dynamics that impact Army flexibility, effectiveness, and resilience.

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas, the Army Modernization Strategy, and the Army People Strategy.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Translational Neuroscience ***Description:*** This effort integrates neuroscience with traditional approaches to understanding Soldier behavior to enable system designs that maximize Soldier performance. ***FY 2022 Plans:*** Will identify relationships between ocular and neural signals to understand visual search behavior in virtual and augmented environments; will investigate methods to augment the brain and predict neural behavior in real-world contexts including social interactions; will create initial neural models of the brain's spatial reasoning system. ***FY 2023 Plans:*** Will combine multiple models of embedded abstract representations to simulate interactions between brain regions observed in the mammalian spatial reasoning system; embed abstract representations discovered from the mammalian spatial reasoning system into topological neuronal networks; integrate opportunistic signals collected during search task with machine learning models to optimize search performance within human-machine teams; apply novel approaches to simultaneous neural recordings from multiple individuals working together as a team. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	3.964	3.827	4.224
Title: Human System Integration ***Description:*** This effort applies a cybernetic approach (i.e., a theoretical study and comparison of communication and control processes in biological and artificial systems) to human systems integration to achieve tighter control of devices and communications among humans and between machines and humans. Use social, computational, and information approaches to extend the scope of interaction beyond individual systems to the full network context. ***FY 2022 Plans:*** Will develop models to predict decisions by human users interacting with autonomous systems using multi-modal sensor measurements; generate initial, real-world physiological tracking of human state to drive optimal human-agent mutual adaptation;	5.200	5.063	4.740

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
will create models for optimizing individual decision making under uncertainty for future technology integration; will generate initial methodologies to analyze brain signals using topological data analysis. ***FY 2023 Plans:*** Will create approaches that enable intelligent systems to predict changes in human adaptation over time to drive optimal human-machine mutual adaptation; discover human-in-the-loop approaches to guide human-machine adaptation by isolating and prioritizing task-relevant information in the environment; create novel biometric-based objective functions that can improve the rate of mutual human-machine adaptation; uncover approaches to gather critical information from groups of people to guide stable machine learning; create mathematical approaches to resolve conflict within groups of people when guiding machine learning. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding decreased to support the creation of ?Hybridization of Team Thinking? task within this Program Element (PE) / Project.			
Title: Continuous Multi-Faceted Soldier Characterization for Adaptive Technologies ***Description:*** This effort investigates technologies that provide the foundation for future Army systems to adapt to individual Soldier states, behaviors, and intentions in real-time. Enable high fidelity, continuous prediction that can account for continuous changes in Soldier physical, cognitive, and social states, such as stress, fatigue, task difficulty, trust, and situational awareness. ***FY 2022 Plans:*** Will examine multi-modal and multi-timescale models of human dynamics to improve understanding of variability over unimodal or short timescale models; will conduct research to validate models predicting performance on military-relevant tasks, incorporating multi-timescale features; will explore adaptive algorithms using multi-timescale approaches for real-time prediction of task performance on specific, laboratory based tasks. ***FY 2023 Plans:*** Will identify which contextual history features and timescales (e.g., days, weeks) explain the most variation in human decisions within human-autonomy teams; create models that characterize human variability of irrational decision making and its contextual correlates; advance human physiological complexity matching indices to enhance predictability of human brain and heart variability; quantify influences of long-timescale processes (> weeks) on human performance variability as compared to short- and mid-timescale processes. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	4.162	4.207	4.639
Title: Training and Soldier Performance ***Description:*** Research relationship between training environment fidelity/level of immersion and Soldier performance and behavior. Understand the level of physical, perceptual, and cognitive interaction necessary for a simulated environment to affect	1.336	1.285	-

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) AA4 / *Training and Human Science Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
performance similar to that in an operational environment. Characterize the appropriate use of different classes of simulated environments to ensure valid results. Develop guidelines for using mobility platforms in simulators to induce physical and cognitive stress representative of the operational environment. Implementation of these guidelines will enhance training effectiveness. ***FY 2022 Plans:*** Will identify training approaches that utilize immersive technologies and individual differences to improve decision-making and adaptability under complexity and uncertainty. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding decreased to support the creation of ?Hybridization of Team Thinking? task within this PE / Project.			
Title: Novel Forms of Joint Human-Intelligent Agent Decision Making ***Description:*** This effort investigates methods for joint human/intelligent agent learning and decision making so that strengths of individual humans and intelligent agents are accentuated and weaknesses are mitigated for improved, emergent group performance. This effort emphasizes deep learning approaches that function under conditions of limited, mismatched, or dynamic data. ***FY 2022 Plans:*** Will develop techniques to incorporate multimodal sensing to improve autonomous system performance under dynamic environments to improve human/intelligent agent joint performance. ***FY 2023 Plans:*** Will investigate human-in-the loop artificial intelligence (AI) algorithms that can rapidly learn a wide range of skills to be able to adapt to novel tasks with minimal additional training. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	0.999	0.939	1.058
Title: Hybridization of Team Thinking ***Description:*** This effort merges novel advances in human-system sciences with neuroscience and training sciences to reconceive human brain processes and optimize human-machine thinking to allow humans to influence technology enabled decisions previously believed to be outside of human capabilities. The effort aims to optimize how humans could think within complex human-technology ecosystems to maximize human potential to adapt the Army on the battlefield. ***FY 2023 Plans:***	-	-	2.293

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) AA4 / *Training and Human Science Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Will merge novel advances in human-guided machine learning with novel advances in neuroscience into a hybrid thinking experimental test-bed; conduct laboratory experiments to show hybrid human-machine adaptation for decisions at the edge of human capability. . ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funds increased as a result of funding realignments from the ?Human Systems Integration? and ?Training and Soldier Performance? tasks within this PE / Project.			
Title: Science of Measurement of Individuals and Collectives ***Description:*** This basic research effort develops advanced psychometric theory and measurement of Soldiers and teams in order to maximize talent management. ***FY 2022 Plans:*** Will conduct research to develop new scoring approaches to improve measurement precision; will continue research to develop integrated frameworks of implicit-explicit personality; will continue research to identify individual contribution to team performance; develop collective and individual measures of performance. ***FY 2023 Plans:*** Will conduct research to advance psychometric theory and measurement of Soldiers and teams to improve selection and assignment. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.887	1.851	2.123
Title: Context of Behavior in Military Environments ***Description:*** This basic research effort develops an integrative theory to understand and model the contextual drivers of individual and group performance. ***FY 2022 Plans:*** Will conduct research to develop integrative multi-disciplinary frameworks of organizational context; will conduct research to develop theory to understand cross-echelon influence of leadership on performance. ***FY 2022 to FY 2023 Increase/Decrease Statement:***	0.899	0.932	-

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA4 / *Training and Human Science Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
This effort was completed in Fiscal Year 2022 (FY22) with the research maturing to higher Technical Readiness Levels (TRLs) earlier than expected.			
Title: Understanding Multilevel and Organizational Dynamics ***Description:*** This basic research effort develops advanced methods and models to understand the relationship of human states, traits, and behaviors on individual, group, and organizational dynamics. ***FY 2022 Plans:*** Will conduct research to develop computational approaches to model impact of organizational structure on team performance; will conduct research to develop frameworks to understand multi-team processes. ***FY 2023 Plans:*** Will conduct research to develop multilevel models of teams in complex organizations to advance understanding of the relationship of human states, traits, and behaviors on individual, group, and organizational dynamics. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.888	1.771	2.076
Title: Formal and Informal Learning and Development ***Description:*** This basic research effort develops a holistic model to understand and inform individual and group learning across assignments, platforms, and contexts throughout the career span. ***FY 2022 Plans:*** Will conduct research to develop approaches to understand and model longitudinal developmental processes of personnel; will conduct research to develop frameworks for building constructive learning environments. ***FY 2023 Plans:*** Will conduct research to advance theoretical understanding of learning methods to maximize the transfer of complex tactical, technical, and interpersonal skills from formal & informal learning environments. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	0.987	0.987	1.027
Title: FY2022 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 Plans:***	-	0.782	-

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA4 / *Training and Human Science Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638			
Accomplishments/Planned Programs Subtotals	21.322	21.644	22.180

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army			**Date:** April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA5 / *Biotechnology and Systems Biology*	

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
AA5: *Biotechnology and Systems Biology*	-	6.042	6.063	6.421	-	6.421	6.518	6.577	6.579	6.577	0.000	44.777

A. Mission Description and Budget Item Justification

This Project conducts fundamental research of biological systems and materials engineered for transformational Army capabilities. This Project focuses on technical core competencies including: Materials from Biology; Biological/Abiological Interfaces; Systems Biology; Computational Biology; Synthetic Biology, and how those competencies address Army needs to reduce logistics burden, increase situational awareness, and improve protection. Research will advance from manipulation of single microorganisms to designed microbial consortia for conversion of flexible feedstocks (indigenous and waste) into consistent products for energy and agile expedient manufacturing; advancing from the production of individual small molecules to gradient/precision/ultra-high molecular weight (UHMW)/specialty materials for production of hierarchical and metamaterials for sensing and protection; and advance from laboratory use to ruggedized organisms and materials for field deployment enabling dynamic, responsive materials, advanced sensing, and materiel protection/denial. Further, understanding the state-of-the-art in genetic engineering and control of biological systems in military environments will allow for understanding the pacing synthetic biology threat to the future operating environment.

Work in this Project is performed by the United States Army Futures Command (AFC).

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas and the Army Modernization Strategy.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Engineered Biotechnology ***Description:*** This effort investigates biological materials for devices and sensors that can be used in the future by the Army to improve force protection and reduce logistical burden. Investigates biological construction of novel materials, structures, and processes for future development of biologically derived materials, sensing materials, information processing, and power and energy to transcend critical gaps in adaptability, manufacturability, and stability in Army relevant environments. ***FY 2022 Plans:*** Will conduct targeted bioprospecting, bio-panning, and expand high throughput study of biological control mechanisms to identify material specific microbes and communities for material degradation; understand the behavior of micro-environment of degrading material through analytical and computational techniques to inform predictive community models; will investigate genetic engineering strategies to tune microbial interactions and adhesion to material interfaces for dynamic microbial/material interactions to identify candidates for degradation and assembly process. ***FY 2023 Plans:*** Will investigate material specific microbes and communities based on analytical and computational techniques; explore synthetic biology genetic tool-kits on selected organisms to modulate microbial interactions with materials for controlled degradation	2.572	2.478	2.746

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
and assembly; investigate the temporal and spatial properties of modulated microbial interactions with materials; investigate interactions of modulated organisms with natural microbial communities and explore the effects on the microenvironment of the materials during degradation and assembly; use predictive community models to identify designer communities for targeted degradation and assembly. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Synthetic Biology for Dynamic Materials ***Description:*** This effort researches the concept of responsive materials imparting living functions for operation in Army-relevant environments to enable disruptive capabilities, such as self-healing, adaptation, protection, and situational awareness. Perform research to enable design and synthesis of materials both enabled by and including biological entities to provide these living functions. ***FY 2022 Plans:*** Will explore new control strategies for harnessing indigenous biology in military environments; continue to examine materials and biologically derived assembly techniques for systems and materials performance; will develop high through-put technology for study of control mechanisms and/or parts in novel organisms; will identify orthogonal tools to allow for organism engineering agility to pivot for Army needs for material production and operational environment; will develop strategy to link high throughput data analysis of bioinformatics and material informatics to bulk material analytics. ***FY 2023 Plans:*** Will pioneer synthetic biology and advanced analytical tools to drive selection of control mechanisms in indigenous (local to Army environment) organisms; investigate and explore tuning parts and control mechanisms for harnessing indigenous biology; investigate dynamic range of orthogonal tools in individual organisms and explore control across different organisms to understand agility; investigate control mechanisms in indigenous organisms exploring behavior in different laboratory contained environments (e.g, temperature, salinity); pioneer synthetic biology methods to tune sequence defined material properties and investigate interface and assembly of materials; explore and investigate strategies for using material analytics bioinformatics and material informatics to understand synthetic biology materials. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	3.470	3.364	3.675
Title: FY2022 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 Plans:***	-	0.221	-

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA5 / *Biotechnology and Systems Biology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638			
Accomplishments/Planned Programs Subtotals	6.042	6.063	6.421

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

N/A

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) AA6 / *Robotics and Mobile Energy*

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
AA6: *Robotics and Mobile Energy*	-	22.353	20.616	21.854	-	21.854	22.173	24.323	24.331	24.324	0.000	159.974

A. Mission Description and Budget Item Justification

This Project fosters basic research to expand the Army's capabilities in the area of propulsion, platform mechanics, and autonomous air and ground platforms. This includes research to enable the investigation of risk-based design methodologies and control algorithms for enduring operation of rotorcraft and ground vehicles, artificial intelligence, and novel mobility mechanics to enable robotic systems to serve as productive embodied teaming agents. This effort researches propulsion and alternative energy systems to increase the reliability, efficiency, and survivability of air and/or ground platforms.

This Project also conducts research in support of advanced military vehicle technology with emphasis on sophisticated vehicle dynamics and simulation, vehicle-terrain interaction, vehicle control, and advanced track and suspension concepts. Advanced propulsion research will dramatically improve power density, performance, and thermal efficiency for advanced engines, transient heat transfer, high temperature materials, and thermodynamics. This Project also supports state-of-the-art simulation technologies to achieve a more fundamental understanding of advanced mobility concepts. The subject research is directed at unique, state-of-the-art phenomena in specific areas such as: non-linear ground vehicle control algorithms, using off-road terrain characteristics; and unique mobility approaches, using advanced analytical and experimental procedures.

The work in this Project supports PE 0602148A (Future Vertical Lift Technology), PE 0602145A (Next Generation Combat Vehicle Technology), and PE 0601104A (University and Industry Rsch Ctrs).

Work in this Project is performed by the United States (U.S.) Army Futures Command (AFC).

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Vehicle Propulsion and Power Research ***Description:*** Basic research to investigate concepts and theories to provide enhanced tools, methods, and innovative concepts to enable improvements in propulsion power density, energy efficiency, reliability, and lifecycle costs for increased performance and capabilities in future Army systems. ***FY 2022 Plans:*** Will validate coupled fluid structure interaction models for dynamic contact angle for molten particulates in hot turbine components; assess emissivity characteristics of oxide/oxide ceramic matrix composites for engine applications; characterize thermo-mechanical behavior of ultra-high temperature composites. ***FY 2023 Plans:***	1.225	1.332	1.633

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA6 / *Robotics and Mobile Energy*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Will perform experiments on smart materials that serve to articulate thin airfoils (e.g., turbine blades) to enable engines that operate efficiently at different speeds; explore discontinuous ultra-high temperature ceramic (UHTC) fibers to fabricate ceramic matrix composites for future hot engine components; develop high fidelity models to study interactions between gas turbine engine combustor and turbine sections. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Novel multi-fuel tolerant small vehicle power ***Description:*** Basic research to enable highly efficient, multi-fuel conversion in small engines with reduced sensitivity to fuel property variation and extreme ambient conditions. This includes research to characterize and investigate extreme fuel properties on ignition chemistry, variable spark enabling concepts for robust ignition, and lightweight highly durable materials for reduced heat loss and wear characteristics. ***FY 2022 Plans:*** Will expand aviation fuel models for robust engine control to include gasoline and other highly volatile fuels; determine fuel property sensing method to differentiate fuel ignition quality; explore ignition behavior at cost start and altitude relight conditions in small gas turbine engine; investigate industrial processing conditions and alloying additions on microstructural evolution of advanced aluminum alloys for high thermomechanical applications; will produce and record lab scale mechanical properties of aluminum alloys with varying microstructures and at varying temperatures; will determine microstructural changes in novel tribological materials that lead to scuffing and coating delamination failures in fuel-lubricated mechanical interfaces in simple and complex geometries. ***FY 2023 Plans:*** Will demonstrate aviation fuel ignition models at both high fidelity for combustion simulation and reduced order for engine control applications; investigate altitude ignition behavior for novel small combustor geometries; assess initial concepts for on platform fuel sensors; investigate production methods of advanced aluminum alloys in initial aviation engine combustion components; assess tailored materials and coatings for damage resistant fuel-lubricated mechanical interfaces with low lubricity fuels. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	3.696	3.203	3.177
Title: Fundamentals for Alternative Energy ***Description:*** Explore novel concepts in energy generation and capture in technologies for efficient conversion of ambient energy to electrical energy for use and storage. Design novel structures to include microscale power devices for multimodal harvesting and efficient distributed power conversion. Focus areas include: energy storage and release from atomic nuclei, new electrochemical materials and processes for energy storage and conversion, and new approaches for solar energy harvesting.	1.235	0.888	0.991

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
FY 2022 Plans: Will study isomer energy release utilizing nuclear excitation by electron capture or other processes, with the goal of testing a non-implantation approach to an isomer power source; will study charge and energy transfer pathways of light absorbing and catalytic electrochemical systems for energy storage chemical reactions using ultrafast spectroscopy and electrochemical characterization. ***FY 2023 Plans:*** Will study electrocatalytic and thermocatalytic processes for chemical energy storage at the interfaces of liquid media, nanocatalysts, and visible/infrared absorbing nanoparticles using electrochemical and spectroscopic characterization methods; study the energy dependences of nuclear excitation by electron capture or other processes for on-demand isomer energy release; investigate isomer production approaches; design a proof-of-concept experiment for an isomer power source. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Materials, Structures, and Analytics for Enduring Platform Operations ***Description:*** Basic research to establish fundamental understanding in structural damage tracking methods, novel material/structures, and prognostic and diagnostic techniques to improve vehicle performance and capability. This includes the advancement of machine learning algorithms for deep learning, and the exploration of novel lightweight, durable, self-sensing structures for improved maneuver and reduced maintenance.	1.538	-	-
Title: Reconfigurable Platform Mechanics and Propulsion ***Description:*** Basic research in reconfigurable platform mechanics and propulsion science to investigate technologies to enable subsystem configuration concepts for efficient hover and high-speed/range Vertical Take-Off and Landing (VTOL) aircraft. ***FY 2022 Plans:*** Will investigate reconfigurable platform mechanics (materials, structures, actuators, aeromechanics) and technologies to enable subsystem configuration concepts (mechanical, electrical, power, and information interfaces) for efficient high-speed, range, and payload VTOL aircraft; will explore interdisciplinary materials research to inform on the viability of engineering materials at the molecular level to achieve highly reconfigurable, mechanically relevant structures; will develop a sizing methodology and performance models for the assessment of advanced unmanned aerial system (UAS) concepts with adaptive structures. ***FY 2023 Plans:*** Will explore optimization algorithms for vehicle reconfiguration and employ machine learning/molecular modeling approach to conceptualize new shape reprogrammable structures by introducing new bio-inspired functionalities for UAS platforms; explore the design space enabled by reconfiguration technologies; develop mathematical models of aeromechanics and flight control of	0.999	0.937	1.046

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA6 / *Robotics and Mobile Energy*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
morphing aircraft platform subsystems and incorporate them in the conceptual design framework to achieve extreme performance and agility attributes. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Robotics Autonomy and Human Robotic Interface Research ***Description:*** Basic research focused on enabling robust autonomous mobility for small and human-scale robotic systems, including autonomous teaming behavior with hybrid human-robotic teams. Enablers for robust autonomous mobility include planning, behaviors, energy efficient maneuver, and the interface of manipulation technologies to support manned-unmanned teaming constructs. ***FY 2022 Plans:*** Will investigate novel methods for energy prediction and energy awareness for heterogeneous unmanned systems; develop algorithms that enable autonomous power distribution between ground and air vehicles for sustained increase in operational duration; investigate optimized vehicle route planning among robot teams under constraints of energy availability and mission demands; develop methods for alternative energy in the form of heat engines for power distribution among robotic teams. ***FY 2023 Plans:*** Will identify characteristics and continue to develop algorithms that enable autonomous energy distribution between ground and air vehicles for sustained increase in operational duration; create algorithms for optimized vehicle route planning for robot teams which factor energy availability and mission constraints; explore alternative power generation methods that will extend autonomous vehicle endurance in logistically uncertain and contested environments. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.513	1.559	1.844
Title: Intelligent Systems ***Description:*** Pursue research in autonomous systems that supports and unburdens Soldiers in a flexible, robust, survivable, and comprehensive manner. This work addresses the cognitive requirements of humans and (non-human) agents, both hardware and software based, operating individually or in collaboration, on the battlefield. Emphasis is placed on perception, reasoning, and collaboration techniques that can apply to and transfer between a broad range of systems (i.e., adaptive communication and data collection networks; crowd-sourcing and information retrieval software agents; and predictive and explanatory decision support systems). ***FY 2022 Plans:***	5.884	5.888	6.443

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Will conduct fundamental research on navigation algorithms capable of assessing route options using limited resources while assessing multiple courses of action over long planning horizons; develop algorithms that allow automated tuning of low level control parameters with limited human feedback; will extend shared representations techniques to enable planning across multiple platforms. ***FY 2023 Plans:*** Will explore navigation techniques capable of assessing route options in partially known environments, and adapting based on limited human examples; create algorithms that allow for rapid adaptation to incomplete or unexpected semantic observations in the environment; extend autonomous vehicle endurance through fundamental research in navigation algorithms which utilize all available resources for route planning while assessing multiple courses of action to enable longer planning horizons; validate algorithms that manage automated tuning of low level control parameters from limited human feedback; create algorithms that intelligently share representations and distributed context to enable planning across multiple vehicles. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflect planned lifecycle of this effort.			
Title: Structurally-Adaptive Unmanned Air Systems Research ***Description:*** Basic research focused on topics that contribute to the body of knowledge required to create future intelligent, unmanned air systems that can effectively team with manned and unmanned aircraft, ground platforms, and human teammates. Emphasis is placed on topics of control and aeromechanics that expand the operational envelope for unmanned systems and enable maneuverability in complex, interactive, and mission relevant environments. ***FY 2022 Plans:*** Will combine aeromechanics models, artificial intelligence/machine learning, and classical mechanics to achieve embodied intelligence to creatively machine design platforms to enhance the performance and resilience of advanced air vehicle structures; develop computationally efficient methods and functional models of aerodynamic interactions for near real-time flight dynamics in virtual environments; acquire wind tunnel and experimental flight data on multi-rotor configurations to enable analytical and computational models for vehicle design methods, explore novel active flow control technologies and measurement methodologies, and assess novel numerical techniques; develop approaches for on-board sensing of airflow and vehicle orientation for automated flight transitions. ***FY 2023 Plans:*** Will investigate novel active materials and structural design concepts to enable transformational capabilities within congested environments for advanced UAS platforms; explore evolutionary algorithms for design of autonomous platforms exhibiting reflexive agility and embodied intelligence to enhance mobility in terrain/environments, including control systems approaches and implications of air vehicle structures; validate computationally efficient methods and functional models of aerodynamic interactions for near real-time flight dynamics in virtual environments; explore the effects of unsteady environments that includes gusts,	2.997	2.883	3.199

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
turbulence, and vehicle wakes, by performing basic research in a wind tunnel facility to identify active and passive control designs as well as novel maneuvers; create new computational modeling methods, active flow controls, and passive vehicle structural designs to mitigate negative impacts of unsteady fight conditions through wind tunnel experiments; pioneer new concepts for small UAS that include reconfigurable and resilient structures, super maneuverability, and extreme endurance. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Air Mobility ***Description:*** Create robust experimental and computational approaches for understanding, modeling, and predicting the complex fluid flow and aerodynamics of next generation rotorcraft concepts. This research includes innovative numerical methods for capturing the details of steady state and non-steady state aerodynamics and acoustics occurring with multi-rotor, rotor-propeller, and rotor hub configurations; and associated experimental techniques needed to verify modeling results. ***FY 2022 Plans:*** Will conduct computational aerodynamics and structural dynamics research aimed to develop novel numerical methods to solve rotary-wing aeromechanics problems including hover and high-speed forward flight; continue to conduct experimental and computational investigations in order to identify, explain, and predict the interactional aerodynamics of multi-rotor configurations by developing pioneering flow measurement techniques and novel numerical algorithms/methods. ***FY 2023 Plans:*** Will conduct high-fidelity computational simulations of detailed rotor wake structure to understand and quantify the vertical instabilities manifest as worm-like flow structures seen in high fidelity experimental measurements; explore reduced order models and machine learning algorithms to study interactional aerodynamics effects over a wide design space. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	2.504	2.460	2.731
Title: Advanced Mathematical Algorithms for Improved Vehicle Efficiency ***Description:*** Research in support of advanced military mobility technologies with emphasis on Terramechanics (vehicle-terrain interaction), and complex vehicle dynamics and simulation. This includes developing the data and underlying models to simulate and predict autonomous vehicle mobility in soft soil and complex organic terrain under a variety of environments. Research is directed at understanding advanced mathematical and computational methodologies using state-of-the-art analytical and empirical procedures. ***FY 2022 Plans:***	0.762	0.707	0.790

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA6 / *Robotics and Mobile Energy*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Will expand investigative research into quantum computing approaches for computationally expensive multi-scale algorithms for modeling a military ground vehicle interaction with terrain / soft soil; research assured mobility with cyber implications; research gaming engine algorithms for autonomous vehicle off-road mobility; conduct explorative research in intelligent autonomous mobility technologies integrating minimal sensor configurations; research deep learning based terrain identification; research and develop robust path planning and control, all on-board and in real time; continue researching the application of deep learning algorithms for generating Go/NoGo maps to other geographic regions. ***FY 2023 Plans:*** Will continue investigative research into quantum computing approaches for computationally expensive multi-scale algorithms for modeling a military ground vehicle interaction with terrain / soft soil; expand research gaming engine algorithms for autonomous vehicle off-road mobility; continue researching the application of deep learning algorithms for generating Go/NoGo maps to other geographic regions; investigate off-road intelligent autonomy for multi-scale vehicle fleets, including fleet energy management; investigative research into energy and power density for highly mobile systems, including reconfigurable in the context of energy routing to endure under potential damage. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: FY2022 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	0.759	-
Accomplishments/Planned Programs Subtotals	22.353	20.616	21.854

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		**Date:** April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA7 / *Mechanics and Ballistics*

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
AA7: *Mechanics and Ballistics*	-	35.368	33.331	35.234	-	35.234	35.760	36.184	36.195	36.186	0.000	248.258

A. Mission Description and Budget Item Justification

This Project conducts basic research in materials and ballistic science to create higher performing, lighter weight, lower cost materials and processes, discover new ways to store and release chemical energy from novel energetic materials, explore fundamental chemistry and physics controlling the launch and flight of gun-launched projectiles and missiles, and understand the interaction of these weapons with armored targets, including the high deformation rate behavior of materials and the mechanics of threat impact and penetration of armored targets. Research involves the study of new experimental capabilities to measure, characterize, and visualize complex phenomena with high temporal and spatial resolutions as well as the development of state-of-the-art computational models that provide predictive capabilities based on at-scale and cross-scale numerical frameworks that capture the relevant physical phenomena. Research in atmospheric science seeks an in-depth understanding of the complex atmospheric boundary layer associated with high-resolution meteorology, the transport, dispersion, optical properties, and characterization of chemical and biological aerosols, the propagation of full-spectrum electro-magnetic and acoustic energy and physics-based multi-scale models for electronic, optical, mechanical, and chemical materials. Efforts seek to explore methodologies and computational capabilities for the quantification of uncertainty in predictive modeling enabling risk-informed decision analysis multi-scale material models and environmental impacts on complex Army systems (manned and unmanned). This research also conducts research in chemistry and physics controlling ballistic propulsion and launch; creating aerodynamic forces on flight bodies to permit radical maneuver at high speeds, and high altitude glide and flight maneuver for increased range of gun launched projectiles. This research results in knowledge products that lead to new materials for armor and armaments, disruptive explosives and propellants, more accurate and non-lethal (NL)/lethal projectiles and missiles, omnisonic maneuver of projectiles, and advanced armors for increased survivability of Army combat systems. This research also funds efforts in the characterization of chemical and biochemical phenomena occurring at or near solid surfaces and interfaces; the interactions between chemical reactions and transport processes on surfaces; theory and modeling of processes at complex surfaces; and the synthesis and characterization of catalysts that function at the nanoscale. Investment in basic research centered on the surface science disciplines will enable growth of a knowledge base that will result in improved understanding of the interactions of complex materials in real world environments.

Work in this Project supports key Army needs and provides the technical underpinnings for several PEs to include PE 0602145A (Next Generation Combat Vehicle Technology); PE 0602146A (Networks C3I Technology); PE 0602147A (Long Range Precision Fires Technology); PE 0602141A (Lethality Technology), and PE 0602143A (Soldier Lethality Technology).

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas and the Army Modernization Strategy.

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2021**	**FY 2022**	**FY 2023**
Title: Protection Sciences ***Description:*** This effort seeks to improve fundamental knowledge of mechanisms that can be exploited to ensure the next generation of lightweight and efficient armor technologies. Provides physics-based discovery of novel Soldier protection	5.000	5.193	5.574

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
mechanisms through increased understanding of wave propagation through tissue, and the resulting deformation and damage of tissue during ballistic and blast events. ***FY 2022 Plans:*** Will initiate micro-mechanical dynamic response experiments on heterogeneous ceramics and MAX phase material; conduct transverse indentation studies to establish the response of Tensylon to impact loading relevant to ballistic environments and use meso-scale validated computational models to obtain the evolution of the stress-state; perform macroscale fracture studies at quasi-static and dynamic strain rates using in-situ x-ray imaging and diffraction techniques to improve computational failure models; investigate a stable and accurate finite element model for ballistic impacts to the human thorax in order to improve personal protective equipment. ***FY 2023 Plans:*** Will develop computational toolsets and experimental techniques that provide core insight into fracture and failure of ceramics and dynamic response of multi material systems; improve understanding along the continuum of armor material response from current near-skin protection to those that may be decoupled from the human body; develop multi-scale modeling and simulations and conduct experiments to optimize performance leading to improved V50 penetration velocity metric in monolithic ceramic material with a goal of 25% predicted improvement in V50 over commercial monolithic ceramic materials; fabricate engineered multi-phase ceramic with structure and properties to provide optimum control and granular flow during a ballistic event. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Microscopic/Nanostructural Materials ***Description:*** This effort explores new materials and creates new computational capabilities based upon fundamental concepts derived from studies of structure, process, and property relationships at the microscopic and nanostructural levels. Research includes synthesis, processing, characterization, and modeling of novel metal alloys and armor ceramics, including control and manipulation of nanostructural features, grain boundaries, texture, and other nano-to-microscale structure. ***FY 2022 Plans:*** Will investigate the quasi-static and high-rate properties of nanostructured materials (iron-based and copper-based) determined to be important to the behavior needed in vehicle armor and lethality applications; investigate novel particulate consolidation methods that preserve the nanostructure at elevated processing temperatures and provide the unique properties needed to be successful; provide a correlation of the processing parameters to the properties observed; continued the development of high diamond content composite ceramic materials to include large enough specimens for sub-scale ballistic assessments for high-rate and resultant microstructural characterization. ***FY 2023 Plans:***	3.245	3.183	3.506

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA7 / *Mechanics and Ballistics*

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2021**	**FY 2022**	**FY 2023**
Will investigate active, tunable materials with high stiffness that can act over short time scales with minimal energy requirements for an integrated approach to Army structural, protection, and lethality applications; develop materials that focus on leveraging mesoscale material architecture modifications to intensify response mechanisms without sacrificing mechanical properties of the material. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: High Deformation Rate Materials ***Description:*** This research addresses Army-unique issues in fundamental materials research involving the performance of advanced materials at high deformation rates for applications including armor and armaments. Fundamental understanding is developed to enable design, processing, and characterization of materials specifically intended for high loading-rate applications, including improved physics based models, methods to characterize materials microstructure, interfaces, and defects and their role on materials response, and the determination of rate-dependent constitutive and failure/fracture behavior of materials. ***FY 2022 Plans:*** Will integrate metals, ceramics, and polymers with unique high rate behaviors into prototype composite armor and composite weapon systems/sub-systems and investigate the influence on the composite response to extreme mechanical loading. ***FY 2023 Plans:*** Will perform modeling and simulation of prescribed, simplified defect structures within metals, ceramics, and polymers, and correlate these results with measured properties from characterization efforts, laying the foundation for future predictive tools; investigate assessment methods that allow for rapid analysis of dominant failure modes and deformation mechanisms in specimens under high rate, high temperature conditions. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	3.386	3.283	3.615
Title: Materiel Research and Processing Using High Energy Fields ***Description:*** Explore interactions between materials and intense energy fields (e.g., magnetic, electric, pressure, etc.) to discover new pathways and mechanisms for controlling and altering material structure, enabling the development of new materials with unique property combinations and abilities to respond adaptively to battlefield conditions. ***FY 2022 Plans:*** Will identify alloy compositions which maximize response under a magnetic field for additive manufacturing alloy design and determine appropriate processing conditions which improve printability and carburization in aluminum and steel systems respectively through the application of descriptive models that incorporate magnetic field based diffusion mechanisms;	2.478	2.395	2.642

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
optimize processing methodology to produce samples large enough to conduct ballistic testing to assess if new material meets performance requirements. ***FY 2023 Plans:*** Will develop a theoretical framework to define the relationship between applied magnetic fields and diffusion mechanisms in alloy compositions; perform ballistic assessment of lightweight armor materials, developed utilizing novel synthesis techniques, for increased Soldier protection and mobility. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: One Dimensional (1D) and Two Dimensional (2D) Materials and Processing Research ***Description:*** Discover novel building block materials that provide disruptive protection mechanisms. Research includes synthesis, processing, characterization, and modeling to discover new 1D and 2D building block materials and associated assembly into protective membranes, smart fibers and films, and other molecular composite architectures. ***FY 2022 Plans:*** Will explore expanding the palette of available 2D polymer chemistries to tune properties for a range of applications, guided in part by artificial intelligence and machine learning (AI/ML) design methodologies; identify processing science advances to enhance the quality, properties, and scalability of 2D polymer films. ***FY 2023 Plans:*** Will develop unifying theory of 2D polymer failure at the molecular level and integrate into multiscale finite element models; implement AI/ML into multiscale models to predict mechanical properties and benchmark with experiments; develop optimal functional groups within 2D polymers for enhanced toughness, stiffness, and strength. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.690	1.601	1.779
Title: Bio-enabled Precision Materials Synthesis and Assembly ***Description:*** Explore new biology-based methods for controlled synthesis and assembly to create materials with precise chemistries, microstructures, properties, and responsive functionalities through controlled molecular placement, spatial architectures, and interfacial structures. This research utilizes biological platforms that can act as micro-environments to control local thermodynamics and kinetics to govern reactions and molecular assembly, thereby providing completely new pathways for materials discovery. ***FY 2022 Plans:***	1.815	1.743	1.913

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Will down-select candidate materials, biopolymers, and composites and study functional behavior after scalable integration and processing; tune biopolymer properties for improvements to control meso-scale assembly and identify structure/function and/or sequence-defined function properties; investigate compatibility of biological materials and organisms and material scaffolds and uncover mechanisms for controlling precision placement and integration of biological and composite material behavior. ***FY 2023 Plans:*** Will continue to identify compatible organisms and material scaffolds for precision placement and integration of biological and composite behavior; investigate and tune precision placement of compatible organisms and material scaffolds for improved meso-scale assembly; improve material, biopolymer, and composite properties for sequence-defined function properties during scalable integration and processing; create predictive models of biopolymer meso-scale assembly for rational design of material scaffolds based on structure-function properties and sequence defined assembly. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Launch and Flight of Gun Launched Projectiles as well as Missiles ***Description:*** Improve the fundamental understanding of the mechanisms controlling the launch and flight of gun-launched projectiles and missiles, and understand the interaction of these weapons with armored targets. ***FY 2022 Plans:*** Will perform studies to examine the aero-thermodynamics of Army-relevant shapes flying at hypersonic speeds and compare computational predictions, wind tunnel measurements, and ballistic free-flight experiments; extend theories of multi-agent perception and control for constrained, high-speed aerial systems. ***FY 2023 Plans:*** Will investigate shock-boundary layer interactions and boundary layer stability/transition for canonical problems; establish feasibility of coupled discipline computational toolset; obtain experimental validation of aero-thermodynamics in sub-scale high-speed ballistic range facility; develop high uncertainty tolerant flight control algorithms for weapons; formulate data-driven multi-agent/sensor estimation algorithms for collaborative delivery; explore emergent behaviors for offensive strike using artificial intelligence and machine learning algorithms. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	3.192	3.094	3.407
Title: Energetic Materials Research ***Description:*** Expand and confirm physics based models and validation techniques to enable design of novel insensitive propellants and explosives with tailored energy release for revolutionary future force survivability and weapons effectiveness.	3.648	3.486	3.838

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
FY 2022 Plans: Will synthesize, characterize, and explore novel high energy density nanometals and extended solids, building off of FY21 successes; transition grain scale dynamic modeling techniques and solid state kinetics methodologies developed in FY21 to large scale efforts for verification and validation; develop fundamental models to aide in the design of newly developed propulsion concepts. ***FY 2023 Plans:*** Will explore and synthesize novel strained ring materials, extended solids, and core-shell nanometals for use in explosive and propulsion applications; explore mesoscale-continuum scale model coupling as well modeling and validation of novel rocket propulsion concepts for eventual transition to long-range fires. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Theory in Atmospheric Characterization, Sensing, and Modeling ***Description:*** New algorithms and methods are developed to account for a variety of complex-terrain physical processes in microscale models. Novel instrumentation and observational methods are developed to advance the understanding of physical processes in the atmosphere. Employ optical techniques to advance detection methods for chemical/biological agents mixed in with atmospheric constituents. Data from high-resolution instrumentation arrays are used to advance and verify evolving atmospheric characterization theory focused on complex terrain and dense urban areas. ***FY 2022 Plans:*** Will apply machine learning techniques to the Dense Urban Area Meteorological Sensor Array (MSA) data to identify previously unknown complex terrain and climatic processes building from research on complex land surface energy budget, water cycle processes, and radiative transfer processes using data collected at the MSA testbed; explore both short timeframe and longer timeframe environmental processes in urban domains; identify additional sensing modalities that could be integrated onto an unmanned aerial system (UAS) platform to facilitate environmental awareness essential for autonomous flight; continue research to quantify thermal and momentum flux of sloping surfaces under stratification to better treat physical processes in complex and urban terrain; study the application of lattice-Boltzmann methods to simulate radiative transfer in the urban environment; explore and devise new/improved methods to characterize and assess the impact of atmospheric environment on aerosols; explore methods of heterogeneous sensing modalities to both characterize the environment and assess the impact of the environment on electro-optic, radio frequency (RF), and acoustic signals. ***FY 2023 Plans:*** Will conduct field experiments of environmental effects on acoustic and electromagnetic signal propagation in urban environments; validate machine-learning methods to enable multi-modal sensor adaptability and optimal data fusion; explore	3.900	4.007	4.411

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
new formulations of thermal forcing in lattice-Boltzmann-based fluid dynamics models; explore algorithms to better simulate warm microphysics processes; study and validate methods to provide bulk characterization of atmospheric quantities such as turbulence, aerosol concentration, and thermal profiles based on non-traditional, limited atmospheric observations; explore methods to connect microscopic scattering processes with detection and bulk impact of aerosols on radiative transfer; investigate impacts of atmospheric and boundary-layer processes on electromagnetic/radio frequency propagation; study aerosol transport due to terrain-related variability in the boundary-layer momentum and heat fluxes and the evolution of transient and recurring flow instabilities on aerosol concentrations and transport; conduct experiments on promising methods for optical detection of biological materials. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Multiscale Modeling for Novel Materials ***Description:*** Explore and develop multi-scale modeling techniques to support fundamental studies of electronic and structural material properties from the atomistic to the continuum. Resulting models will be used to design and develop materials for more efficient, longer lifetime sensors and power and energy devices, and lighter materials for vehicle and soldier protection. This effort includes coupled research with two 5-year Collaborative Research Alliances (CRAs): the Materials in Extreme Dynamic Environments CRA and the Multi-scale/Multidisciplinary Modeling of Electronic Materials CRA. These CRAs are funded under PE 0601104A (University and Industry Research Centers) / Project AB7 (Army Collaborative Research and Tech Alliances).	3.546	-	-
Title: Environmental Quality ***Description:*** This effort conducts research on innovative environmentally-friendly technologies that support the warfighter focusing on pollution prevention technologies. ***FY 2022 Plans:*** Will conduct innovative basic research in the systematic study of new innovative environmentally friendly energetics through the study of fundamental aspects of compounds and precursors and bench scale synthesis including experimental research; conduct modeling and simulation of various compounds and the study of alternative solvents and processes to reduce the hazards associated with the manufacturing of energetics; research new green coatings through the study of various shaped and sized nanoparticles to replace hazardous chemicals for a variety of armament and energetic materials, enhancing coloration while reducing toxicity; conduct research on innovative methods to replace toxic chemicals in the coating of metals for corrosion inhibition. ***FY 2023 Plans:*** Will conduct research on environmental issues associated with the exploration of current and future energetic development to include: fundamental aspects of compounds, solvents, precursors, and bench scale synthesis; conduct research in the	1.107	1.068	1.186

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
replacement of hazardous solvents and alternative methods to process chemicals for energetics to reduce environmental, safety, and occupational health (ESOH) issues. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Surface Science Research ***Description:*** The activities in this program are related to performing basic research in chemistry, biology, and physics on fundamental problems related to surfaces, interfacial dynamics, thin film materials, chemical-biological catalysis, and opto-electronic/sensory technologies. ***FY 2022 Plans:*** Will conduct research and studies focused on chemical and biological interactions on solid surfaces including interfaces between materials and the surface. Areas of interest include transport, deposition, reactivity, and removal of biological and chemical compounds of interest, material interactions and properties arising from physical or biological synthetic processes, and enabling models and theory of interfacial interactions or processes that may relate to bulk properties. ***FY 2023 Plans:*** Will conduct basic research related to fundamental studies, predictive modeling, for advanced materials processes as it relates to chemical-biological materials and sensors. Research will focus on expanding the body of knowledge related to processing parameters, structure property relationships, surface interactions and performance of materials and sensors with respect to chemical/biological exposure, decontamination, aging and use in extreme temperatures; explore the utilization of novel manufacturing processes such as 3-dimensional bio-printing, integrated heterogeneous materials (i.e. Metal-Organic Frameworks) and in-situ polymerization and/or component integration during processing; advance fundamental scientific understanding of particle dispersion for novel utilization of next generation obscurants with novel pyrotechnics in areas such as disrupting command, control, and communications; investigate advanced/multispectral obscurant payload or concealment/camouflage/deception/false targets resulting in overall signature management or sensor defeat. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	2.361	2.297	2.533
Title: Terminal Ballistic Design and Evaluation for Next Generation Materials ***Description:*** Research will focus on novel terminal ballistic designs utilizing engineered materials to provide lightweight protection and low-energy penetrator solutions for combat-relevant threats. Specific architecture materials will be identified and utilized based on high-throughput material synthesis and characterization, and data-driven physics based modeling approaches. ***FY 2022 Plans:***	-	0.764	0.830

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Will develop analysis methods for penetration mechanics of non-homogeneous materials for Army applications; develop a canonical experiment approach to relate lab-scale material properties to ballistic response. ***FY 2023 Plans:*** Will combine computational modeling and automated processes to assist in the design and assessment of alloys as structural materials for use in armor and weapon systems applications. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: FY2022 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	1.217	-
Accomplishments/Planned Programs Subtotals	35.368	33.331	35.234

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 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
AA8: *Sensing and Electromagnetics*	-	9.006	13.589	13.619	-	13.619	13.499	14.160	14.840	14.940	0.000	93.653

A. Mission Description and Budget Item Justification

This Project conducts basic research on semiconductor materials, layered structures, and novel devices for optical sources, detectors, integrated optoelectronic circuits, and energy generation and storage devices. Efforts include multiscale modeling, material and structure growth and characterization, and novel device design and fabrication. The research has application to Soldier power, sensors, lower power communications, quantum networks; unattended sensor networks, including distributed sensor fusion; ground vehicle sensors and auxiliary power systems; alternative position, navigation, and timing (PNT) systems for Global Positioning System (GPS)-denied environments; and sensors and power for small unattended ground and air vehicles.

Work in this Project is performed by the United States (U.S.) Army Futures Command (AFC).

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas and the Army Modernization Strategy.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Photonic Materials and Device Research ***Description:*** Conduct research into novel material and device structures operable throughout the electromagnetic spectrum from long wave infrared (LWIR) to ultraviolet (UV) including sources, detectors, and integrated photonic devices to increase situational awareness in open and complex terrains; allow assured communication, improved target detection, identification, and discrimination; and create new device functionalities while reducing size, weight, and power requirements.	0.999	-	-
Title: Advanced Materials Research ***Description:*** This effort conducts research in modeling, fabrication, and characterization of semiconductor materials and structures that leads to revolutionary device functionality in sensing, low power electronics, quantum networks, and power generation. This effort investigates novel complex crystal structures that can lead to devices with performance beyond normal semiconductor transistors, including neuromorphic computing structures and topological insulator based heterostructure with low operating voltage. ***FY 2022 Plans:*** Will optimize topological insulator materials for use in topological enhanced devices for atta joule computing at the edge; develop methodologies and algorithms to demonstrate basic arithmetic operations based on specialized arrays needed for realizing	2.699	3.333	1.558

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
neuromorphic computing; study the electrical properties of silicon terminated diamond surfaces with the objective of operative transfer doping at higher temperatures. ***FY 2023 Plans:*** Will investigate fundamental properties of acoustic, seismic, electric field, magnetic, gravimetric, passive radar, and integrated photonic analogs of macro-scale non-traditional sensor systems (e.g. laser vibrometry) to determine cross-correlative properties as a function of sensing vantage and range; research multi-modal and distributed sensing for detection confidence, clutter rejection, range enhancement, and Signal-to-Noise Ratio (SNR) improvement; investigate distributed sensor processing architectures for single and multi-agent state estimation, leveraging the ability to process sensor data locally with limited computational processing and distribute the processed data over an austere and intermittent network to achieve high confidence detection. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding decreased in Fiscal Year 2023 (FY23) to support the creation of the ?Foundational Sensing? task within this Program Element (PE) / Project.			
Title: Distributed Sensor Research ***Description:*** This effort creates more survivable and secure sensors and displays, investigates new acoustic, seismic, magnetic- and electric-field sensor technologies for personnel, activity, vehicle, and weapon-fire, and develops means to correlate, fuse, and interpret data from diverse sensors. This effort investigates novel algorithms and electromagnetic models to better understand radio frequency (RF) propagation and exploitation in complex clutter environments for improved RF and radar sensing. ***FY 2022 Plans:*** Will investigate novel RF sensing modes for tactical Army applications; investigate and develop algorithms to enable the coherent integration of synthetic aperture radar (SAR) data across an aperture generated by sensor platform forward motion; research and develop low complexity signal processing for RF sensors detecting and tracking personnel in complex multi-path backgrounds; investigate cross-modality geophysical interactions and coupling between three-dimensional low-frequency electromagnetic fields, acoustic particle velocity, and torsional seismic waves. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding decreased in FY23 to support the creation of the ?Foundational Sensing? and ?Foundational Distributed Radar? tasks within this PE / Project.	1.716	1.676	-
Title: Materials Science for Army Power and Communications ***Description:*** This research includes modeling of advanced battery materials and structures, and modeling of electromagnetic fields interacting with catalytic materials. High bandgap materials including silicon carbide and gallium nitride with modified composition will be used to fabricate diodes for improved performance as optical communication sources, sensors, and high	1.664	1.132	1.268

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
power components. Materials, designs, and fabrication techniques will be studied for the future development of Micro-Electro-Mechanical Systems (MEMS) for RF)devices and sensors. ***FY 2022 Plans:*** Will validate previously developed models of impact ionization effects through experimental studies on appropriate structures; investigate how leakage currents are effected by lateral versus vertical structures; investigate interfacial interactions of adsorbed chemical species and excited states in plasmonic, electrocatalytic, and photoelectrocatalytic systems; identify causes of high leakage currents in wide band gap, silicon carbide (SiC) diode structures. ***FY 2023 Plans:*** Will examine impact of planar versus vertical architectures on leakage currents in SiC diode structures under high electric (E)-fields; validate interfacial interactions of adsorbed chemical species and excited states; investigate novel materials and structures enabling low-size, weight, and power (SWaP) optical communication and time transfer and investigate material systems for chip-scale lasers for next-generation clocks and sensors; study the nature of how adsorbed species impact charge and thermal energy transfer across interfacial boundaries between photocatalytic substrates and reaction media and investigate how to modulate the thermal envelope around a plasmonic nano-heating reactor to control reaction rate dynamics when illuminated; study molecular and atomistic processes at interface in aqueous and multivalent battery systems and investigate ionic, electronic, and water transport at these interfaces to suggest model-based strategies to promote stable, high rate interfaces with enhanced cycle stability. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Fundamentals for Precision Measurement for Contested Environments ***Description:*** This effort explores new materials, novel device architectures, and unique processing techniques to successfully maintain communication and information sharing protocols in GPS-denied, actively jammed, or austere environments. ***FY 2022 Plans:*** Will investigate the optical properties and its environmental dependence of the permittivity near zero metamaterial based air-ring resonator; develop a new tuning method for the soliton based micro-optical-frequency-comb and explore the locking mechanism to lock the optical frequency comb to the environmental-insensitive resonator for long-term stability. ***FY 2023 Plans:***	0.709	0.701	0.777

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Will investigate epsilon-near-zero resonator bidirectional coupling mechanisms with purpose-built waveguides for advanced testing and future coupling to optical frequency comb micro-resonators; experimentally explore use of new locking mechanism of optical frequency comb to epsilon-near-zero resonator. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Functional Materials ***Description:*** This effort supports basic research in polymer science and textile technology, nano and biotechnology, and multifunctional materials to achieve technologies that support the Soldier of the future through multi-functional materials with clothing/protective equipment functionality that also embody electronic functionality. ***FY 2022 Plans:*** Will explore fabrication and characterization of novel materials with unique compositions and structures that result in tunable optical and electromagnetic properties; study human physiological responses to blue light exposure to understand the impact on sleep attributes and alertness. Knowledge gained will support optimization of Soldier performance, as well as inform design and usage of visual displays, such as in integrated headborne systems. ***FY 2023 Plans:*** Will combine experimental and modeling approaches to investigate molecular structure, interactions, and dynamic behavior of mechanochromic liquid crystals incorporated within polymer matrices with varying mechanical properties. Results will support advances in smart materials that rapidly sense and respond to external stimuli for situational awareness and signature management applications; gain understanding of molecular-scale properties and dynamic deformation behavior of various polymer and composite materials to inform future development of material systems for improved Soldier protection. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.219	1.186	1.311
Title: High Energy Laser (HEL) Materials and Thermal Management ***Description:*** This effort investigates and matures novel laser gain materials and other laser components with advanced thermal, thermo-mechanical, and thermo-optical properties. This effort investigates new materials and methods for controlling thermal transients to reduce the size and weight of thermal management components while increasing the energy magazine of systems operating in burst modes. ***FY 2022 Plans:*** Will explore new classes of passive and active phase change materials and processing methods to improve transient thermal management; investigate methods to tune and characterize thermal properties such as thermal conductivity and specific energy	-	1.241	1.047

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
storage; investigate innovative techniques of reliable measurement of thermal resistivity for novel gain materials and innovative fiber designs; conduct laser experiments utilizing improved transient thermal management based on new active phase change materials; investigate thermal interfaces and thermal transport in phase change materials; explore controlled crystallization of all-glass, low nonlinearity fibers as well as thermo-optic tailoring of novel, low-nonlinearity glasses. ***FY 2023 Plans:*** Will investigate and assess the tenability of phase change thermal materials and study the thermal transfer characteristics of the materials and interfaces; conduct laser experiments using fibers with advanced glass compositions aimed at improving thermo-mechanical and thermo-optical properties for better power scaling. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Physics-Informed Machine Learning for Complex Phenomena ***Description:*** Existing machine-learning approaches are not guided by the laws governing physical systems and unable to provide predictions of a physical system response with quantifiable uncertainty. Research will explore and develop modeling techniques incorporating machine-learning approaches to support fundamental studies of physical systems. Resulting models will be used to design and develop novel physical systems, such as diamond for high power RF applications. ***FY 2022 Plans:*** Will investigate deficiencies of existing machine-learning approaches when applied to modeling of physical systems; validate the use of existing machine-learning techniques to construct models of physical systems; examine existing methods for incorporating physical constraints into machine-learning models of physical systems; conduct research into assimilation of multiple-fidelity data into machine-learning models of physical systems; explore techniques for uncertainty quantification of machine-learning models. ***FY 2023 Plans:*** Will explore methods to improve major deficiencies of existing machine-learning approaches when modeling physical systems; based on previous accuracy assessments, identify classes of physical systems on which to focus; examine the use of geometrical methods for incorporating physical constraints into machine-learning models of physical systems; validate most promising methods for assimilating of multiple-fidelity data into machine-learning models of physical systems; analyze existing techniques for uncertainty quantification of machine-learning models for efficacy. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	-	3.150	3.436
Title: Semiconductor Modeling for Advanced Electronics ***Description:*** 3D numerical modeling basic research activities are scattered and insular, not effectively leveraging the combined capabilities of Government, Academia, and Industry. The problems are diverse and complicated, and need a focused and	-	0.673	0.971

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) AA8 / *Sensing and Electromagnetics*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
multi-disciplinary approach to gain fundamental understanding. This effort will build an ecosystem for foundational modeling and research in semiconductor materials and devices that leverages the broad combined knowledge base from academia, industry, and government laboratories to develop new and advanced semiconductor materials and devices for sensors, emitters, neuromorphic, and topological device applications. ***FY 2022 Plans:*** Will investigate recombination mechanisms in Type-II Long Wave Infrared (LWIR) and Medium Wave Infrared (MWIR) strained layer superlattices (SLS) to develop understanding for improving transport and efficiency in these materials for sensing; investigate methodologies for mitigation strategies for optimal device design for sensing; investigate the interface properties between a topological insulator (TI) and a ferromagnetic and antiferromagnetic layers, which is needed for realizing low power switching electronic devices. ***FY 2023 Plans:*** Will apply new materials understanding to Type-II super lattice (T2SL) device structures in collaboration with industry/academia materials to study performance; transition higher order modeling code for high field electro-optical simulations in house for investigation, design, and optimization of avalanche photodiodes (APDs); predict transport and magnetic exchange characteristics of low power switching electronic devices comprised of TI and either ferromagnetic or antiferromagnetic layers. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** In FY 2023, funding increased to support additional research in transport and magnetic exchange characteristics.			
Title: Foundational Distributed Radar ***Description:*** This research seeks to investigate novel signal processing techniques to develop distributed, GPS-independent, autonomous capabilities. This effort investigates tools and techniques for modeling, simulations, and emulation of distributed RF sensors and effectors. This research investigates advanced materials-based antennas for low size, weight, power, and cost (SWaP-C), multi-function systems. ***FY 2023 Plans:*** Will investigate concepts for novel radar and multi-function RF signal processing in distributed and complex environments; explore modeling, simulation, and emulation techniques for phenomenology of complex distributed environments for phase synchronous and distributed operation; explore concepts for reconfigurable materials-based antennas and harmonically-operated array elements. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding realigned from the ?Distributed Sensor Research? task in this PE / Project to support the creation of this task in FY23.	-	-	1.231
Title: Foundational Sensing	-	-	2.020

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2021**	**FY 2022**	**FY 2023**
Description: This effort explores innovative methods to remotely sense and discriminate threat vehicle formations deep in the battlefield. This effort investigates novel mechanical wave sensing physics to enhance signal features in complex and high noise environments as well as investigates fundamental properties of E-field and Magnetic (H)- field signals in cluttered environments. ***FY 2023 Plans:*** Will investigate multi-component, reduced size, weight, and power (SWaP) acoustic, seismic, gravimetric, passive radar, and integrated photonic analogs of macro-scale non-traditional sensor systems (e.g. laser vibrometry) and sensing methods that are insensitive to decoys, obscurants, and jamming on ground or airborne platforms; validate sensor performance in tactical environments with improved wide-area modeling and simulation of sensor response and target signatures; research novel domain adaptive processing/learning algorithms for robust target tracking and implement distributed processing framework for single and multi-agent state estimation, leveraging the ability to process target data locally with limited computational processing and distribute the processing of data over an austere and intermittent network. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding realigned from the ?Advanced Materials Research? and ?Distributed Sensor Research? tasks in this PE / Project to support the creation of this task in FY23.			
Title: FY2022 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	0.497	-
Accomplishments/Planned Programs Subtotals	9.006	13.589	13.619

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		**Date:** April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA9 / *Information and Networking*

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
AA9: *Information and Networking*	-	40.376	40.435	42.839	-	42.839	43.480	43.875	43.889	43.877	0.000	298.771

A. Mission Description and Budget Item Justification

This Project supports basic research to enable intelligent and survivable command, control, communication, computing, and intelligence (C4I) systems for the future force. As the combat force structure decreases and operates in more dispersed formations, information systems must be more robust, intelligent, interoperable, and survivable if the Army is to retain both information and maneuver dominance. This research addresses the areas of information assurance, signal processing for wireless battlefield communications, information extraction from multi-modal data human-agent naturalistic communication, and intelligent systems for C4I. Research will focus on understanding and solving inherent vulnerabilities associated with using standardized protocols and commercial technologies while addressing survivability in a unique hostile military environment that includes highly mobile nodes and infrastructure, bandwidth-constrained communications at the edge, resource-constrained sensor networks, diverse networks with dynamic topologies, high-level multi-path interference and fading, jamming and multi-access interference, levels of noise in speech signals and document images, and information warfare threats. These C4I technologies must accommodate heterogeneous security infrastructures, multi-service and multi-national interoperability, and information exchange/security mechanisms between multiple levels of security. The intelligent systems for C4I research focuses on providing machine learning methods to overcome noisy, sparse, and heterogeneous data with artificial intelligence algorithms that can transfer learning from one domain to another. This foundational research will help identify highly relevant tactical events for mounted or dismounted commanders, leaders and Soldiers; improve the timeliness, quality, and effectiveness of actions; and speed the decision-making process of small teams operating in complex natural or urban terrain.

Work in this Project supports key Army needs and provides the theoretical underpinnings for PE 0602146A (Network C3I Technology), PE 0602143A (Soldier Lethality Technology), and PE 0602145A (Next Generation Combat Vehicle Technology).

Work in this Project is performed by the United States (U.S.) Army Futures Command (AFC).

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas and the Army Modernization Strategy.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Communications in Complex Dynamic Networks	5.475	5.128	5.655
Description: Perform research to provide communications capability for a fully-mobile, fully-communicating, and situationally-aware force operating in a highly dynamic, wireless, mobile networking environment populated by hundreds to thousands of networked nodes. This research includes techniques that enable predictions of performance and stability of large, complex communications networks. It takes into account the impact of Soldier information needs, modalities of access and use of communication networks in complex adversarial environments, high mobility, and adversarial effects such as jamming or cyber-attacks. Also to be considered are computational modeling approaches that capture dynamics of information that flows through the network and/or is stored within the network, and undergoes continual changes as new information arrives and other information ages or is refuted/superseded by newly arrived information.			

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
FY 2022 Plans: Will conduct research on network models that jointly characterize combinations of the environment, network topology, communication technology diversity, computational resources, and/or mission objectives; develop and analyze multi-layer network protocols for optimizing network performance given technological, objective diversity, operational, and environmental constraints; explore novel network emulation approaches to support the development of future networks featuring vast scale and complexity; conduct emulation and physical experiments that characterize the performance of novel networking control protocols for intelligent, adaptive, and/or distributed operation. ***FY 2023 Plans:*** Will explore techniques and experimentation capabilities that dynamically monitor and identify adaptations of network resources and distributed analytics configurations to account for dynamics in-network resource availability and environmental state; conduct simulation- and emulation-based experiments to characterize performance of emerging networking capabilities, including high-speed networking technologies, unconventional spectrum, and joint classical/quantum networking; conduct research into heterogeneous networks comprising diverse communications capabilities, focusing on identifying and analyzing intelligent protocols for adapting to complex, dynamic, and/or spatially varying mission requirements and environments by leveraging unique features of component network technologies. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Data to Knowledge to Support Decision Making (Information Mediation) ***Description:*** Research a laboratory-scale common information processing infrastructure, inclusive of cloud computing, for networking processes that aids the transformation of data into actionable intelligence to support decision-making under uncertainty. Perform research to utilize real-time, tactical, Soldier-centric information for improved decision-making and situational awareness. Perform research in support of rapidly enhancing long-duration, complex, dynamic decision-making capabilities of individual Warfighters and units through the integration of cognitive augmentation and course of action recommender technologies. ***FY 2022 Plans:*** Will investigate models and approaches to enable autonomous systems to transform information to facilitate increased comprehension, decreased ambiguity, and maintain effective op-tempo decision making and responsive situational awareness; explore human-in-the-loop and human-on-the-loop machine learning strategies for interoperability and rapid autonomous mediation of inter and cross-domain data from heterogeneous sources; investigate computational models, novel training corpora, and algorithms that enable automated computer systems to understand and interpret information content from multimedia data	5.221	4.063	4.486

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
and construct knowledge networks for concept recognition, explanation, and inferences for downstream analytics to support collaborative decision making. ***FY 2023 Plans:*** Will investigate theories and fundamental models for facilitating increased comprehension, decreased uncertainty, and maintaining effective op-tempo decision making and responsive situational awareness and understanding; research design methods of visualizations to characterize impact of information in the dynamic operating environment under conditions of time sensitive and dynamically changing information; investigate gaps related to human cognition and system interface in decision making on novel and emerging cross-reality visualization technologies; explore fundamental understanding of, and theories for, decision making phenomena in immersive environments and Joint, Coalition, and/or multi-domain data; investigate computational models, linguistic approaches, and rule-based algorithms for automated systems to detect, analyze, and interpret content from multimodal information sources and create methods and algorithms for knowledge networks for concept recognition, information foraging, semantic search, and advanced data analytics; explore theories for inferencing algorithms to derive context from multimodal, multisource information; investigate theoretical and computational models of causality, information uncertainty, and automated reasoning to recognize changing context, course of action recommendations, and ad hoc autonomous or collaborative decision making. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Information Protection in Mobile Dynamic Networks ***Description:*** Perform research on protecting information in highly mobile, wireless tactical environments, where networks must operate under severe bandwidth, energy, and processing constraints, and without reliance on centralized security services. ***FY 2022 Plans:*** Will advance the use of machine learning in cyber security, with minimal need for subject matter experts, to counter swift attacks in a constrained environment; pursue innovative intelligent countermeasures against adversarial machine learning attacks that reduces burden on the defender and increases the cost to the adversary; investigate techniques to predict adversary tactics, techniques, and procedures (TTPs) for proactive network defense and to support honeynet generation which is situation-aware and realistic enough to attract and mislead an intelligent adversary; using machine learning and computational game theory, develop modeling approaches with the following features: (a) prediction of frequency and occurrence of network attacks by type for effectively implementing adaptive honeynets and (b) analysis of impact of software defined networks (SDN) for mobile network architectures; study and analyze the performance alternative methods of entanglement creation and distribution to mitigate entanglement degradation; explore and characterize the performance of fundamental quantum networking elements such as switches and interfaces. ***FY 2023 Plans:***	4.742	4.887	5.395

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Will conduct experiments on the direct transmission of entangled quantum states through various networking elements, including fiber and free-space channels, switches, and frequency converters; explore and analyze methods for creating, manipulating, and measuring hyper- and multipartite-entangled states; investigate defenses to adversarial machine learning based attacks on network security systems; reduce/eliminate misclassification of malicious network traffic as legitimate; reduce/eliminate misclassification of legitimate network traffic as malicious traffic to cause false positives; develop techniques to improve model performance through adversarial retraining. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Naturalistic Behavior for Shared Understanding and Explanation with Intelligent Systems ***Description:*** Establishes formal methods for bridging language barriers in tactical environments, incorporating state-of-the-art techniques in machine translation and natural language processing.	1.226	-	-
Title: Advanced Computing Architectures and Algorithms ***Description:*** Investigate advanced computing and high performance computing (HPC) networking architectures, memory/ storage architectures, processing algorithms, and visualization techniques to support advanced battle command applications for Command, Control, Communications, Computers, and Intelligence (C4I) systems. ***FY 2022 Plans:*** Will study protocols and algorithms to enable sets of decentralized and distributed heterogeneous computing systems; research energy efficient algorithms for coordination and consensus; explore methodology and algorithms to enable information processing scaled across heterogeneous computing hardware; investigate both high performance processing capabilities, scalable to heterogeneous hardware platforms, and novel approaches to enable ingesting, extracting, translating, processing, and analyzing heterogeneous data. ***FY 2023 Plans:*** Will explore algorithms to discover and assess resource availability and capability in decentralized teams of agents; research optimized, constraints-based, resource allocation methodologies and algorithms for system of systems; analyze generalized algorithm reduction, compression, and scaling methodologies for size, weight, power and time constrained devices at the tactical edge; study emerging computing architectures designed specifically for neural network inferencing to determine best viable candidates; develop algorithms, benchmarks, and techniques to measure performance of a neural network on a specific architecture; engage in hardware / software co-design efforts to maximize inferencing performance; enable trade-space analysis of performance characteristics in order to meet specified requirements in machine learning inferencing. ***FY 2022 to FY 2023 Increase/Decrease Statement:***	3.891	3.757	4.149

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Funding change reflects planned lifecycle of this effort.			
Title: Assured Operations in the Physical, Social and Cyber Domain ***Description:*** Conduct research that will enhance the survivability of information by radically dispersing and continuously moving data across a multitude of inter-networked devices. This effort seeks to address the growing demands on information assurance, reliability, and transmission in resource constrained environments. Theories and methods will be investigated for securing information across heterogeneous devices/sources and networks, detecting and creating information obfuscation and deception techniques, managing risk of information quality and trust, and fusing and regenerating needs-relevant information from highly fragmented and dispersed data. ***FY 2022 Plans:*** Will investigate and assess algorithms enabling intelligent intrusion detection and threat categorization; explore techniques for automated network forensics and analytics, and integrate with Machine Learning techniques to lay foundations for incorporating autonomous agents and decision making; conduct research on low-complexity, distributed, and/or robust cyber techniques based on machine learning for proactive evading, detecting, and responding to adversarial activity; develop rigorous mathematical frameworks and analyses of adaptive and responsive friendly and adversarial cyber protocols; continue to examine theories and algorithmic methods that measure information interoperability, quantify information/model uncertainty, and optimize information synthesis; investigate algorithmic approaches that quantifies the predictive uncertainty of automated decisions under adversarial computational-equivalency and conditions; validate algorithms which infer value of information characteristics from sensor and other information assets in information dissemination and mediation contexts; explore stochastic-process-based models of physical systems to incorporate random-field approaches; investigate methods for incorporating uncertainty into decision-making processes leveraging complex physical behaviors. ***FY 2023 Plans:*** Will conduct research to develop algorithms to efficiently and robustly understand performance of complex analytics in a variety of situations and network and environmental states, and can optimally identify adaptation and reconfiguration strategies toward the allocation of network and analytics resources; study algorithms for multi-agent systems to allow optimal decision making in teams of agents that are resilient to critical failures; investigate scientific theories and methods that optimize information synthesis under constrained battlefield environment; research methodologies to identify and exploit high-value information from physical sensors, information assets, and intelligence given highly dynamic and optempo conditions, unreliable network, and adversarial presence; research contextually-sensitive resilient dissemination and mediation of multi-domain battlefield information based on value-based selection, prioritization, and mission factors; investigate theories and novel methods for resilient information-network that allow dynamic information pathways and improve time and reliability of information/data over constrained tactical networks; study new methods for single and multi-modal machine-learning based reconstruction algorithms for one-dimensional (1-D) and two-dimensional (2-D) signals; investigate machine-learning methods to derive controlling parameters from data in	6.000	6.084	6.544

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
physical systems (inverse problems); assess performance of low-resource methods for aggregating and propagating uncertainty in physical systems. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Machine Learning for Intelligent Agent and Human Decision Making ***Description:*** This effort researches methodologies and algorithms for machine learning with incomplete, unstructured, potentially deceptive, and heterogeneous information, enabling joint decision making for Intelligent Agent-Human teams which adapt to unknown environments and missions. Research includes methods for learning and decision making that occur under short time frames and constrained resources (e.g., computation, power, spectrum, and networks). ***FY 2022 Plans:*** Will develop models and algorithms for predicting impacts of diversification strategies on system assets, including network, applications and cybersecurity, to provide decision support to defenders, operators, and commanders on the battlefield; conduct empirical analysis of models and algorithms when pinned against malware and other intrusions; enable repeatable experimentation focused on systematic automation that will realize continuous model refinement; explore techniques that allow for reasoning over incomplete semantic data to draw inferences about semantic observations and introduce greater contextual richness into a shared world model; investigate multi-agent coordination techniques that facilitate the development of tactical behaviors across small teams of autonomous agents; extend distributed world model by investigating intelligent sharing of salient data streams based on operational context; identify, define, and explore computational models, novel training corpora, and machine learning approaches that enable intelligent systems to recognize shared and contrastive content in multiple forms of text, video, acoustic, and other modes of information sharing and multimodal communications; define algorithms, models, and machine learning techniques to enable intelligent systems to automatically identify context and intent to construct, generate, or transform relevant representations of information for enhanced situational awareness and decision-making. ***FY 2023 Plans:*** Will explore the tradeoffs of performance and accuracy in machine learning algorithms while exercising model-efficiency techniques; investigate ability to instantiate realistic honeynets in a novel multi-fidelity testbed; develop and assess proof-of-concept approaches for SDN-based technologies for tactical applications; examine phenomena and create theoretical approaches that allow small teams of heterogeneous agents to coordinate, decide, and act based on environmental context and observations for tactically relevant situations; determine best mathematical methods and create algorithms for shared representations across teams of heterogeneous assets using salient data streams; research collaborative game-theoretic Intelligence, Surveillance, Reconnaissance (ISR) task execution in contested environments, adversarial evasion, and autonomous maneuver to a position of advantage, and autonomous navigation to target location while avoiding detection; investigate fundamental methods for dynamic bi-directional interaction between Soldiers and autonomous systems to maintain a consistent world model and shared	3.981	5.533	6.103

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
understanding during joint collaborative tasks; explore fundamental techniques to enable multi-agent systems to autonomously adapt group behaviors through machine learning and theoretical models of coordination. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Image Analytics and Understanding ***Description:*** This effort investigates new methodologies and techniques for improved scene and situational understanding using multi-modal imaging sensors from heterogeneous air and ground platforms. This work explores novel machine learning approaches for applications in resource constrained environments. ***FY 2022 Plans:*** Will investigate artificial intelligence/machine learning methods for assessing value of targets in unstructured scenes; develop deep reinforcement learning approaches for scene understanding to feed rapid strategic decision making for Command and Control in complex Multi Domain Operation (MDO) environments; investigate domain transfer approaches for effective training of machine learning algorithms for scene understanding with synthetic data; investigate algorithm optimization approaches for scene understanding performance retention in resource constrained computation environments such as low size, weight, and power (SWaP) processors onboard unmanned air and ground vehicles. ***FY 2023 Plans:*** Will investigate machine learning methods for situational understanding based on vision sensor data for rapid decision-making in complex and dynamic environments with constrained computing resources; investigate methods for synthesizing image data for training machine learning algorithms for improved real-world performance; investigate methods for fusing information from aerial geospatial data with ground data for context-aware route planning and autonomous navigation; conduct experiments with electro-optical infrared (EO/IR) data collections using unmanned aerial vehicles (UAVs) of humans performing activities; develop computer graphics and motion capture solutions to generate synthetic activity data, increasing the amount of data available over real-world only data for algorithm training. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	2.231	2.148	2.380
Title: Fundamentals for Energy Efficient Electronic & Photonic Components ***Description:*** This effort addresses the power draw (demand) of radio frequency (RF) front ends for communication and electronic materials for the digital back-end, as well as efficient materials for delivery of power (supply) for electronics on energy constrained platforms. The work explores new materials with inherently higher energy efficiencies in conjunction with advances in circuits and systems to provide improvements in power efficiencies, linearity, and noise at the subsystem level for unique Army requirements for demand and supply electronics.	1.947	1.872	2.077

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
FY 2022 Plans: Will investigate mechanism of energy deposition and transfer through ultra-wide bandgap materials through the use of time-dependent pulsed beam stimulation and repetitive photoluminescence (PL) and cathode luminescent (CL) measurement of charge carrier kinetics; investigate ferroelectric and anti-ferroelectric materials in nanoscale 3D scaffolding for high energy density capacitors for rapid recharge applications; explore materials and fabrication techniques for devices needed for through metal wireless power transfer and wearable, stretchable wireless power; research ultra-wide bandgap material structures based on Diamond/Boron Nitride technology for high efficiency RF components; investigate mechanisms for detection of circular polarized light in several topological materials through growth and characterization for efficient communications. ***FY 2023 Plans:*** Will investigate and identify limitations of radiation tolerance in Ultra-Wide Bandgap (UWBG) materials through modeling and alpha and electron beam radiation exposure assessments; investigate structurally metastable nitrides for electric field-induced phased transitions using x-ray crystallography and electrothermal characterization; explore the effects of metallization of additively manufactured composite materials on circuit performance in 3-Dimensional (3-D) printed structural power devices and electronics; design and fabricate metasurfaces specific for addressing future needs in imaging, radar, and communications applications. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Quantum Information Sciences ***Description:*** This effort investigates interactions between light and quantum systems, including atoms, ions, and solid-state materials, for developing the fundamental building blocks of distributed quantum systems. A particular emphasis is efficient light matter interfaces, including optical cavities, nanophotonics, and high density atomic systems. This effort also explores quantum algorithms for entanglement distribution. ***FY 2022 Plans:*** Will investigate optimal approaches for storing and manipulating quantum information in physical platforms of atoms, ions, and material systems for entanglement-enhanced sensing and communications; investigate multiplexed quantum memory in cold-atom systems; investigate schemes for efficient readout of Rydberg sensor information; extend atom-atom interaction distance through optical nanofibers for distributing entanglement; explore charge-state dynamics of solid-state defect materials for optimization of sensor capabilities and magnetometers; explore frequency conversion in ion trap systems for long-range entanglement through optical fiber. ***FY 2023 Plans:*** Will investigate interfaces between electromagnetic fields and atomic/material systems for novel sensors, building blocks of entanglement distribution, and approaches to low size, weight, and power timekeeping; investigate experimental implementation	5.662	5.484	6.050

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
of proposed techniques for quantum gate operations in atomic systems; explore 1-D physics of interacting quantum systems; explore sub-thermal readout of electric field sensors; investigate all-optical approaches to photonic qubits; explore effect of defect density on clock and sensor performance in solid-state sensors. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: FY2022 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	1.479	-
Accomplishments/Planned Programs Subtotals	40.376	40.435	42.839

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army			**Date:** April 2022
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COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
AB1: *Basic Res in infect Dis, Oper Med and Combat Care*	-	31.957	36.910	4.405	-	4.405	4.465	4.607	4.580	4.578	0.000	91.502

A. Mission Description and Budget Item Justification

This Project builds fundamental scientific knowledge contributing to the sustainment of United States Army scientific and technology information to solving military medical problems related to infectious diseases, operational medicine and combat care. This Project provides the means to exploit scientific breakthroughs and avoid technological surprises, and fosters innovation in areas where there is little or no commercial investment due to limited markets (e.g., drugs and treatments for tropical diseases) and maintains laboratory capability to perform these functions.

The work is consistent with the Under Secretary of Defense (Research and Engineering) science and technology focus areas and the Army Modernization Strategy.

Work is performed by the Army Futures Command.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Damage Control Resuscitation ***Description:*** This effort conducts studies to define and identify cellular processes and metabolic (biochemical activity) mechanisms associated with blood clotting to understand the relationships between the human immune processes and bleeding in trauma.	1.640	-	-
Title: Combat Trauma Therapies ***Description:*** This effort conducts studies of trauma to tissues and organs, including dental (facial and oral) injuries, extremity wounds and fractures, and burns, and ways to mitigate and/or repair this damage.	0.664	-	-
Title: Pre-hospital tactical Combat Casualty Care ***Description:*** This effort conducts basic science studies to determine physiological responses to trauma and aid in development of life-saving interventions. ***FY 2022 Plans:*** Will perform feasibility study to support development of an extremity tourniquet prototype able to provide guidance to operators of all skill levels on its proper application, optimal placement, and maximum time to be left on and management, and decrease complications associated with prolonged use. ***FY 2022 to FY 2023 Increase/Decrease Statement:***	1.411	0.885	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.			
Title: Traumatic Brain Injury ***Description:*** This effort conducts basic research in poly-trauma (multiple injuries)/Traumatic Brain Injury (TBI) model, mechanisms of cell death, and the discovery of novel drugs and medical procedures to mitigate the effects of TBI	1.356	-	-
Title: Prolonged Field Care ***Description:*** This effort conducts basic research to study the physiological implications of delayed medical evacuation and limited access to definitive surgical care in severely injured casualties. ***FY 2022 Plans:*** Will perform In vitro and in vivo efficacy studies of medical treatments for burn in environments contaminated with nerve agent. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.	2.729	2.355	-
Title: Injury Prevention and Reduction ***Description:*** This effort identifies biological patterns of change in Warfighters during states of physical exertion, identifies physiological (human physical and biochemical functions) mechanisms of physical injury and exertion that will predict musculoskeletal (muscle, bone, tendons, and ligaments) sensory (auditory, ocular, and vestibular) and blunt, blast or accelerative injury. ***FY 2022 Plans:*** Will further the characterization of cellular and physiological pathways responsible for bone adaptation after strenuous exercise and characterize normal and abnormal pathways responsible when using non-steroidal anti-inflammatory drugs. Will develop scaling and correlations of bio mechanical and injury perturbations across multiple species to develop injury criteria for blast over pressure exposure resulting from improvised explosive devices. ***FY 2022 to FY 2023 Increase/Decrease Statement:***	2.519	2.479	-

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.			
Title: Physiological Health ***Description:*** This effort conducts fundamental research on the physiological mechanisms of sleep, fatigue, and nutrition on Soldier health, readiness and performance. In addition, this effort discovers basic understanding of physiological and genetic processes leading to biomedical performance enhancement in in the physical, cognitive and psychological domains. ***FY 2022 Plans:*** Will continue to define the role of nutrition support for metabolic recovery from military activity. Will continue to understand field-based impact of sleep on operational performance. Will continue to investigate basic mechanisms of non-invasive brain and peripheral nervous system (outside the brain and spinal cord) stimulation for enhancing operational performance Will investigate physiologic, metabolic and genetic biomarkers of resilience to military stressors. ***FY 2023 Plans:*** Will finalize basic research to understand field-based impact of sleep on operational performance. Will initiate research to understand neurobiological mechanisms of chronic fatigue incurred during extended operational conditions. Will finalize definition of the role of nutrition support for metabolic recovery from military activity. Will initiate research to understand the interface of nutrition modulation and immune regulation of disease susceptibility and injury recovery. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding decreased due to realignment of US Army Medical Research and Development Command to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.	4.926	3.861	2.555
Title: Environmental Health ***Description:*** This effort involves the understanding of physiological (human physical and biochemical functions) mechanisms of exposure to extreme heat, cold, altitude, and other environmental stressors. This effort establishes scientific evidence for specific and sensitive diagnostics of exertional heat illness to optimize Warfighter performance in austere environments. ***FY 2022 Plans:***	1.089	1.090	1.013

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Will research animal models for basic mechanisms of injuries from heat exposure and those factors that accelerate improved recovery; will establish screening methods to determine the underlying molecular mechanisms for degraded physical and behavioral performance of susceptible individuals in challenging dense urban and subterranean environments. ***FY 2023 Plans:*** Will utilize models to identify basic mechanisms of heat-related injuries which could be exploited as factors to accelerate and improve recovery. Will determine the efficacy of inspiratory muscle training to improve performance in high Carbon dioxide (CO2) and low Oxygen (O2) environments. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding decreased due to realignment of US Army Medical Research and Development Command to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.			
Title: Psychiological Health and Resilience ***Description:*** This effort conducts research into the basic mechanisms of the ability to overcome traumatic events including determination of underlying neurobiological mechanisms (nervous system control of cellular and molecular processes) related to Acute Stress Reactions, early characteristics of Post-Traumatic Stress Disorder (PTSD), depression, and other neuropsychiatric sequalae of trauma/stress. ***FY 2022 Plans:*** Will identify new candidate therapeutic targets to promote resilience to stressors using a novel evidence-synthetic receptor-based strategy, to speed the process of drug discovery. Will identify new compounds and pharmacologics for rapid recovery from acute stress reactions using preclinical experiments and will identify molecular markers of recovery from acute stress symptoms after intervention (pharmacological and non-pharmacological). Will research candidate pharmacological solutions for their ability to provide rapid recovery from acute stress symptoms by enhancing Soldier resilience to recover from high-stress events with minimal side effects using preclinical testing. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.	1.717	0.787	-
Title: Basic Research on Drugs and Vaccines Against Parasitic Diseases (previously titled: Basic Research to Prevent Parasitic Diseases)	5.835	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2021**	**FY 2022**	**FY 2023**
Description: Discover and identify new chemical compounds for further characterization and optimization as potential drug leads against malaria. Discover and identify new antigens, virulence factors and adjuvants that will lead to the development of effective malaria vaccines, develop approaches for multivalent vaccines that achieve protective efficacy across genetically diverse malaria parasites and identify correlates of protection in animal models and in humans.			
Title: Bacterial Disease Threats ***Description:*** Discover and identify new antigens, virulence factors and adjuvants that will lead to the development of effective diarrheal vaccines against Enterotoxigenic Escherichia Coli (ETEC), Shigella and Campylobacter. Identify approaches to develop multivalent vaccines that achieve protective efficacy across several bacterial serotypes and species, as well as identify correlates of protection from bacterial diarrheal disease in animal models and in humans.	1.721	-	-
Title: Viral Threats Research ***Description:*** Discover and identify new antigens, virulence factors and adjuvants that will lead to the development of effective vaccines against hemorrhagic fever viruses (e.g. dengue and Hantaviruses). Identify approaches to develop multivalent vaccines that achieve protective efficacy across all dengue serotypes, and discover and identify correlates of protection from viral diseases in animal models and in humans.	1.700	-	-
Title: Insect Vector Basic Research ***Description:*** Identify and characterize specific populations of vectors that may carry and transmit infectious disease, inform vector control countermeasures, and develop detection assays for vectors and vector-borne pathogens.	1.594	-	-
Title: Network Sciences Initiative ***Description:*** This effort uses mathematical models and algorithms to extract medical information from large-scale datasets (generated from the study of cellular genetic makeup, protein structures and function, wearables, and whole organism responses) to improve understanding, prevention, diagnostics, and treatments of those injuries and diseases that pose a threat to Warfighter readiness: e.g., musculoskeletal injury, PTSD, uncontrolled bleeding, infectious diseases, hard-to-diagnose pulmonary disease, and exposure to environmental stressors and hazards.	3.056	-	-
Title: Biology of Operational Pain ***Description:*** This effort performs basic research to support development of novel, non-opioid drugs to treat pain in the austere battlefield environment with minimal side effects. ***FY 2022 Plans:***	-	1.101	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Understand the mechanisms that contribute to the transition from acute to chronic pain and identifying novel drug therapy targets to alleviate pain. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.			
Title: Extremity Trauma ***Description:*** This effort performs basic research to support development of treatments to preserve tissues and function of severely mangled limbs. ***FY 2022 Plans:*** Will perform basic research of cellular metabolism in injured limb tissues to support identification of potential means to protect injured, viable tissues from further damage during the period from time of injury until definitive care is made available. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.	-	0.565	-
Title: Expeditionary Medicine ***Description:*** This effort performs basic research to support development of treatments to protect non-injured and injured, but viable, tissues from oxygen deprivation, metabolic disruption, and further injury following severe trauma. ***FY 2022 Plans:*** Will perform basic research to support development of new technologies to improve provision of critical care in forward, austere and logistically restricted areas of the battlefield). ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.	-	0.486	-
Title: Hemorrhage, Shock, Coagulopathy of Trauma	-	1.640	-

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2021**	**FY 2022**	**FY 2023**
Description: This effort conducts studies to define and identify cellular processes and metabolic (biochemical activity) mechanisms associated with excessive blood clotting to understand the relationships between the human immune processes and bleeding in trauma. ***FY 2022 Plans:*** Will perform conceptual studies to support design, development, and optimization of a diagnostic tool that can predict overall hemostatic efficiency of an injured casualty. Will perform hemostatic functional assays of a novel dried whole blood product. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.			
Title: Endovascular Hemorrhage Control ***Description:*** This effort performs basic research to support development of devices that when introduced into arteries or veins may be used to stop internal bleeding. ***FY 2022 Plans:*** Will conceptualize and evaluate synthetic and animal models in which to test feasibility of novel vascular access approaches. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.	-	0.467	-
Title: Burn Injury ***Description:*** This effort performs basic research to support development of treatment and clinical management tools for severe burns. ***FY 2022 Plans:*** Will perform In vitro and in vivo efficacy studies of medical treatments for burn in environments contaminated with nerve agent in order to examine the effects of the chemical agent and decontamination agents on the burn wound and surrounding viable tissues, and to examine the effects of acute burn wound treatment on decontamination. ***FY 2022 to FY 2023 Increase/Decrease Statement:***	-	2.786	-

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.			
Title: TBI Neurotrauma/Brain Dysfunction ***Description:*** This effort conducts basic research in poly-trauma (multiple injuries)/Traumatic Brain Injury (TBI) model, mechanisms of cell death, and the discovery of novel drugs and medical procedures to mitigate the effects of TBI. ***FY 2022 Plans:*** Will evaluate efficacy of Tactical Combat Casualty Care blood product resuscitation strategies in a swine model of penetrating TBI and polytrauma. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.	-	1.388	-
Title: Soldier Performance Augmentation ***Description:*** This effort investigates and defines fundamental physiological mechanisms underlying Soldier capabilities to execute military tasks. Understands basic biological mechanisms underlying Soldier capabilities to include physical endurance, cognitive capacity and individual and group decision making. ***FY 2022 Plans:*** Will study relationship between underlying brain characteristics (e.g., density of neural synapses, glymphatic flow, and cortical thickness) to Soldier military performance. Will discover indices of brain dysfunction and repair related to Soldier job-related awakedness and recovery following sleep. Will investigate biomedical mechanisms of inter-individual differences in vulnerability to cognitive performance and attention related to time-on-task. ***FY 2023 Plans:*** Will continue to investigate basic mechanisms of non-invasive brain and peripheral nervous system (outside the brain and spinal cord) stimulation for enhancing operational performance. Will investigate physiologic, metabolic and genetic biomarkers of resilience to military stressors. ***FY 2022 to FY 2023 Increase/Decrease Statement:***	-	1.871	0.837

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2021**	**FY 2022**	**FY 2023**
Funding decreased due to realignment of US Army Medical Research and Development Command to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.			
Title: Prolonged Field Care - Infectious Diseases ***Description:*** Discover and identify new prophylactic and treatment (antibodies, drugs and biologics) approaches that will lead to the development of effective prevention and treatment strategies for combat wound infections and sepsis in a prolonged field care environment. Identify approaches to develop antibodies, drugs and biologics that achieve protective effectiveness and discover and identify correlates of protection from combat wound infections in models and in humans. ***FY 2022 Plans:*** Will discover, identify, and characterize the following for prevention and treatment of combat wound infections and sepsis in a prolonged field care environment: new substances that induce an immune response in the body; molecules produced by microorganisms that help them attach, evade host responses and allow spread; and substances that enhance the body's immune response; generate, characterize, and evaluate proteins produced in response to and against combat wound infections; characterize combat wound infections to inform development of prophylactics and treatments. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.	-	4.442	-
Title: Medical Readiness - Infectious Diseases ***Description:*** Discover and identify new prophylactics and treatment (antibodies, drugs and biologics) approaches that will lead to the development of effective prevention and treatment strategies for endemic bacterial and viral infectious diseases. Identify approaches to develop antibodies, drugs and biologics that achieve protective efficacy and discover and identify correlates of protection from endemic diseases in animal models and in humans. ***FY 2022 Plans:*** Will discover, identify, and characterize the following for the prevention and treatment of endemic bacterial and viral infectious diseases: new substances that induce an immune response in the body; molecules produced by microorganisms that help them attach, evade host responses and allow spread; and substances that enhance the body's immune response; generate, characterize, and evaluate proteins produced in response to and against endemic bacterial and viral infectious diseases; characterize endemic bacterial and viral infectious diseases to inform development of prophylactics and treatments. ***FY 2022 to FY 2023 Increase/Decrease Statement:***	-	6.884	-

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2021**	**FY 2022**	**FY 2023**
Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.			
Title: Medical Computational Modeling ***Description:*** This effort uses mathematical models and AI algorithms to extract medical information from large-scale datasets (generated from the study of cellular genetic makeup, protein structures and function, wearables, and whole-organism responses) to improve understanding, prevention, diagnostics, and treatments of those injuries and diseases that post a threat to Warfighter readiness: e.g., musculoskeletal injury and fatigue, Post-traumatic stress disorder (PTSD), heat stress, and infectious diseases. ***FY 2022 Plans:*** Will design algorithms to identify the impact of load carriage and stride-length on the risk of stress-related bone fracture in Warfighters during basic combat training. Will develop and refine computational strategies that allow us to use Artificial Neural Network and Machine Learning methods to solve military biomedical problems even when the sample sizes are small. Will quantitatively compare existing cooling strategies currently recommended by the United States Army and identify the most efficacious ones in reducing core body and organ temperatures following exposure to specific heat-stress conditions. Will identify genes and mechanisms of drug resistance in the malaria parasite, as a model organism, and validate their involvement in mitigating resistance against new antimalarial drugs. Will use a mathematical skeletal-muscle model based on biophysical principles to identify and assess interventions that delay muscle fatigue, reduce injury, and prolong optimal performance. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding and mission realigned as part of US Army Medical Research and Development Command transfer to the Defense Health Agency in order to meet Congressional intent as outlined in NDAA 2019 (Section 711) and NDAA 2020 (Section 737). Funding transferred to Program Element 601117DHA, Project Code 371F.	-	3.050	-
Title: SBIR/STTR Tax ***FY 2022 Plans:*** SBIR/STTR tax. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638.	-	0.773	-
Accomplishments/Planned Programs Subtotals	31.957	36.910	4.405

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		**Date:** April 2022
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C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, **RDT&E Project Justification:** PB 2023 Army	**Date:** April 2022

Appropriation/Budget Activity	**R-1 Program Element (Number/Name)**	**Project (Number/Name)**
2040 / 1	PE 0601102A / *Defense Research Sciences*	AB2 / *Protection, Maneuver, Geospatial, Natural Sciences*

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
AB2: *Protection, Maneuver, Geospatial, Natural Sciences*	-	17.089	17.967	19.201	-	19.201	19.478	19.749	19.897	19.892	0.000	133.273

A. Mission Description and Budget Item Justification

This Project advances fundamental science in areas of military engineering, biosciences, geospatial, and data sciences. The Project expands basic understanding of complex biological, chemical, geospatial, and material properties and processes at varying scales and time to support applied research and advanced technology development in the future.

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas and the Army Modernization Strategy.

Work is performed by the United States (U.S.) Army Engineer Research and Development Center and coordinated with U.S. Army Futures Command.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Mapping, remote sensing, signature physics and terrain state	3.868	3.819	4.277
Description: Investigates compact mathematical representations of terrain data, explores automated learning of built elemental features unique to location, formulates new techniques for automatically retrieving Earth surface features, properties and patterns, explores sensing phenomenology and surface state as affected by terrain and weather, studies optimizing and adapting decision making based on changing geospatial conditions. ***FY 2022 Plans:*** Investigate signal processing algorithms for automatic target recognition. Basic research characterizes urban noise fields at ground level, for both acoustic and electromagnetic waves, relevant to military operations. ***FY 2023 Plans:*** Will investigate parameterized anomalous sound propagation effects derived from ground turbulence blocking to localize and track elevated acoustic sources. Will investigate if a link exists between mechanical properties of snow permeability, elastic modulus, and acoustic response. Will quantify thin snow absorption, emission, and scattering processes influencing radiative transfer. Will use this fundamental research to inform deep learning models for a forest canopy that predicts understory parameters. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Fundamental Adaptive Protection and Projection Research	4.700	4.639	4.782

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AB2 / *Protection, Maneuver, Geospatial, Natural Sciences*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Description: Conduct fundamental studies on the theory and modeling of future revolutionary geological, structural, and signature reducing materials; and examine, investigate and model complex geophysical, littoral, and other environments that fill critical Army knowledge gaps in adaptive protection and projection. ***FY 2022 Plans:*** Investigate physical drivers of currents in the littoral swash zone to inform the geo-environmental conditions of autonomous vehicles; study thermal conductivity in cold environments to understand the electrical performance limitations of crystalline materials; determine the mechanisms that enable tunability of specific materials for novel unconventional countermeasures and survivability applications. ***FY 2023 Plans:*** Will determine if density class interactions in multiple density mixtures lead to nonlinear sediment transport curves based on the proportion of dense material. Will use parallel treatment of grains and bonds to understand how microscale snow parameters, particularly sintered bonds, impact the macroscale compressive strength. Will systematically investigate multi-scale steel fiber influence on damage processes in Ultra-High Performance Concrete (UHPC). Will combine this novel research and experimental data with recently available data-driven discovery methods to capture near-surface aerodynamics and wind-driven process characterizations in dry-land environments. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Fundamental Infrastructure Sciences ***Description:*** Explores fundamental theory of artificial intelligence, robotics, autonomous construction, three-dimensional (3D) printing materials, self-assembly and advanced or innovative material science as related to advancing military construction and Engineer operations. ***FY 2022 Plans:*** Explore the potential of resonance energy transfer as a light harvesting mechanism to inform future development of advanced materials; investigate the structure-function relationship in compartmentalized nanoreactors for future application in on-demand chemical reactions and real time monitoring. ***FY 2023 Plans:*** Will investigate the protein responsible for the durable, water resistant and thermally regulated mud dauber wasp nest. Will investigate characterizations of liquid Gallium diffusion in Aluminum to potentially inform future infrastructure engineering	1.817	1.796	2.012

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AB2 / *Protection, Maneuver, Geospatial, Natural Sciences*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
advancements. Will use dynamic hyperbolic data projection to reveal knowledge from hyperdimensional datasets that existing methods are incapable of exposing. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Biological, Chemical and Physical Sciences ***Description:*** Explore novel approaches of innovative data analytics, bio-inspired materials, and chemical experimentation to understand basic principles of biological and chemical mechanisms, organisms, and natural processes of the environment. ***FY 2022 Plans:*** Investigate mechanisms in cold-dwelling bacteria (psychrophiles) and frozen media to support future development of cold-specific Army technologies; explore how synthetic biology can be combined with new materials to allow manipulation of materials on demand. ***FY 2023 Plans:*** Will investigate soil disturbance and emissions using volatile compounds. Will explore the relationship between atmospheric phenomena and natural processes. Will explore synthetic engineering of bacteria to function as a non-model synthetic biology chassis. Will investigate fundamental principles of cryptobiosis by engineering mechanisms into cells. Explorative research will investigate current and signal propagation dynamics in fungal melanin. New research into genetic adaptations of lichens will be conducted to exploit biological engineering functionalities. Will investigate biological reactivity of carbon nanofiber strength with select proteins; results acquired from Basic Research may inform future capability advancement and adverse impacts on Army operations. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort, the increase provides for adequate investigation and experimentation to explore the relationship between atmospheric phenomena and natural processes, and also for further investigation into bacteria manipulation.	6.704	7.057	8.130
Title: FY 2022 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 to FY 2023 Increase/Decrease Statement:***	-	0.656	-

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AB2 / *Protection, Maneuver, Geospatial, Natural Sciences*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Funding transferred in accordance with Title 15 USC ?638			
Accomplishments/Planned Programs Subtotals	17.089	17.967	19.201

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

N/A

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army			**Date:** April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** CH9 / *Advancing Concepts and Technology Forecasting*	

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
CH9: *Advancing Concepts and Technology Forecasting*	-	-	3.573	3.793	-	3.793	3.845	3.873	3.875	3.874	0.000	22.833

A. Mission Description and Budget Item Justification

This Project works across the Army Futures Command Combat Capabilities Development Command and with the Futures & Concepts Center to identify emerging and disruptive basic scientific research outcomes in order to translate, integrate, and ingrain research outcomes with Army Warfighting Concepts which describe how the Army will fight in the far-term future. Outcomes describe the projected future operational effects of science in the context of Army concepts to enable informed decision making and mitigate risk for future Army capabilities.

Advancing Concepts ensures Army Concepts are grounded by recent discoveries in basic scientific research. Army basic research is use-inspired to address the future capability needs identified in the Army Concepts, and learning opportunities are created to advance Army Concepts and operationalize science for transformational overmatch.

Technology Forecasting develops timely, objective, scientifically-grounded projections of scientific advances that hold promise to impact future operational capabilities for the Army. Emerging scientific areas are described and communicated across the Army Modernization Enterprise to inform Science and Technology decisions.

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas and the Army Modernization Strategy. Work in this Project is performed by the United States Army Futures Command (AFC).

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Advancing Concepts and Technology Forecasting ***Description:*** Advancing Concepts identifies emerging and disruptive basic scientific research outcomes in order to translate, integrate, and ingrain research outcomes with Army Warfighting Concepts which describe how the Army will fight in the far-term future. Technology Forecasting provides long-range, scientifically grounded technology forecasts of basic research topics to enable informed decision-making. ***FY 2022 Plans:*** Will perform initial integration of basic scientific research outcomes with a priority focus on far-term Maneuver, Fires, and Mission Command Army Warfighting Concepts; perform long-range technology forecasts of Army Priority Basic Research Areas, including Synthetic Biology, Artificial Intelligence, and Disruptive Energetics. ***FY 2023 Plans:***	-	3.443	3.793

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** CH9 / *Advancing Concepts and Technology Forecasting*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Will combine basic scientific research outcomes into emerging Army Warfighting Concept priorities for far-term decision dominance, deception and protection, sustained operations, and maximizing human potential; provide objective estimates of anticipated basic scientific research advances, across the Army Priority Research Areas, to Army decision-makers to aid in basic research program formulation. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: FY2022 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2022 to FY 2023 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	0.130	-
Accomplishments/Planned Programs Subtotals	-	3.573	3.793

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army			**Date:** April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** T14 / *BASIC RESEARCH INITIATIVES - AMC (CA)*	

COST ($ in Millions)	Prior Years	FY 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
T14: *BASIC RESEARCH INITIATIVES - AMC (CA)*	-	48.000	73.000	-	-	-	-	-	-	-	0.000	121.000

Note

Congressional Interest Item funding provided for Defense Research Sciences.

A. Mission Description and Budget Item Justification

Congressional Interest Item funding provided for Defense Research Sciences.

The cited work is consistent with the Under Secretary of Defense for Research and Engineering priority focus areas and the Army Modernization Strategy.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022
Congressional Add: Multi-fuel ignition, chemistry and control strategies for unmanned aircraft systems hybrid propulsion ***FY 2021 Accomplishments:*** Program Increase supported basic research on Multi-Fuel Ignition, Chemistry, and Control Strategies for Unmanned Aircraft Systems Hybrid Propulsion. Work executed by Army Futures Command.	15.000	-
Congressional Add: Program increase ***FY 2021 Accomplishments:*** Program Increase supported basic research on Defense Research Services. Work executed by Army Futures Command. ***FY 2022 Plans:*** Congressional Interest Item funding provided for Basic Research	10.000	25.000
Congressional Add: Program increase - explosives and opiods dual-use UV detection ***FY 2021 Accomplishments:*** Program Increase supported basic research on Explosives and Opiods Dual-Use UV Detection.	3.000	5.000

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) T14 / *BASIC RESEARCH INITIATIVES - AMC (CA)*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022
Work executed by Army Futures Command. ***FY 2022 Plans:*** Congressional Interest Item funding provided for Explosives and Opiods Dual-Use UV Detection		
Congressional Add: Program increase: Artificial intelligence complex multi?material composites processing ***FY 2021 Accomplishments:*** Program Increase supported basic research on Artificial Intelligence Complex Multi-Material Composites Processing. Work executed by Army Futures Command.	10.000	-
Congressional Add: Program Increase: Cell-Free Expression for Biomanufacturing ***FY 2021 Accomplishments:*** Program Increase supported basic research on Cell-Free Expression for Biomanufacturing. Work executed by Army Futures Command. ***FY 2022 Plans:*** Congressional Interest Item funding provided for Cell-Free Expression for Biomanufacturing	10.000	10.000
Congressional Add: Digital Thread for Advanced Manufacturing ***FY 2022 Plans:*** Congressional Interest Item funding provided for Digital Thread for Advanced Manufacturing	-	5.000
Congressional Add: Joint Research Labratories ***FY 2022 Plans:*** Congressional Interest Item funding provided for Joint Research Labratories	-	20.000
Congressional Add: Lightweight High Entropy Metallic Alloy Discovery ***FY 2022 Plans:*** Congressional Interest Item funding provided for Lightweight High Entropy Metallic Alloy Discovery	-	3.000
Congressional Add: Unmanned Aerial Systems Propulsion ***FY 2022 Plans:*** Congressional Interest Item funding provided for Unmanned Aerial Systems Propulsion	-	5.000
Congressional Adds Subtotals	48.000	73.000

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2023 Army		Date: April 2022
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** T14 / *BASIC RESEARCH INITIATIVES - AMC (CA)*

D. Acquisition Strategy

N/A