Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Army	**Date:** May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	343.481	344.031	297.241	-	297.241	-	-	-	-	-	-
AA1: *ILIR - AMC*	-	10.014	10.780	10.917	-	10.917	-	-	-	-	-	-
AA2: *ILIR - SMDC*	-	0.915	0.965	0.979	-	0.979	-	-	-	-	-	-
AA3: *Single Investigator Basic Research*	-	93.691	100.773	90.542	-	90.542	-	-	-	-	-	-
AA4: *Training and Human Science Research*	-	19.949	21.322	21.781	-	21.781	-	-	-	-	-	-
AA5: *Biotechnology and Systems Biology*	-	5.511	6.042	6.076	-	6.076	-	-	-	-	-	-
AA6: *Robotics and Mobile Energy*	-	20.807	22.353	20.793	-	20.793	-	-	-	-	-	-
AA7: *Mechanics and Ballistics*	-	32.734	35.368	33.359	-	33.359	-	-	-	-	-	-
AA8: *Sensing and Electromagnetics*	-	8.229	9.006	13.611	-	13.611	-	-	-	-	-	-
AA9: *Information and Networking*	-	37.502	40.376	40.540	-	40.540	-	-	-	-	-	-
AB1: *Basic Res in infect Dis, Oper Med and Combat Care*	-	31.269	31.957	37.103	-	37.103	-	-	-	-	-	-
AB2: *Protection, Maneuver, Geospatial, Natural Sciences*	-	16.510	17.089	17.967	-	17.967	-	-	-	-	-	-
CH9: *Advancing Concepts and Technology Forecasting*	-	-	-	3.573	-	3.573	-	-	-	-	-	-
T14: *BASIC RESEARCH INITIATIVES - AMC (CA)*	-	66.350	48.000	-	-	-	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

This 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

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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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	354.480	303.257	311.641	-	311.641
Current President's Budget	343.481	344.031	297.241	-	297.241
Total Adjustments	-10.999	40.774	-14.400	-	-14.400
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	48.000			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-	-			
• SBIR/STTR Transfer	-10.999	-7.226			
• Adjustments to Budget Years	-	-	-14.400	-	-14.400

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2020	FY 2021
Project: T14: *BASIC RESEARCH INITIATIVES - AMC (CA)*		
Congressional Add: *Propulsion Technology*	10.000	-
Congressional Add: *Ballistic and Materials Technology*	10.000	-
Congressional Add: *Flexible LED Lighting*	5.350	-
Congressional Add: *Military Waste Stream Conversion*	5.000	-
Congressional Add: *Multi-layer and dynamically responsive macromolecular composites*	5.000	-
Congressional Add: *Advanced hemostat products*	2.000	-

Exhibit R-2, **RDT&E Budget Item Justification:** PB 2022 Army	**Date:** May 2021
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Congressional Add Details ($ in Millions, and Includes General Reductions)	**FY 2020**	**FY 2021**
Congressional Add: *Multi-fuel ignition, chemistry and control strategies for unmanned aircraft systems hybrid propulsion*	9.000	15.000
Congressional Add: *Transmission electron microscope*	20.000	-
Congressional Add: *Program increase*	-	10.000
Congressional Add: *Program increase - explosives and opiods dual-use UV detection*	-	3.000
Congressional Add: *Program increase: Artificial intelligence complex multi?material composites processing*	-	10.000
Congressional Add: *Program Increase: Cell-Free Expression for Biomanufacturing*	-	10.000
Congressional Add Subtotals for Project: T14	66.350	48.000
Congressional Add Totals for all Projects	66.350	48.000

Change Summary Explanation

$4.000 million of FY22 will be realigned to APE 611102AB1 (Basic Research in Infect Dis, Oper Med and Combat Care) from PE 0603002A (Medical Advanced Technology), APE 633002MM9((Tech Base/Enabling Research for Infect Dis Adv Tech)

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
AA1: *ILIR - AMC*	-	10.014	10.780	10.917	-	10.917	-	-	-	-	-	-

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 2020	FY 2021	FY 2022
Title: Edgewood Chemical Biological Center (ECBC) ***Description:*** Basic research in chemistry, biology, biotechnology, toxicology, and aerosols for creating the science base needed for countering improvised explosive devices (IEDs), explosives forensics, obscurants, and defeating targets. ***FY 2021 Plans:*** Conduct innovative, high-risk, basic research that explores new phenomenology at the boundaries of chemistry, biology, mathematics, and physics. Specifically will conduct fundamental research in novel materials, synthetic biology, novel sensing, molecular toxicology, aerosol sciences, and machine learning. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	0.885	1.001	1.008
Title: Armaments Research, Development and Engineering Center (ARDEC)	1.327	1.446	1.485

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
Description: Funds basic research in weapons component physics, explosives synthesis/detection, and the fundamental science base of area denial. ***FY 2021 Plans:*** Conduct innovative basic research that results in powerful explosives for enhanced lethality, novel structural materials for armament system components, novel structural materials for armament system components, physics-based modeling of components and ingredients (e.g., energetics and warheads) in extreme temperature and pressure regimes. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Title: Tank Automotive Research, Development and Engineering Center (TARDEC) ***Description:*** This effort funds basic research in ground vehicle technologies to include power, mobility, and unmanned systems. ***FY 2021 Plans:*** Conduct competitively selected, basic research to understand Scientific principles in support of Army ground vehicles in areas such as novel control methods for vehicle systems; advanced control of autonomous systems, high fidelity and reduced order modeling and simulation, optimal path planning for autonomous systems, advanced coatings, lightweight materials, additive manufacturing, joining processes, advanced diesel engine heat transfer, and multi-cell battery modeling and control. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.118	1.235	1.238
Title: Natick Soldier Research, Development and Engineering Center (NSRDEC)	1.009	1.126	1.158

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020**	**FY 2021**	**FY 2022**
Description: This effort funds basic research in food sciences, textiles, and lightweight materials with potential for individual protection. ***FY 2021 Plans:*** Conduct basic research to explore the angular dependence and thermal effects of infrared light scattering from patterned microstructure arrays and microparticle-loaded films to enable control of diffuse infrared scattering in order to inform advances in signature management and defense against electromagnetic threats; examine the effects of high altitude exposure on human cognition and gut microbiome to understand the impact of stress on the human gut-brain axis, which influences Soldier performance and decision-making. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
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 2021 Plans:*** Investigate the fundamental nature of complex network dynamics for enhanced security communication and sensor systems; research theoretical model of component processes for the generation of entangled microwave photons for quantum-enhanced detection; study the potential use of machine learning to discover novel, high-performance energetic materials; investigate the properties of polaritons based on representations of the electromagnetic field in a linear medium for improved sensors; explore properties of nanoscale materials and metamaterials for optimal energy management, sensor protection, and sensor enhancement. ***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	2.327	2.394	2.405

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army			Date: May 2021
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 2020	FY 2021	FY 2022
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 2021 to FY 2022 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 2021 Plans:*** Conduct basic research experiments to examine the relationship between surface finish, contact traction coefficient, and micropitting, and how it affects the reliability and life of gears and bearings; investigate machine learning techniques to augment lower-order models using data from high-fidelity computational fluid dynamics models; conduct basic fluid dynamic research in the areas of vorticity dynamics, unsteady flow separation, and flow control to identify fundamental governing principles. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.227	1.344	1.381
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 2021 Plans:*** Conduct research on performance of Gallium Nitride/Silicon Carbide (GaN/SiC) transistor models at the upper F-Band (130 GHz ? 140 GHz); investigate highly tunable dielectric materials for radar and communication utilizing highly textured films to achieve high tenability and low power loss; study reducing the interfacial resistance between cathode and solid electrolyte through conducting lithium glass to improve contact between the cathode and solid electrolyte; investigate the geometry of inductive coupling coils	2.121	2.234	2.242

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
for potential applications in high efficiency wireless power transfer; explore non-destructive, in situ metrology to molecular beam epitaxy (MBE) of antimonide-based infrared detector structures, used in advanced infrared focal plane arrays (IRFPAs). ***FY 2022 Plans:*** 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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Accomplishments/Planned Programs Subtotals	10.014	10.780	10.917

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army	**Date:** May 2021

Appropriation/Budget Activity	**R-1 Program Element (Number/Name)**	**Project (Number/Name)**
2040 / 1	PE 0601102A / *Defense Research Sciences*	AA2 / *ILIR - SMDC*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
AA2: *ILIR - SMDC*	-	0.915	0.965	0.979	-	0.979	-	-	-	-	-	-

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 Technologies / AD2 (High Energy Laser (HEL Enabling and Support Technologies).

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 2021 Plans:*** Perform laser modeling of other atomic transition line parameters to determine if efficient lasing is possible; models laser cavity parameters, and expand laser spectroscopy to include improved plasma parameters; develops new atmospheric turbulence models to better predict turbulence strength and variation as a function of altitude as the boundary layer varies as a function of weather conditions, solar loading, and terrain parameters; investigates new areas of research in laser phenomenology with potential to transition to the next generation of HEL technology such as Ultra Short Pulsed Lasers (USPL). ***FY 2022 Plans:***	0.915	0.965	0.979

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort			
Accomplishments/Planned Programs Subtotals	0.915	0.965	0.979

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, **RDT&E Project Justification:** PB 2022 Army			**Date:** May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
AA3: *Single Investigator Basic Research*	-	93.691	100.773	90.542	-	90.542	-	-	-	-	-	-

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 2020	FY 2021	FY 2022
Title: Basic Research in Life Sciences	11.890	12.102	10.592
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 2021 Plans: Elucidate empirical guidelines for the design of polyvalent deoxyribonucleic acid (DNA) origami that can bind a target with high selectivity and can interface with electrochemical systems to report binding that in the long term may reveal mechanisms to rapidly detect active viral pathogens at the point of care or in the field; determine how mitochondrial hydrogen sulfide affects health and functional cellular performance that in the long term may enable methods to modulate mitochondrial integrity in the treatment of post-traumatic stress disorder or possibly to extend the time that highly trained experienced warfighters can remain fit for duty;			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
define how mechanical stress can alter the assembly and efflux functions of the E. coli tripartite efflux pump that in the long term may enable new mechanisms to protect the warfighter from pathogens or to engineer microorganisms that will synthesize key materials or compounds even in remote locations; combine electrophysiological and mechanical recordings and manipulations to fully determine the forward and reverse coupling between the somatic membrane potential and active mechanical dynamics in Xenopus saccular hair cells that in the long term will elucidate the encoding of information by the auditory system and define new connectivity and modulation rules for noninvasive human-machine interfaces and artificial intelligence, with applications ranging from prosthetics for the wounded warrior to remote autonomous vehicles; investigate the empirical implications of the theoretical synthesis model, which indicate that in segregated groups the focus of collective action shifts from large-scales to local scales, that in the long term may lead to algorithms that accurately predict conflict emergence, particularly in urban environments, characterized by segregated communities, which will in turn enable enhanced mission planning and decision-making. ***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 H2S homeostasis in tolerant and non-tolerant 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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding that supports research in the area of impacts that can alter the assembly and efflux functions of the E. coli tripartite efflux pump was reduced to support the Army Advanced Biological Control Center and Army Advanced Energetics Center in PE 0601104A Project AB7.			
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	16.515	14.664	11.467

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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 2020	FY 2021	FY 2022
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 for identification by the enemy, and advance warning of explosive, chemical, and biological weapons and dangerous industrial chemicals. ***FY 2021 Plans:*** Design and assemble a novel photo-capillary reactor in which starting compounds will be mixed and exposed to multiple laser photons, harnessing photochemistry that depends on the wavelengths of the photons, the intensity of the laser pulses, and the time delay between the pulses, which will be used to characterize potential new energetic materials, that in the long term may enable new methods for chemical manufacturing and the creation of optimized energetic materials; synthesize polymers that mimic protein primary structure via a templated step-growth polymerization method that in the long term may lead to the creation of a new class of materials with properties inherent to biological materials, thereby enabling the design of materials that are smart, environmentally responsive, and self-healing; determine the fundamental design rules to access hydrochemically stable metal-organic frameworks with various functionalities and diverse topologies in aqueous media at room temperature, which in the long term may enable/lead to functional materials for more environmentally-benign chemical neutralization methods; generate a hot-electron, low temperature transient pulsed plasma using high voltage nanosecond pulses in the local vicinity of a surface containing Au nanoparticles, and use in situ spectroscopy to determine the reaction pathway, which in the long term may lead to the development of lower-weight power storage and generation. ***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 2021 to FY 2022 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
In FY 2022, funding that supports research in the area of polymers that mimic protein primary structure was reduced to support the Army Radio-Frequency (RF) Electronics Center and the Army Advanced Energetics Center in PE 0601104A Project AB7.			
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 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 2021 Plans:*** Determine the effects of the shape, curvature, and geometry of both one- two- and three dimensional conducting structures such as supersymmetry-enabled optical materials, on electromagnetic wave scattering properties, that in the long term may enable fundamentally-new ways to control light, enabling lighter components and lower power devices, which can lighten the warfighter? s load, as well the possibility of developing totally new functionalities, such as more sensitive detectors or capabilities at new wavelengths; investigate entanglement between trapped polar molecular ions for improving quantum state readout, optimized cooling, and dipolar entanglement that in the long term may enable the precision measurement of molecular transitions which is important for chem/bio detection capability and quantum metrology; co-trap molecular ion (CaH+) with an atomic ion (Ca+) within a selected transition, and then sympathetically cool the molecular ion, followed by performing an entangling operation between Ca+ and CaH+ acting as a qubit, that if successful may lead to future breakthroughs in quantum sensing, quantum spectroscopy, and quantum computing; electrically induce topological superconductivity in a single material system enabling the exploration of the related electronic phases that comprise and enable this possibility, and if successful, study the physics of the topological superconducting state, which in the long term may enable low-power electronics and enhanced applications in communications. ***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	16.519	11.607	12.065

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
that if successful would provide on-chip information processing and high-powered semiconductor microlaser sources for secure high-speed optical communications. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funding reduction reflects planned lifecycle of this effort because research into the study of topological superconducting state has ended.			
Title: Basic Research in Electronics and Photonics ***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 2021 Plans:*** Establish the physical limits of biological sensing and signal processing with precision quantum measurements on the nitrogen vacancy embedded in nanodiamonds that in the long-term could enable probing of the intracellular environment to significantly influence soldier medicine and performance; create novel optical responses in magnetic Weyl semimetal and multi-fold fermions that in the long-term could lay a foundation for new spintronic memory devices for high-speed information processing and energy efficient electronics; create efficient long-wave infrared (LWIR) detectors that in the long-term could enhance long-range detection and adaptive optical systems, and even enable free-space laser communications; investigate high efficiency and high-speed nanoscale, subwavelength light emitting diodes that in the long-term could lead to the development of photonic integrated circuits for extremely low energy data communication. ***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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding increased to support additional research into the relationship between genetic responses and bioelectric networks within cell communities.	6.242	10.449	8.852
Title: Basic Research in Materials Sciences	12.209	11.760	11.319

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 provide support for the Army in firepower, mobility, communications, personnel protection, infrastructure and installations, and will directly affect virtually all mission areas. ***FY 2021 Plans:*** Study fundamental liquid-surface interactions in order to design and create patterned and functionalized surfaces that in the long-term could provide passive water harvesting and novel decontamination devices; explore donor-acceptor charge transfer complexes and develop a series of new co-crystal materials that in the long-term could develop new tunable organic ferroelectric materials for advanced communications and sensing capabilities; investigate a novel colloidal assembly process for complex macrostructures that in the long-term could enable multifunctional materials that could simultaneously provide both structural support and power storage; research a new paradigm for force-responsive polymers based on a molecular ladder structure for an amplified response that in the long-term could enable new structural health monitoring strategies and advanced sensors. ***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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding that supports research in the area of donor-acceptor charge transfer complexes was reduced to support the Army Radio-Frequency (RF) Electronics Center and the Army Advanced Biological Control Center in PE 0601104A Project AB7.			
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,	6.076	11.188	8.818

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
energy generation and multi-dimensional systems, and solid mechanics especially at high strain rates in composite materials for novel armor and protection systems. ***FY 2021 Plans:*** Construct an elastic theory of active solids that are far-from-equilibrium that in the long-term could enable dramatically enhanced vibration mitigation and energy generation in military structures; design and investigate novel composites with triply periodic minimal surface structures that in the long-term may lead to unique lightweight structures for mechanical support, thermal conservation and impact shielding; conduct the first ever simultaneous measurements of velocity and temperature, in situ, for a reacting turbulent combustion event that in the long-term may provide critical validation of engine model codes for revolutionary future engine design; and determine the effects of compressibility on the complex flow physics of stability and transition in boundary layers for the transonic flight regime that in the long-term could provide new paradigms for future transonic energy efficient aircraft. ***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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding was increased to support additional research in the area of the Ultra-Short Pulse Off-Axis Digital Holography (USPODH) technique proof-of-concept work.			
Title: Basic Research in Computing Sciences ***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 2021 Plans:***	6.199	8.648	6.641

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Create distributed algorithms that are dynamic, flexible and can scale and adapt to the massive degree of heterogeneity present in new and future computer architectures or applications and the massive amount of data that characterize future computing needs; investigate methods based on Bayesian modeling, information theory and information physics to characterize semantic information content in multimodal data; establish new scientific understanding in managing long and short term memory models that enable life-long learning while mitigating the effects of catastrophic forgetting; explore and gain new insights into visual concept reasoning by extending the deep reinforcement learning theory for estimating probabilistic rewards; and developing new graph matching techniques to infer new links between known objects in a dynamic visual environment; establish resilient and robust learning and adaptation techniques for better cyber defense in contested domains where the environment and system characteristics may change rapidly and unpredictably over time due to adversarial manipulations and attacks. ***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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding that supports research in the area of learning and adaptation techniques was reduced to support the Army Radio-Frequency (RF) Electronics Center and the Army Advanced Biological Control Center in PE 0601104A Project AB7.			
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 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 2021 Plans:*** Design low overhead millimeter-wave (mm-Wave) mobile ad hoc networks (MANETs) for highly-mobile vehicular systems with side information such as position and motion, direction of users, terrain and environment information, and locations of surrounding	12.955	10.807	10.946

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
objects; investigate properties of social networks for graph separator properties, which can then be used to design compositional algorithms for applications such as the problem of processing incredibly large graphs (millions to billions of nodes and edges) to identify small portions of it that are important in the context of understanding societies -- e.g., small adversarial groups embedded in large urban population; study brain structure (i) to analyze time-varying synchronization patterns in brain networks with new theories and tools aimed at characterizing how localized perturbations may have their network-wide effects and (ii) to discover optimal information transmission (and possibly control) of brain networks by exploiting the geometric structure of interconnection patterns for well-defined cognitive processing tasks; investigate a theoretical framework for an Intelligent Trust Modulation (ITM) system for Human-Agent Teams that uses multimodal sensors to measure human, machine, and team ?states? relating to trust, and intelligently selects real-time adaptations of system components to optimize team trust dynamics and team effectiveness. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding reduction reflects planned lifecycle of this effort because research into an Intelligent Trust Modulation (ITM) system has ended.			
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 2021 Plans:***	5.086	9.548	7.342

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Create new mathematical tools and methods for performing complex, multi-system analysis and modeling to enhance soldier and weapon-system performance, including investigation of mathematical principles and algorithms for rapid/reliable statistical inference, computational capability for new scientific understanding and advanced design, analysis and control of biological systems, and modeling of complex systems; model brain circuitry with realistic dynamics, combined with information processing and learning, through multiscale, multiphysics properties of the brain combined with biologically realistic learning rules to train the models to generate purposeful behavior, that will enable development of better biologically-inspired AI applications that can more transparently interact with humans in a closed loop, improving human-agent teaming; expand machine learning techniques beyond optimal functions on a single data set that is then extrapolated to others, to instead find many good functions on a data set and extrapolate them in a way to generate many predictions which can be used to establish a level of confidence in the prediction; study mathematical language tools to manipulate both physical process and analytic properties together in a potentially arbitrary number of dimensions, which physicists could use as basis for new quantum information science capability; investigate mathematical tools (statistical hypothesis testing, modeling of geometric flows over networks) to enable logistics planners to account for task organization, scheme of maneuver, and environment in generating forecasted logistical demand by priority and to optimize the flow of sustainment through the logistics network. ***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 2021 to FY 2022 Increase/Decrease Statement:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
In FY 2022, funding increased to support additional research in the area of a mathematical network of interlocking analogies between physics, topology, logic, and computer science.			
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 2021 to FY 2022 Increase/Decrease Statement:*** in FY 2022, funding realigned from Basic Research in Life Sciences, Basic Research in Chemical Sciences, Basic Research in Physics, Basic Research in Electronics and Photonics, Basic Research in Materials Sciences, Basic Research in Mechanical Sciences, Basic Research in Computing Sciences, Basic Research in Network Sciences, and Basic Research in Mathematical Sciences within this Project to support HBCU/MI institution extramural research in the areas of chemical sciences, computing sciences, electronics and photonics, life sciences, material sciences, mathematical sciences, mechanical sciences, network sciences, and physics.	-	-	2.500
Accomplishments/Planned Programs Subtotals	93.691	100.773	90.542

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
AA4: *Training and Human Science Research*	-	19.949	21.322	21.781	-	21.781	-	-	-	-	-	-

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 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 2020	FY 2021	FY 2022
Title: Translational Neuroscience ***Description:*** This effort integrates neuroscience with traditional approaches to understanding Soldier behavior to enable system designs that maximize Soldier performance. ***FY 2021 Plans:*** Examine the relationship between arousal and visual search accuracy in degraded visual environments; investigate network methods to understand rapid neural dynamics that predict future behavior; establish methods to determine the role of environmental context on visual target detection and identification. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	3.646	3.964	3.998
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 2021 Plans:*** Generate novel approaches to predict fluctuations in marksmanship accuracy to enhance the performance of closed-loop systems; create generalized models using machine learning methods that improve signal detection robust to time and environment changes; investigate algorithms to integrate information over multiple timescales from hybrid teams for improved situational awareness; identify metrics to improve adaptive human-autonomy joint decision making in crew station scenarios. ***FY 2022 Plans:***	5.203	5.200	5.290

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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; 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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
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 2021 Plans:*** Investigate approaches for modeling how individual differences impact team dynamics; investigate heart-based metrics that can robustly predict changes in task performance; research methods to continuously measure and assess social interactions, physical activity, and task dynamics in real-world contexts. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	4.055	4.162	4.395
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 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 2021 Plans:***	1.070	1.336	1.342

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Identify methods to utilize immersive technologies and individual differences to improve training for spatial tasks and efficient navigation. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
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 2021 Plans:*** Study techniques to reduce data requirements for autonomous systems by incorporating knowledge from humans using natural interactions. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	0.760	0.999	0.981
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 2021 Plans:*** Conducting research to identify individual contribution to performance within a group; conducting research to develop new integrative framework of implicit personality; conducting research in psychometric models for sensor data sources (e.g., data streams). ***FY 2022 Plans:***	2.658	1.887	1.968

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
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 2021 to FY 2022 Increase/Decrease Statement:*** N/A			
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 2021 Plans:*** Conducting research studying a theory of event-based leadership and identify contextual factors impacting individual and group decision making. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	-	0.899	0.932
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 2021 Plans:*** Conducting research on mathematical algorithms for composing teams and assessing team performance; conducting research to understand and model social contagion of motivation within groups. (e.g., how does motivation spread among group members). ***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.	2.557	1.888	1.888
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.	-	0.987	0.987

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		**Date:** May 2021
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 2020**	**FY 2021**	**FY 2022**
FY 2021 Plans: Conducting research on adaptive performance to identify predictors and barriers to behavior change and learning; conducting research to develop an integrated framework of self-regulated learning behaviors, motivation, and attitudes related to individual and group informal learning. ***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.			
Accomplishments/Planned Programs Subtotals	19.949	21.322	21.781

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		**Date:** May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
AA5: *Biotechnology and Systems Biology*	-	5.511	6.042	6.076	-	6.076	-	-	-	-	-	-

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 2020	FY 2021	FY 2022
Title: Engineered Biotechnology (previously titled: Biological and Bio-derived Materials and Devices) ***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 2021 Plans:*** Utilize established bioprospecting, bio-panning and high throughput screening capabilities to identify potential individual microbes and communities for materials degradation; investigate modeling and experimental techniques to design and build microbial communities; investigate the role of microbial / material interfaces in degradation and assembly processes for tunable adhesion to control optical/electronic properties. ***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	2.326	2.572	2.577

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
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 2021 to FY 2022 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 2021 Plans:*** Identify discovery tools to bridge gaps in foundational understanding of materials production and harnessing of indigenous biology in military environments; identify materials and biologically derived assembly techniques for tuning material and system performance; research tools for manipulation and control of Army relevant organisms enabling access to targeted material production and operational environments, investigate synthetic biology derived sense and respond circuits for biological microorganisms; identify tools to link bioinformatics and materials informatics for high throughput data analysis. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	3.185	3.470	3.499
Accomplishments/Planned Programs Subtotals	5.511	6.042	6.076

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		**Date:** May 2021
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA5 / *Biotechnology and Systems Biology*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army			Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
AA6: *Robotics and Mobile Energy*	-	20.807	22.353	20.793	-	20.793	-	-	-	-	-	-

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 Research Centers).

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

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 2021 Plans:*** Investigate ultra-high temperature materials and coatings in a high temperature continuous combustion environment to enable the development of future Army propulsion systems with higher power density. ***FY 2022 Plans:***	0.864	1.225	1.395

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding increased to support additional research in the area of coupled fluid structure interaction models.			
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 2021 Plans:*** Investigate ignition chemistry of novel aviation fuel blends determine the ignition map formulation for wide-range ignition models to support robust engine control schemes; investigate novel tribological materials to enable reliable low viscosity fuel delivery from storage to the site of energy conversion; investigate advanced lightweight aluminum alloys for application under extreme thermomechanical dynamic stresses to enable the development of reliable engine components with reduced weight. ***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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding decrease reflects planned reduction in research in the area of novel tribological materials.	3.827	3.696	3.354
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 materials for topological insulators for energy conversion, and new designs for solar cells.	1.051	1.235	0.930

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
FY 2021 Plans: Investigate the process of nuclear excitation by electron capture (NEEC) as a means of releasing energy stored in nuclear isomers for a potential disruptive power source; investigate aqueous battery chemistries involving multi-valent cations (e.g., Zinc and Magnesium)) and the protection of anode surface low potential materials (e.g., graphite and Lithium metal); study the electrochemical and catalytic processes with advanced infrared spectroscopic methods to explore novel approaches to improve the stability and performance of battery and other electrochemical energy storage/conversion devices. ***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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding was reduced in this effort because research into aqueous battery chemistries ended.			
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. ***FY 2021 Plans:*** Investigate novel approaches of combining material informatics, artificial intelligence/machine learning, and classical mechanics to achieve new mechanics to predict materials behavior and structural properties to enhance the performance and resilience of advanced air vehicle structures. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** In FY22, funding is realigned to PE 0601601A (Artificial Intelligence Basic Research) / Project CL3 (AI/ML Basic Research Hub) to focus on advanced efforts in Artificial Intelligence, as part of the Program Evaluation Groups (PEG) efficiency drill	1.225	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 2021 Plans:***	0.826	0.999	0.981

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
Investigate and design robust, reconfigurable vehicle structures that will enable future air vehicles to function efficiently and adapt to several operational modes; investigate novel approaches to synthesize bio-inspired material systems capable of mimicking distributed energy mechanisms, to enable complex motions for stability, robustness, and compliance in dynamic platforms. ***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 vertical take-off/landing (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 2021 to FY 2022 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 2021 Plans:*** Investigate methods to enhance intelligent robotic performance and reduce algorithmic brittleness in a mission-relevant and hybrid teaming context; determine mechanisms to enhance resilience of robotic performance; establish methods to increase robotic operational tempo under supervised and unsupervised autonomous operating conditions; explore impacts and methods to mitigate sporadic network connectivity. ***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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding increased in this effort to support additional research into autonomous power distribution between ground and air vehicles.	1.201	1.513	1.632
Title: Intelligent Systems	6.059	5.884	6.166

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
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 2021 Plans:*** Conduct fundamental research to extend the techniques of transfer learning, reasoning, and reinforcement outside of simulation to live environments; investigate previous work in intelligence architecture frameworks across distributed heterogeneous agents to include distributed world models and shared representations. ***FY 2022 Plans:*** 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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects 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 2021 Plans:*** Investigate new experimental aeromechanics approaches for characterizing and optimizing efficiency, speed, and maneuverability for novel advanced vehicle configurations; investigate the effects of interactional aerodynamics associated with the transition from vertical flight to forward flight for novel vertical lift unmanned air vehicle concepts; research methods to capture human agents, enemy behavior, and human-agent interaction in multi-agent simulation framework; investigate fluid-structure interaction models to inform the structural design of an adaptive Unmanned Aerial Ssystem with enhanced aerodynamic performance. ***FY 2022 Plans:***	2.827	2.997	3.019

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
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 2021 to FY 2022 Increase/Decrease Statement:*** Funding increase 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 2021 Plans:*** Conduct experimental and computational investigations to better understand interactional aerodynamics of multi-rotor configurations by exploring pioneering flow measurement techniques and novel numerical algorithms/methods; conduct computational aero-science investigations using numerical methods including work on validating the physical assumptions forming the building blocks of the underlying theory. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	2.333	2.504	2.576
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	0.594	0.762	0.740

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
directed at understanding advanced mathematical and computational methodologies using state-of-the-art analytical and empirical procedures. ***FY 2021 Plans:*** Continue to review and quantify the effectiveness and efficiency of the multi-scale computational algorithms for modeling a military ground vehicle traversing over fine soil particles; apply deep learning algorithms for generating Go/NoGo maps to other geographic regions; continue to expand human cognitive models based on use cases and human roles for integration into autonomy modeling; explore intelligent autonomous mobility technologies integrating minimal sensor configurations, deep-learning based terrain identification, high-fidelity mobility simulations, robust path planning and control, all on-board and in real time; investigate a terrain deoxyribonucleic acid concept that correlates to distinct mobility performances. ***FY 2022 Plans:*** 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 2021 to FY 2022 Increase/Decrease Statement:*** N/A			
Accomplishments/Planned Programs Subtotals	20.807	22.353	20.793

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, **RDT&E Project Justification:** PB 2022 Army		**Date:** May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
AA7: *Mechanics and Ballistics*	-	32.734	35.368	33.359	-	33.359	-	-	-	-	-	-

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); 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 2020	FY 2021	FY 2022
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	5.284	5.000	5.394

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
mechanisms through increased understanding of wave propagation through tissue, and the resulting deformation and damage of tissue during ballistic and blast events. ***FY 2021 Plans:*** Investigate computational methods and perform ballistic experiments on lightweight metal alloys and brittle materials to capture multiple deformation and failure mechanisms occurring simultaneously under ballistic and blast loading conditions; perform novel experiments to probe and quantify high-rate deformation mechanisms at small length scales to improve multi-scale computations; investigate a human-derived thorax model for measuring and relating the human structural and injury response in ballistic impacts to produce substantiated design parameters for personal protection systems. ***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 2021 to FY 2022 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 2021 Plans:*** Investigate nanostructured materials properties achieved through novel processing routes for potential use in and transition to vehicle armor and lethality applications. ***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	2.971	3.245	3.307

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
diamond content composite ceramic materials to include large enough specimens for sub-scale ballistic assessments for high-rate and resultant microstructural characterization. ***FY 2021 to FY 2022 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 2021 Plans:*** Investigate material mechanisms in metals, ceramics and polymers which contribute to novel behaviors at high rates of loading, making them suitable for lethality and protection applications. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	3.096	3.386	3.410
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 2021 Plans:*** Investigate the use of field-based processing methods to influence microstructural control, phase transformation, and texturing behavior in various materials systems. For metals, processing under magnetic fields will lead to the determination of mechanisms and development of descriptive models to enable enhanced diffusion control and expansion of manufacturing process space, particularly in additive manufacturing. For ceramics, field-based parameters and conditions are investigated to develop an intelligent processing capability that incorporates in-situ characterization, modeling, and real-time processing controls to fabricate consistent, high performance materials. ***FY 2022 Plans:***	2.254	2.478	2.488

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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; optimize processing methodology to produce samples large enough to conduct ballistic testing to assess if new material meets performance requirements. ***FY 2021 to FY 2022 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 2021 Plans:*** Explore synthetic methods to produce novel 2D polymer molecules and examine the assembly of platelets into ensemble films; explore structure-property relationships of 2D films, in an attempt to assess their mechanical properties for ballistic applications. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.286	1.690	1.663
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 2021 Plans:*** Investigate the biological synthesis of inorganic materials, biopolymers, and composites for scalable integration and processing with an emphasis on materials for electro-optic, electromagnetic, and sensing applications; investigate strategies for scalable integration that are compatible with large scale polymer and industrial processes; explore synthetic high throughput biology routes	1.523	1.815	1.811

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
to engineer biological systems for tunable material properties such as elemental doping of structures and creation of tunable scaffolding; explore integration strategies for living/responsive function that can leverage microorganism response to external triggers. ***FY 2022 Plans:*** 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 2021 to FY 2022 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 2021 Plans:*** Investigate computational tools for coupling of thermal-fluids and structural mechanics with analysis of high-speed munitions; explore the feasibility of adding chemistry to tools for propulsion and/or plasma applications; research munition control technologies (e.g., flight control algorithms, control mechanisms) to improve maneuverability of small munitions in extreme mechanical and thermal environments and gain further understanding using advanced coupled mechanics computations; understand basic phenomena (e.g., shock interactions, thermal loading) associated with high speed munition flight using computational tools and experimental data; formulate basic estimation theory for multiple agents with constrained sensors and actuators; research estimation algorithm and image processing frameworks which combine model-based and data-driven approaches. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	2.846	3.192	3.214
Title: Energetic Materials Research	3.350	3.648	3.621

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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. ***FY 2021 Plans:*** Continue synthesis of new energetic ingredients and polymers for use in gun propellants; refine new melt cast ingredients and formulations identified in FY20; analyze performance characteristics of disruptive-type materials (e.g. extended solids and fast reacting metals) and structural reactive materials; validate and verify response to dynamic compression of ingredients developed in FY20; continue numerical simulations that aide in understanding the kinetic rates of newly developed propellants and propulsion technologies. ***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 2021 to FY 2022 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 2021 Plans:*** Continue to research urban land surface energy budget and radiative transfer processes using data collected at the MSA testbed and apply machine learning techniques to MSA data to identify previously unknown complex terrain and urban processes and for anomaly detection; conduct laboratory investigation of aerodynamics of vertical takeoff and landing Unmanned Aircraft Systems, and integration of environmental sensors to facilitate environmental awareness essential for autonomous flight; research thermal and momentum flux of sloping surface under stratification to better treat physical processes in complex and urban terrain, and adequately express the uncertainty for decision support tools; couple a newly-developed radiative transfer code with the Atmospheric Boundary Layer Environment-Lattice Boltzmann Method (ABLE-LBM) forecast model and conduct initial simulations of idealized, radiatively-forced boundary layers; evaluate the performance of emerging acoustic vector sensing hardware/data as applied to beam forming (source-localization) and atmospheric acoustic tomography; assess the viability of multi-aperture	3.846	3.900	4.162

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
remote sensing capability for atmospheric aerosol, wind, and temperature retrieval; characterize, quantify, and assess the impact of atmospheric conditions on aerosols using optical characterization techniques (e.g., elastic and inelastic scattering) in the laboratory and the field. ***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 2021 to FY 2022 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). ***FY 2021 Plans:*** Incorporate uncertainty model predictions and a basic set of non-deterministic aspects of microstructure and it?s evolution into numerical methods for computer models of materials; assess predictive capabilities of selected new at-scale models for simple material systems; enable ?on-the-fly? delta-machine learning approaches for lower-accuracy models, yielding full resolution Density Functional Theory (DFT) accuracy at near classical computational speed or cost; investigate electro-optical vertical transport models for real devices; investigate hydrodynamic transport modeling to topological materials to understand and validate physics within material and devices. ***FY 2021 to FY 2022 Increase/Decrease Statement:***	3.262	3.546	-

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
In FY 2022, funding was realigned from this effort to Terminal Ballistic Design and Evaluation for Next Generation Materials within this Project and to support Physics-Informed Machine Learning for Complex Phenomena in PE 0601102A Project AA8.			
Title: Environmental Quality ***Description:*** This effort conducts research on innovative environmentally-friendly technologies that support the warfighter focusing on pollution prevention technologies. ***FY 2021 Plans:*** Perform basic research to understand and reduce the environmental impact of energetic compounds, their chemical pre-cursors, and solvents used during their processing and formation; characterize and synthesize novel, nanoparticles for easier chemical detection of trace compounds; study controlled electrodeposition techniques from ionic liquids for the synthesis of new class of layered coatings for corrosion protection of materials used in armament systems; research a statistical method for the screening of alternative solvents for energetic materials to reduce the environmental impact of energetic material synthesis; study the mechanism for adhesion and colonization of the primary colonizing fungi on composites reduce fungi growth on materials. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	0.859	1.107	1.109
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 2021 Plans:*** Continue studies to understand and characterize chemical and biochemical phenomena occurring at or near solid surfaces and material interfaces, to include transport, binding energy, deposition, chemical reactivity, and interactions between these	2.157	2.361	2.386

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
processes; conduct basic research to understand effects of surface structure, morphology, and surface group properties; and continue to study the theory and investigate models of processes at complex surfaces. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
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:*** 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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding realigned from Multiscale Modeling for Novel Materials effort within this Project.	-	-	0.794
Accomplishments/Planned Programs Subtotals	32.734	35.368	33.359

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army			**Date:** May 2021
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA8 / *Sensing and Electromagnetics*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
AA8: *Sensing and Electromagnetics*	-	8.229	9.006	13.611	-	13.611	-	-	-	-	-	-

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 2020	FY 2021	FY 2022
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. ***FY 2021 Plans:*** Explore fundamental issues limiting extraction efficiency and injection efficiency in deep ultraviolet emitters; investigate the use of III-Nitride semi-polar planes to increase light extraction in light emitting diodes operating in the solar-blind region; examine carrier transport in these structures through experiment and modelling. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding realigned to HEL Materials and Thermal Management in this Project.	0.886	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	2.675	2.699	3.465

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
semiconductor transistors, including neuromorphic computing structures and topological insulator based heterostructure with low operating voltage. ***FY 2021 Plans:*** Understand and optimize growth conditions of topological crystalline materials to achieve the necessary properties to create proof of concept device structures; investigate, characterize, and model interface physics between semiconductors exhibiting topological properties and ferromagnetic materials to optimize predicted low power switching capabilities; investigate methodologies to achieve desired topological device effects that can be achieved under real-world conditions (e.g., at or near room temperature); study diamond interface devices based on single crystal diamond and transition metal oxides with the objective of using superior thermal properties of diamond for high power radio frequency (RF) applications. ***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 neuromorphic computing; study the electrical properties of silicon terminated diamond surfaces with the objective of operative transfer doping at higher temperatures. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funding realigned from Materials Science for Army Power and Communications within this Project to support additional research in diamond material properties for radio frequency and power electronic devices.			
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 2021 Plans:*** Research methods to improve the speed and utility of full-wave electromagnetic scalar and vector Helmholtz solvers for extremely large (up to a trillion elements) quasistatic-, magnetic- and electric-field sensing problems with distributed processing; study multi-function, acoustic particle-velocity-based, multi-target algorithms; investigate robust, inexpensive, multi-axis vector sensors for airborne and terrestrial mechanical wave exploitation; research robust methods to enhance perception of targets from onboard Size, Weight and Power (SWaP) constrained platforms; understand and create new radar data. ***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	1.543	1.716	1.742

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 3D low-frequency electromagnetic fields, acoustic particle velocity, and torsional seismic waves. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
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 power components. Materials, designs, and fabrication techniques will be studied for the future development of Micro-Electro-Mechanical Systems (MEMS) for radio frequency (RF) devices and sensors. ***FY 2021 Plans:*** Examine fundamental issues leading to high leakage currents in wide band gap, silicon carbide (SiC) diode structures under bias conditions resulting in internal electric fields; fabricate p-i-n diode structures to identify sources of leakage current; explore impact of modifying trap states on leakage currents in the diode structures through deep level transient spectroscopy, ultra-fast time resolved spectroscopy, and leakage current measurements; conduct multiscale modeling of the hybrid aqueous electrolytes to assist design of safe batteries with an improved energy density and fast charge; study methods to improve ion transport prediction accuracy to within 15% of the experimentally measured values; conduct multiscale modeling of selective ionic transport and energy conversion during electrochemical redox under dynamic field changes. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding realigned to Advanced Materials Research within this Project in FY 2022.	1.500	1.664	1.177
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 Global Positioning System (GPS)-denied, actively jammed, or austere environments.	0.535	0.709	0.729

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2021 Plans: Fabricate and perform experimental analysis of environmentally stable (i.e., temperature, vibration) electro-optic air-ring resonator using specialized indium tin oxide materials deposited on a silicon metamaterial structure. ***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 2021 to FY 2022 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 2021 Plans:*** Measure reaction rates of metal oxide photoelectrode materials and characterize the interaction mechanisms of metal oxides with aqueous toxic chemical solutions to inform future advancements in water remediation and decontamination; conduct experiments to gain mechanistic understanding of the impact of transcranial electrical stimulation on muscle output (i.e., isokinetic and whole-body kinematic performance) to inform development of future systems intended to moderate neuronal activity to enhance cognitive and motor performance. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.090	1.219	1.233
Title: 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	-	-	1.290

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding realigned from Electro-Optic Materials Research within this Project, and from all the Projects in Basic Research portfolio as part of the Program Evaluation Groups (PEG) efficiency drill.			
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 radio frequency (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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding realigned from Multiscale Modeling Novel Materials in PE 0601102A Project AA7.	-	-	3.275
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 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,	-	-	0.700

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 2021 to FY 2022 Increase/Decrease Statement:*** Funding realigned from all the Projects in Basic Research portfolio as part of the Program Evaluation Groups (PEG) efficiency drill.			
Accomplishments/Planned Programs Subtotals	8.229	9.006	13.611

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army			**Date:** May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
AA9: *Information and Networking*	-	37.502	40.376	40.540	-	40.540	-	-	-	-	-	-

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 (Networks 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 2020**	**FY 2021**	**FY 2022**
Title: Communications in Complex Dynamic Networks ***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.	5.532	5.475	5.337

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2021 Plans: Research methods for the control of social, information, and communication networks (and composite networks thereof) that enable enhanced operation in complex dynamic tactical environment through, e.g., software configurability, incorporation of the operational context of information within the network(s), scalable energy-efficient protocols, and/or the augmentation with unconventional communication and networking modalities; conduct simulation, emulation, and experimentation of such networks accounting for requirements on heterogeneity and scalability, and will utilize results to investigate novel improvements to network control methods; explore and characterize the performance of communication and networking methods that address adversarial physical and cyber threats to the network through, for example, the adaptive use of low-probability-of-detection techniques. ***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 2021 to FY 2022 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 2021 Plans:*** Explore fundamental understanding of, and theories for, decision making phenomena in immersive environments and massive amounts of Joint, Coalition, and/or multi-domain data; research theories and methods that deliver accelerated decision making for tactical and military intelligence, through the use of virtualization and machine learning augmented autonomous and human information interaction techniques; investigate fundamental issues in defining an enhanced event ontology for multimodal event representation with support for causal and temporal reasoning by intelligent systems that augment Solder decision-making; define annotation approaches for situated training data, conduct investigation of statistical, rule-based, and other algorithmic approaches for information transformation to create an abstract semantic representation for multi-domain data from heterogeneous information	4.850	5.221	4.228

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
sources; create theoretical models of the features and characteristics in military artifacts that are the most relevant to course of action generation and disposition; study knowledge elicitation techniques and conduct human-in-the-loop empirical studies of tactical operations to define knowledge representation models optimized for inferencing and real-time situational awareness. ***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 and construct knowledge networks for concept recognition, explanation, and inferences for downstream analytics to support collaborative decision making. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, a portion of the funding has been realigned to support Machine Learning for Intelligent Agent and Human Decision Making within this Project.			
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 2021 Plans:*** Investigate secure communication protocols that can be practically implemented in tactical (resource-constrained) environments by featuring the adaptability of theoretical guarantees on the level of security as a function of the finite available (e.g., computational, energy, and/or communication bandwidth) resources and that optimize for broadcast and network security (not just for point-to-point links); model and characterize the effect of communication channels and networking devices on the transfer and use of quantum entanglement and create protocols to mitigate deleterious effects; research methods on intrusion detections, malware defense, data modeling, game theory, autonomy and resilience for military systems on both tactical and enterprise networks and provide resilience in robust and austere environments; research new algorithms and methodologies for deceiving attackers; explore tradeoffs between machine learning-enabled deception and information capacity for contested tactical networks in efficiently conveying battlefield environment awareness. ***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	4.610	4.742	5.086

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 2021 to FY 2022 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. ***FY 2021 Plans:*** Define computational approaches for incorporating natural language into human-robot interaction to create dialog management system software capable of semantic comprehension of ambiguities, lack of specificity, and op-tempo communication for future application to Soldiers in the field conducting route reconnaissance, intelligence preparation of the battlefield, and multi-domain operations; explore neural machine translation approaches for document exploitation to identify fundamental issues in information transformation that maintains context, intent, and linguistic accuracy given data-driven machine learning techniques. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding and research realigned from this effort to Machine Learning for Intelligent Agent and Human Decision Making within this Project.	0.890	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 2021 Plans:*** Investigate and create novel approaches for enhanced computing by optimizing for size, weight, and power of computational resources; investigate new approaches using reconfigurable computing for machine learning using convolutional neural networks that will fit in memory-constrained deployed platforms; research new methods to categorize computing capacity of deployed devices to facilitate processor selection and assignment to required computing task; study training of decentralized reinforcement	3.502	3.891	3.910

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
learning agents to optimize a diverse set of properties (e.g., security, efficiency, etc.) while maintaining communication integrity in mobile networks. ***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 2021 to FY 2022 Increase/Decrease Statement:*** 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 2021 Plans:*** Research methods for the identification and detection of structure, dynamics, and/or traffic in social, information, and communication networks that correlate with network performance, and will create protocols for adapting network formation and/or operation based on such identification/detection; create and characterize methods for obscuring pertinent features of network operation from adversarial interpretation, and identify and characterize potential vulnerabilities and exploits (and corresponding mitigation strategies) of machine-learning-based network protocols; research Intrusion Detection Systems (IDS) using Machine Learning (ML) linear classification; investigate theories to defend against ML based IDS that have been compromised by adversarial ML techniques; create methods for construction of surrogate models of battlefield environments to expedite uncertainty quantification; create grounding theory and machine learning algorithms that measure and automate information interoperability, quantify information/model uncertainty, and aggregate information; investigate algorithmic approaches to uncertainty quantification in machine learning models and formal theories for network/system state estimation under adversarial machine learning conditions; research theories algorithms to identify, characterize, and exploit the value of information from sensor and other information assets for information dissemination and mediation. ***FY 2022 Plans:***	5.753	6.000	6.331

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2020**	**FY 2021**	**FY 2022**
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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding increased to support additional research in the area of low-complexity, distributed and robust cyber techniques.			
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 2021 Plans:*** Investigate and evaluate algorithms enabling intelligent sharing of system control between humans and autonomous artificial agents and machine learning techniques that can learn from real-time interaction with humans via demonstration, intervention, and feedback modalities; explore methods to address challenges of online learning over streaming data and reasoning over incomplete semantic data to predict, rank, and recommend courses-of-action for autonomous and human-collaborative decision makers; investigate theories and machine learning algorithms that automate reasoning, learn and predict information requirements and preference, and minimize information search for the purposes of accelerating autonomous and non-autonomous decision making; explore neural network and machine learning methods to create custom acoustic models for future application to adaptable automated speech recognition components that can rapidly adapt to sub-population language, military domain terminology, and task-specific communication between coalition partners and during joint human-agent collaboration; research methods for Cyber situational awareness & threat classification methods; research active defense algorithms and risk assessment for vulnerability exploitation. ***FY 2022 Plans:***	3.600	3.981	5.758

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 2021 to FY 2022 Increase/Decrease Statement:*** In FY22, funding has been realigned from Naturalistic Behavior for Shared Understanding and Explanation with Intelligent Systems, and Data to Knowledge to Support Decision Making (Information Mediation) to this effort to support additional research in tactical behaviors of intelligent systems.			
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 2021 Plans:*** Create artificial intelligence/machine learning algorithms for real-time scene understanding and situational awareness from multimodal imaging sensors on distributed heterogeneous aerial and ground, manned and unmanned, platforms for potential application to mobility and maneuver engagement scenarios; identify point-of-need image data exploitation methods capable of real-time inference on size, weight, and power-limited computing architectures at the edge; research synthetic data generation methods to augment limited availability of real-world data to enhance algorithm training and effectiveness; investigate computational vision approaches for enhanced scene understanding in visually degraded 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	1.874	2.231	2.235

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
understanding performance retention in resource constrained computation environments such as low size, weight, and power (SWaP) processors onboard unmanned air and ground vehicles. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
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. ***FY 2021 Plans:*** Better understand charge transfer mechanisms from hydrogen terminated diamond surfaces to suitable electron acceptor layers; conduct research on the growth of topological materials and fabricate heterostructures of topological crystalline materials along with ferromagnetic insulator thin films; investigate and optimize the interplay between a topological material and the ferromagnetic insulator to understand the device characteristics of the topological heterostructures and determine if theoretical predictions can be realized under real-life conditions; investigate radiation tolerance of wide-band-gap semiconductors for betavoltaic energy conversion and quantify the measured performance degradation using 1-200keV electron beams. ***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 radio frequency (RF) components; investigate mechanisms for detection of circular polarized light in several topological materials through growth and characterization for efficient communications. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.635	1.947	1.948
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	5.256	5.662	5.707

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
matter interfaces, including optical cavities, nanophotonics, and high density atomic systems. This effort also explores quantum algorithms for entanglement distribution. ***FY 2021 Plans:*** Conduct research to achieve a broad understanding of strong interactions between light and quantum systems for ultrasecure communications and enhanced sensors; study quantum information storage in atomic ensembles and how to multiplex read/write quantum operations; investigate limits of Rydberg atomic systems for radio frequency and microwave sensing and communications for novel communications schemes; explore interactions between nanophotonic systems with cold atoms; research silicon-carbide growth capabilities for high-quality solid-state defects as qubits and sensors; and identify entanglement-enhanced measurement and sensing in cold ion systems. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.			
Accomplishments/Planned Programs Subtotals	37.502	40.376	40.540

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
AB1: *Basic Res in infect Dis, Oper Med and Combat Care*	-	31.269	31.957	37.103	-	37.103	-	-	-	-	-	-

Note

In FY 2022 this Project funding was realigned from:

PE 0602787A (Medical Technology)
*Project MM4 (Cbt Casualty Care Applied Rsch Technology)
*Project MK4 (Warfigher Health Applied Rsch Technology)

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.

FY20 realignments are due to financial restructuring in support of Army Modernization Priorities.

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

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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. ***FY 2021 Plans:*** Identify candidate key additives for improving platelet and whole blood storage that delay or inhibit the biochemical processes leading to platelet death during storage; expand on previous stem cell studies to include feasibility for use to treat traumatic hemorrhage; conclude cell culture screening of drugs that protect cells from the effects of blood loss and oxygen deprivation;	1.573	1.640	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
perform basic research studies to identify candidate components for engineered plasma to reverse impaired blood clotting that occurs subsequent to severe trauma. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned to other efforts within Project AB1 (Hemorrhage, Shock, Coagulopathy of Trauma).			
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. ***FY 2021 Plans:*** Study new conceptual approaches to accelerate healing of severe burn wounds; perform studies to better understand the human immune response to skin grafts; perform basic research to better understand stem cell use as means to reduce inflammation and organ injury following severe burns. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned to other efforts within Project AB1 (Burn Injury, Expeditionary Medicine).	1.410	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 2021 Plans:*** Perform conceptual studies to guide development of animal models to assess novel agents that protect the kidney during hemorrhage with and without resuscitation, and to assess effects of blast injury on the ability to survive hemorrhage as well as the effect of hemorrhage on neural damage induced by blast injury; perform conceptual studies to support minimally invasive control of non-compressible hemorrhage; characterize cellular effects of crush injury. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned to other efforts within Project AB1 (Endovascular Hemorrhage Control).	1.258	1.411	0.909
Title: Traumatic Brain Injury	1.300	1.356	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 2021 Plans:*** Perform conceptual studies to guide animal model development for assessment of novel treatments for severe traumatic brain injury that may be administered by combat medical personnel at the point of injury. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned to other efforts within Project AB1 (TBI Neurotrauma/Brain Dysfunction).			
Title: Prolonged Field Care ***Description:*** This effort performs basic research to study the physiological implications of delayed medical evacuation and limited access to definitive surgical care in severely injured casualties. ***FY 2021 Plans:*** Characterize changes that occur within the cells that line the arteries when oxygen-carrying blood substitute drugs are introduced into the body; explore novel approaches to treat lung injury; examine feasibility of possible new treatments for sepsis (life-threatening complication of an infection) following trauma; characterize ability of stem cells to mitigate organ failure following traumatic injury in rodent models; perform conceptual studies to identify new approaches to accelerate healing of orthopedic injuries; utilize computer modeling simulations to characterize biological changes to the pain system following traumatic injury; identify novel pain therapeutic targets based on computer models, and investigate these targets in both currently utilized and newly developed animal models of traumatic injury; investigate newly identified targets as potential biomarkers for pain and analgesic efficacy. ***FY 2022 Plans:*** Will perform In vitro and in vivo efficacy studies of medical treatments for burn in environments contaminated with nerve agent. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned to other efforts within Project AB1 (Biology of Operational Pain).	0.814	2.729	2.418
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) injury. Also includes the characterization of ocular injury pathways resulting from blast exposure in small animal models.	2.166	2.519	2.545

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2021 Plans: Characterize bone injury predictive biomarkers that identify increased risk for musculoskeletal injury during BCT; down-select the most relevant genetic and physiological markers associated with injury risk; research and refine whole body blast animal and human based injury models that can inform blast injury criteria for next generation bomb suit and blast exposure health hazard assessment criteria. ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned life cycle of this effort.			
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 2021 Plans:*** Define the role of nutrition support for metabolic recovery from military activity; understand CNS correlates of chronic sleep restriction and recovery; understand field-based impact of sleep on operational performance; investigate non-invasive brain and peripheral nervous system (outside the brain and spinal cord) stimulation for enhancing operational performance; study relationship between underlying brain characteristics (e.g., density of neural synapses, glymphatic flow, and cortical thickness) to Soldier military performance; discover indices of brain dysfunction and repair related to Soldier job-related awakedness and recovery following sleep; investigate biomedical mechanisms of inter-individual differences in vulnerability to cognitive performance and attention related to time-on-task. ***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 2021 to FY 2022 Increase/Decrease Statement:***	5.152	4.926	3.965

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Funds realigned to other efforts within Project AB1 (Soldier Performance Augmentation).			
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 2021 Plans:*** Research animal models for basic mechanisms of injuries from exposure to heat that degrade health and performance and those factors that accelerate improved recovery; establish screening methods to determine the underlying molecular mechanisms for degraded physical and behavioral performance of susceptible individuals in extreme respiratory-challenging dense urban and subterranean environments. ***FY 2022 Plans:*** 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 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned life cycle of this effort.	1.088	1.089	1.119
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 Post-Traumatic Stress Disorder (PTSD) and depression. ***FY 2021 Plans:*** Design biomedical research strategies to overcome technological barriers for research on physiological and psychological factors limiting Warfighter effectiveness and will research methods for characterizing health hazards generated by military systems and resulting from military operations; research militarily relevant aspects of the neurobehavioral aspects of 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	1.898	1.717	0.808

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AB1 / *Basic Res in infect Dis, Oper Med and Combat Care*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned to other efforts within Project AB1 (Soldier Performance Augmentation).			
Title: Basic Research on Drugs and Vaccines Against Parasitic Diseases (previously titled: Basic Research to Prevent Parasitic Diseases) ***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. ***FY 2021 Plans:*** Identify and discover new chemical entities for treatment and prevention and treatment of malaria; research assays and platforms for assessment and prioritization of new compounds; discover, identify, and characterize: 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 malaria; characterize malaria parasites to inform future development of prophylactics against malaria. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned to other efforts within Project AB1 (Medical Readiness ? Infectious Diseases).	6.050	5.835	-
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. ***FY 2021 Plans:*** Discover, identify, and characterize the following for treatment and prevention of bacterial diarrheal 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	1.527	1.721	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army			Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
produced in response to and against bacterial diarrheal diseases; characterize diarrhea-associated bacteria to inform future development of prophylactics against bacterial diarrheal diseases. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned to other efforts within Project AB1 (Prolonged Field Care ? Infectious Diseases).			
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. ***FY 2021 Plans:*** Discover, identify, and characterize the following for treatment and prevention of viral 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 viral diseases; characterize viruses to inform development of prophylactics against viral diseases. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned to other efforts within Project AB1 (Prolonged Field Care ? Infectious Diseases).	1.632	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. ***FY 2021 Plans:*** Identify unique biological markers (e.g., proteins, genes) and technologies/platforms that can be used to produce improved identification and detection tools; identify and characterize vector populations and the pathogens they transmit to inform vector control countermeasures and develop risk assessment tools. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned to other efforts within Project AB1 (Prolonged Field Care ? Infectious Diseases).	1.529	1.594	-
Title: Clinical and Rehabilitative Medicine	0.943	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2020**	**FY 2021**	**FY 2022**
Description: This effort conducts basic studies of mechanisms of tissue growth and traumatic injury to gain an understanding that will assist or facilitate the healing or transplantation process. The focus is placed on severe blast trauma to the limbs, head, face (including eye), genitalia (organs of reproduction), and abdomen.			
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. ***FY 2021 Plans:*** Research three-dimensional computational capabilities to accurately simulate blood-clotting processes to identify promising strategies to improve clot formation following trauma; conduct research on individualized algorithms that predict the risk of musculoskeletal stress-fracture injury in Warfighters during basic combat training; conduct research on a systematic, computational approach that determines what antibody sequences are associated with vaccine protection and how these antibodies are generated under different conditions; study artificial intelligence (AI) algorithms to predict biomarkers indicative of toxic chemical exposure and organ damage; identify mechanisms of malaria parasite drug resistance, and validate their involvement in mitigating resistance against a new antimalarial drug; research AI models to identify brain activity during sleep that may be indicative of PTSD and enhance resilience of healthy Soldiers to sleep deprivation ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned to other efforts within Project AB1 (Injury Prevention & Readiness and Medical Computational Modeling).	2.929	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:*** Understand the mechanisms that contribute to the transition from acute to chronic pain and identifying novel drug therapy targets to alleviate pain. ***FY 2021 to FY 2022 Increase/Decrease Statement:***	-	-	1.131

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Funds realigned from other efforts within Project AB1 (Prolonged Field Care).			
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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned from other efforts within Project AB1 (Combat Trauma Therapies).	-	-	0.580
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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned from other efforts within Project AB1 (Combat Trauma Therapies).	-	-	0.499
Title: Hemorrhage, Shock, Coagulopathy of Trauma ***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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned from other efforts within Project AB1 (Damage Control Resuscitation).	-	-	1.684
Title: Endovascular Hemorrhage Control	-	-	0.479

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned from other efforts within Project AB1 (Pre-Hospital Tactical Combat Casualty Care).			
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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned from other efforts within Project AB1 (Combat Trauma Therapies).	-	-	2.861
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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned from other efforts within Project AB1 (Traumatic Brain Injury).	-	-	1.425
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.	-	-	1.921

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned from other efforts within Project AB1 (Psychological Health and Resilience and Physiological Health).			
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 animal 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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned from other efforts within Project AB1 (Bacterial Diseases, Vector Control, Viral Disease).	-	-	4.561
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,	-	-	7.067

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned from other efforts within Project AB1 (Parasitic Diseases).			
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, 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 U.S. 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 2021 to FY 2022 Increase/Decrease Statement:*** Funds realigned from other efforts within Project AB1 (Network Sciences Initiatives).	-	-	3.131
Accomplishments/Planned Programs Subtotals	31.269	31.957	37.103

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army	**Date:** May 2021

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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
AB2: *Protection, Maneuver, Geospatial, Natural Sciences*	-	16.510	17.089	17.967	-	17.967	-	-	-	-	-	-

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.

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2020**	**FY 2021**	**FY 2022**
Title: Mapping, remote sensing, signature physics and terrain state ***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 2021 Plans:*** Investigates a novel approach for rapidly observing the spatial variation of key parameters affecting the optical transmissivity and reflectivity of falling and blowing snow. Fundamental research also validates computational models to infer mechanisms of collective motion that initiate social contagion. ***FY 2022 Plans:*** Will investigate signal processing algorithms for automatic target recognition. Basic research will also characterize urban noise fields at ground level, for both acoustic and electromagnetic waves, relevant to military operations. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	3.738	3.868	3.964
Title: Fundamental Adaptive Protection and Projection Research ***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.	4.261	4.700	4.815

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
FY 2021 Plans: Explore the effects of nano-crystalline grains on high-rate deformation mechanisms and plastic flow of alloys for structural materials; investigate the mechanical response and damage evolution of high-strength cementitious materials under confined dynamic loading to enhance new structural material development. ***FY 2022 Plans:*** Will investigate physical drivers of currents in the littoral swash zone to inform the geo-environmental conditions of autonomous vehicles; will study thermal conductivity in cold environments to understand the electrical performance limitations of crystalline materials; will determine the mechanisms that enable tunability of specific materials for novel unconventional countermeasures and survivability applications. ***FY 2021 to FY 2022 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 2021 Plans:*** Investigate the interfacial transition zone (ITZ) chemical and mechanical properties of concrete materials with the inclusion of biomimetic adhesive polymer inspired by marine organisms; explore polymer functionality that gives rise to stimulus-responsive reactions. ***FY 2022 Plans:*** Will explore the potential of resonance energy transfer as a light harvesting mechanism to inform future development of advanced materials; will investigate the structure-function relationship in compartmentalized nanoreactors for future application in on-demand chemical reactions and real time monitoring. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funding change reflects planned lifecycle of this effort.	1.650	1.817	1.864
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.	6.861	6.704	7.324

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020	FY 2021	FY 2022
FY 2021 Plans: Investigate the fundamental processes and phenomena involved in infrared (IR) reflectance of biological materials; explore the properties of bio-inspired nanomaterials for future novel Army functionalities; investigate foundational knowledge for multilayer reflector mechanisms that enable color and reflectance switching. ***FY 2022 Plans:*** Will investigate mechanisms in cold-dwelling bacteria (psychrophiles) and frozen media to support future development of cold-specific Army technologies; will explore how synthetic biology can be combined with new materials to allow manipulation of materials on demand. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Funding increase in FY22 will support increased investigation of novel materials and processes.			
Accomplishments/Planned Programs Subtotals	16.510	17.089	17.967

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army			**Date:** May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
CH9: *Advancing Concepts and Technology Forecasting*	-	-	-	3.573	-	3.573	-	-	-	-	-	-

Note

This is a new start in FY 2022.

This is a new start for FY 2022.

A. Mission Description and Budget Item Justification

Advancing Concepts 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. Perform long-range technology forecasts of Army-relevant basic research topics to enable informed decision making for the deep 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 in this Project is performed by the United States Army Futures Command (AFC).

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
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. Provides long-range, scientifically grounded technology forecasts of basic research topics to enable informed decision-making. ***FY 2022 Plans:***	-	-	3.573

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		**Date:** May 2021
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 2020**	**FY 2021**	**FY 2022**
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 2021 to FY 2022 Increase/Decrease Statement:*** In FY 2022, funding realigned from multiple sources within the Army Futures Command basic research portfolio to support far-term basic scientific research integration with Army Warfighting Concepts, as well as long-term technology basic research-driven forecasts that will inform the Future Operational Environment.			
Accomplishments/Planned Programs Subtotals	-	-	3.573

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army			**Date:** May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
T14: *BASIC RESEARCH INITIATIVES - AMC (CA)*	-	66.350	48.000	-	-	-	-	-	-	-	-	-

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 2020	FY 2021
Congressional Add: Propulsion Technology ***FY 2020 Accomplishments:*** Program Increase to support basic research on propulsion Technologies Work executed by Army Futures Command.	10.000	-
Congressional Add: Ballistic and Materials Technology ***FY 2020 Accomplishments:*** Program Increase to support basic research on ballistic and materials technology Work executed by Army Futures Command.	10.000	-
Congressional Add: Flexible LED Lighting ***FY 2020 Accomplishments:*** Program Increase to support basic research on Flexible LED Lighting Work executed under the direction of the Army Futures Command.	5.350	-
Congressional Add: Military Waste Stream Conversion ***FY 2020 Accomplishments:*** Program Increase to support basic research on military waste stream conversion Work executed under the direction of the Army Futures Command.	5.000	-
Congressional Add: Multi-layer and dynamically responsive macromolecular composites	5.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Army		Date: May 2021
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 2020**	**FY 2021**
FY 2020 Accomplishments: Program Increase to support multi-layer and dynamically responsive macromolecular composites Work executed under the direction of the Army Futures Command.		
Congressional Add: Advanced hemostat products ***FY 2020 Accomplishments:*** Program Increase to support basic research on advanced hemostat products Work executed under the direction of the Army Futures Command.	2.000	-
Congressional Add: Multi-fuel ignition, chemistry and control strategies for unmanned aircraft systems hybrid propulsion ***FY 2020 Accomplishments:*** Program increase to support multi-fuel ignition, chemistry and control strategies for unmanned aircraft systems hybrid propulsion Work executed under the direction of the Army Futures Command. ***FY 2021 Plans:*** 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.	9.000	15.000
Congressional Add: Transmission electron microscope ***FY 2020 Accomplishments:*** Program increase for transmission electron microscope equipment in support of basic research. Work executed under the direction of the Army Futures Command.	20.000	-
Congressional Add: Program increase ***FY 2021 Plans:*** Program Increase supported basic research on Defense Research Services. Work executed by Army Futures Command.	-	10.000
Congressional Add: Program increase - explosives and opiods dual-use UV detection ***FY 2021 Plans:*** Program Increase supported basic research on Explosives and Opiods Dual-Use UV Detection.	-	3.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021
Work executed by Army Futures Command.		
Congressional Add: Program increase: Artificial intelligence complex multi?material composites processing ***FY 2021 Plans:*** 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 Plans:*** Program Increase supported basic research on Cell-Free Expression for Biomanufacturing. Work executed by Army Futures Command.	-	10.000
Congressional Adds Subtotals	66.350	48.000

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A