Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Army											Date: February 2020	
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 2019**	**FY 2020**	**FY 2021 Base**	**FY 2021 OCO**	**FY 2021 Total**	**FY 2022**	**FY 2023**	**FY 2024**	**FY 2025**	**Cost To Complete**	**Total Cost**
Total Program Element	-	306.347	354.480	303.257	-	303.257	311.641	320.262	323.932	326.791	0.000	2,246.710
305: *ATR Research*	-	2.141	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	2.141
31B: *Infrared Optics Rsch*	-	3.714	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	3.714
52C: *Mapping & Remote Sens*	-	2.109	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	2.109
53A: *Battlefield Env & Sig*	-	3.940	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	3.940
74A: *Human Engineering*	-	15.124	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	15.124
74F: *Pers Perf & Training*	-	5.385	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	5.385
AA1: *ILIR - AMC*	-	0.000	10.443	11.007	-	11.007	11.232	11.454	11.580	11.697	0.000	67.413
AA2: *ILIR - SMDC*	-	0.000	0.941	0.988	-	0.988	1.007	1.039	1.051	1.051	0.000	6.077
AA3: *Single Investigator Basic Research*	-	0.000	97.703	103.455	-	103.455	107.062	110.540	111.856	113.008	0.000	643.624
AA4: *Training and Human Science Research*	-	0.000	20.792	21.871	-	21.871	22.284	22.801	23.059	23.060	0.000	133.867
AA5: *Biotechnology and Systems Biology*	-	0.000	5.748	6.089	-	6.089	6.213	6.338	6.409	6.473	0.000	37.270
AA6: *Robotics and Mobile Energy*	-	0.000	21.700	22.794	-	22.794	22.948	23.406	23.666	23.904	0.000	138.418
AA7: *Mechanics and Ballistics*	-	0.000	34.139	36.048	-	36.048	37.451	38.202	38.633	39.021	0.000	223.494
AA8: *Sensing and Electromagnetics*	-	0.000	8.582	9.066	-	9.066	9.567	9.759	9.868	9.968	0.000	56.810
AA9: *Information and Networking*	-	0.000	39.112	41.035	-	41.035	41.452	42.282	42.753	43.184	0.000	249.818
AB1: *Basic Res in infect Dis, Oper Med and Combat Care*	-	0.000	32.126	33.167	-	33.167	33.856	35.272	35.675	36.042	0.000	206.138
AB2: *Protection, Maneuver, Geospatial, Natural Sciences*	-	0.000	16.844	17.737	-	17.737	18.569	19.169	19.382	19.383	0.000	111.084
ET6: *BASIC RESCH IN CLINICAL & REHABILITATIVE MED*	-	4.403	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	4.403

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Army												Date: February 2020
Appropriation/Budget Activity 2040: *Research, Development, Test & Evaluation, Army I* BA 1: *Basic Research*					R-1 Program Element (Number/Name) PE 0601102A *I Defense Research Sciences*							
F20: *Adv Propulsion Rsch*	-	3.544	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	3.544
F22: *Rsch In Veh Mobility*	-	0.749	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	0.749
H42: *Materials & Mechanics*	-	11.851	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	11.851
H43: *Research In Ballistics*	-	11.420	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	11.420
H44: *Adv Sensors Research*	-	9.681	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	9.681
H45: *Air Mobility*	-	2.410	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	2.410
H47: *Applied Physics Rsch*	-	5.700	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	5.700
H48: *Battlespace Info & Comm Rsc*	-	31.363	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	31.363
H52: *Equip For The Soldier*	-	1.177	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	1.177
H57: *Single Investigator Basic Research*	-	98.050	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	98.050
H66: *Adv Structures Rsch*	-	3.116	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	3.116
H67: *Environmental Research*	-	1.065	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	1.065
S13: *Sci BS/Med Rsh Inf Dis*	-	10.237	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	10.237
S14: *Sci BS/Cbt Cas Care Rs*	-	4.957	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	4.957
S15: *Sci BS/Army Op Med Rsh*	-	6.306	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	6.306
T14: *BASIC RESEARCH INITIATIVES - AMC (CA)*	-	39.000	66.350	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	105.350
T22: *Soil & Rock Mech*	-	4.561	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	4.561
T23: *Basic Res Mil Const*	-	1.777	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	1.777
T24: *Signature Physics And Terrain State Basic Research*	-	1.719	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	1.719
T25: *Environmental Science Basic Research*	-	6.621	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	6.621
T63: *Robotics Autonomy, Manipulation, & Portability Rsh*	-	9.246	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	9.246
T64: *Sci BS/System Biology And Network Science*	-	2.722	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	2.722

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Army													Date: February 2020
Appropriation/Budget Activity 2040: *Research, Development, Test & Evaluation, Army* / BA 1: *Basic Research*					R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*								
VR9: *Surface Science Research*	-	2.259	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	2.259	

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 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.

All FY20 adjustments align program financial structure to Army Modernization Priorities in support of the National Defense Strategy.

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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	315.660	297.976	302.259	-	302.259
Current President's Budget	306.347	354.480	303.257	-	303.257
Total Adjustments	-9.313	56.504	0.998	-	0.998
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-9.846			
• Congressional Rescissions	-	-			
• Congressional Adds	-	66.350			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-1.771	-			
• SBIR/STTR Transfer	-7.542	-			
• Adjustments to Budget Years	-	-	0.998	-	0.998

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2019	FY 2020
Project: T14: *BASIC RESEARCH INITIATIVES - AMC (CA)*		
Congressional Add: *Basic Research Program Increase*	35.000	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Army	Date: February 2020
Appropriation/Budget Activity 2040: *Research, Development, Test & Evaluation, Army I* BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601102A *I Defense Research Sciences*

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2019	FY 2020
Congressional Add: *Counter UAS Technology*	3.000	-
Congressional Add: *UAV fuel systems enhancements*	1.000	-
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
Congressional Add: *Multi-fuel ignition, chemistry and control strategies for unmanned aircraft systems hybrid propulsion*	-	9.000
Congressional Add: *Transmission electron microscope*	-	20.000
Congressional Add Subtotals for Project: T14	39.000	66.350
Congressional Add Totals for all Projects	39.000	66.350

Change Summary Explanation

FY20 increase related to $66.350 million of Congressional Add funding and an excess growth reduction of $9.846 million.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army										Date: February 2020		
Appropriation/Budget Activity 2040 / 1					R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*				Project (Number/Name) 305 / *ATR Research*			
COST ($ in Millions)	**Prior Years**	**FY 2019**	**FY 2020**	**FY 2021 Base**	**FY 2021 OCO**	**FY 2021 Total**	**FY 2022**	**FY 2023**	**FY 2024**	**FY 2025**	**Cost To Complete**	**Total Cost**
305: *ATR Research*	-	2.141	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	2.141

Note

In Fiscal Year (FY) 2020 this Project was realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA9 Information and Networking

A. Mission Description and Budget Item Justification

This Project fosters research for automatic target recognition (ATR) concepts to enhance the effectiveness of Army systems while simultaneously reducing the workload on the Soldier. This Project focuses on the fundamental underpinnings of aided and unaided target detection and identification techniques for land warfare scenarios. This research enables Army systems that can act independently of the human operator to detect and track targets including clandestine tracking of non-cooperative targets. Such capabilities are needed for smart munitions, unattended ground sensors, and as replacements for existing systems. Critical technology issues include low depression angle, relatively short range, and highly competing background clutter. The resulting research will provide a fundamental capability to predict, explain, and characterize target and background signature content, and reduce the workload on the analyst. This research is aimed at determining the complexity and variability of target and clutter signatures and ultimately utilizing that knowledge to conceptualize and design advanced ATR paradigms to enhance robustness and effectiveness of land warfare systems. ATR research strategies include emerging sensor modalities such as spectral and multi-sensor imaging. Research in this Project builds knowledge for several technology efforts including multi-domain smart sensors, third generation Forward Looking Infrared (FLIR), and advanced multi-function laser radar (LADAR).

Work is this Project supports key Army needs and provides the technical underpinnings to PE 0602270A (Electronic Warfare Technology) / Project 906 (Tactical Electronic Warfare Applied Research).

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

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 2019	FY 2020	FY 2021
Title: ATR Algorithms ***Description:*** Investigate new algorithms to improve aided/unaided target detection and identification.	2.141	-	-
Accomplishments/Planned Programs Subtotals	2.141	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** 305 / *ATR Research*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army										Date: February 2020		
Appropriation/Budget Activity 2040 / 1					R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*				Project (Number/Name) 31B / *Infrared Optics Rsch*			
COST ($ in Millions)	**Prior Years**	**FY 2019**	**FY 2020**	**FY 2021 Base**	**FY 2021 OCO**	**FY 2021 Total**	**FY 2022**	**FY 2023**	**FY 2024**	**FY 2025**	**Cost To Complete**	**Total Cost**
31B: *Infrared Optics Rsch*	-	3.714	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	3.714

Note

In Fiscal Year (FY) 2020 this Project was realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA8 Sensing and Electromagnetics

A. Mission Description and Budget Item Justification

This Project supports Army research in materials and devices for active and passive infrared (IR) imaging systems; radio frequency (RF) photonics for radar, communications, and electronic warfare applications; and laser technology for missile threat countermeasure protection. This research aims to generate new technologies for unprecedented battlefield situational awareness and to continue the dominance of Army units during night operations. To achieve these objectives, IR focal plane arrays (FPAs) and lasers with significantly improved performance, lower cost, and increased operating temperatures are required. This research has direct application to Army ground vehicles, aviation platforms, weapon systems, and the individual Soldier. Research is focused on material growth, detector and laser design, and processing for large-area, multicolor IR FPAs, ultraviolet (UV) avalanche photodiodes (APDs), and mid-wavelength IR and UV lasers. The principal efforts are directed towards novel materials for detectors and lasers, and investigating energy band-gap structures in semiconductor materials to enhance the performance of lasers, IR FPAs and UV APDs. In the area of RF Photonics, near-IR modeling and nanofabrication techniques are applied to the design and fabrication of IR photonic-crystal waveguide structures having customized IR properties. This research also is intended to lay the foundation for the development of integrated optoelectronic circuits using active and passive devices and components such as lasers, waveguides, and detectors in conjunction with fiber optic interconnects for the generation, distribution, processing, and control of microwaves. The fundamental physics of signal processing and noise generation as well as the conversion between the time and frequency domains and the optical and electrical domains in these optoelectronic circuits/systems will also be studied. The technical goals are to: 1) manage and control defects in the raw, unprocessed materials, maintaining quality control in the fabrication of the devices and arrays, 2) limit introduction of impurities in the material, shielding device surfaces so that they are resistant to degradation over time and 3) thermal management, particularly as it applies to lasers. In the area of Advanced Materials, the research is to investigate the fundamental physics of energy, charge, and spin transport along and across active heterogeneous interfaces such as topological insulators, van der Waals heterostructures, solid/liquid interfaces, and bio/a-bio interfaces, and in new materials to achieve new electronic/optoelectronic device functionalities.

Work in this Project supports key Army needs and provides the technical underpinning to PE 0602709A (Night Vision Technology) / Project H95 (Night Vision and Electro-Optic Technology).

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

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

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** 31B / *Infrared Optics Rsch*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Optoelectronic and Integrated Photonic Materials and Device Research ***Description:*** Conduct research into materials and structures used for IR devices, UV emitters and detectors, and integrated photonic devices to increase situational awareness in open and complex terrains; improve target detection, identification, and discrimination; and create new device functionality while reducing size, weight, and power requirements.	0.991	-	-
Title: Advanced Materials ***Description:*** Investigation of the fundamental physics of energy, charge, and spin materials with an emphasis on understanding the transport along and across novel designed surfaces and active heterogeneous interfaces to achieve new electronic/ optoelectronic device functionalities. Additionally, study beta-photovoltaic and beta-voltaic energy capture.	2.723	-	-
Accomplishments/Planned Programs Subtotals	3.714	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) 52C / *Mapping & Remote Sens*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
52C: *Mapping & Remote Sens*	-	2.109	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	2.109

Note

In Fiscal Year (FY) 2020 this Project was realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AB2 Protection, Maneuver, Geospatial, Natural Sciences

A. Mission Description and Budget Item Justification

This Project increases knowledge of terrain and human geography with a focus on improving the generation, management, analysis/reasoning, and modeling of geospatial data, and the exploitation of multi-source data. This fundamental knowledge forms the scientific "springboard" for the future development of applications, techniques, and tools to improve the tactical commander's knowledge of the operating environment. Results of this research are used to: extract and characterize natural and man-made features from reconnaissance imagery in near-real time; understand socio-cultural influences; exploit terrain analysis and reasoning techniques; and explore the potential of space, airborne, and terrestrial geospatial sensor technologies to provide real-time geospatial intelligence to all Army Warfighting functions. This research uses terrain and socio-cultural data to improve situational awareness and enhance information dominance, leading to increased survivability, lethality, and mobility.

Work in this Project provides theoretical underpinnings for PE 0602784A (Military Engineering Technology) / Project 855 (Topographical, Image Intel & Space).

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

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 2019	FY 2020	FY 2021
Title: Sensor Phenomenology and Spatial-Temporal Pattern Discovery ***Description:*** Conduct fundamental research to inform the development of applications, techniques, and tools to improve the tactical commander's knowledge of the operating environment.	2.109	-	-
Accomplishments/Planned Programs Subtotals	2.109	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** 52C / *Mapping & Remote Sens*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) 53A / *Battlefield Env & Sig*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
53A: *Battlefield Env & Sig*	-	3.940	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	3.940

Note

In Fiscal Year (FY) 2020 this Project was realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA7 Mechanics and Ballistics

A. Mission Description and Budget Item Justification

This Project focuses on research to seek 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; and the propagation of full-spectrum electro-magnetic and acoustic energy. The future Army will operate in very complex environments (e.g., urban, mountainous, forested and jungle terrain) requiring new approaches to understand, characterize, and depict environmental phenomena and their effects on military systems, personnel and operations. The lack of a complete understanding of the meteorological aspects of the complex microscale boundary layer in which the Army operates continues to impact our ability to provide predictable, actionable, accurate and timely tactical environmental intelligence to battlefield commanders and small Soldier units. This Project focuses on producing the foundational environmental science research to characterize the atmospheric boundary layer and deliver novel capabilities and techniques including urban turbulence characterization for its effects on micro platforms and sensor payloads, high resolution urban wind flow modeling for more efficient and accurate prediction of the transport and dispersion of obscurants and chemicals, battlefield aerosol characterization and the interaction between aerosols and meteorological processes for Soldier health initiatives, characterization and detection of bio-warfare agent aerosols, environmental effects on acoustic and electromagnetic signal propagation in urban and other complex domains for improved target location and imaging, exploration of previously unexploited regions of the acoustic and electro-magnetic spectrum, and formulation of objective analysis tools that can assimilate on-scene all-source weather observations, atmospheric composition, and fuse this information with forecasts to provide immediate Nowcast products and actionable information. These capabilities will have a direct impact on ensuring Soldier survivability, weapon system lethality, effective surveillance and reconnaissance, and the mobility required for future warfighter mission planning and execution operations.

Work in this Project supports key Army needs and provides the theoretical underpinnings for PE 0602784A (Military Engineering Technology) / Project H71 (Meteorological Research for Battle Command).

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

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 2019	FY 2020	FY 2021
Title: Predictive Modeling of the Boundary Layer	3.940	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** 53A / *Battlefield Env & Sig*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: Increase survivability and improve situational awareness for a variety of sensors, optics, and flying objects (e.g., projectiles, unmanned aircraft systems, etc.) through fundamental research to enhance accuracy of predictive modeling of the atmospheric boundary layer and improve the ability to function effectively in adverse conditions.			
Accomplishments/Planned Programs Subtotals	3.940	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army										Date: February 2020		
Appropriation/Budget Activity 2040 / 1					R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*				Project (Number/Name) 74A / *Human Engineering*			
COST ($ in Millions)	**Prior Years**	**FY 2019**	**FY 2020**	**FY 2021 Base**	**FY 2021 OCO**	**FY 2021 Total**	**FY 2022**	**FY 2023**	**FY 2024**	**FY 2025**	**Cost To Complete**	**Total Cost**
74A: *Human Engineering*	-	15.124	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	15.124

Note

In Fiscal Year (FY) 2020 this Project was realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA4 Training and Human Science Research

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 performance such as auditory spatial orientation (e.g., perception of azimuth, elevation and distance of sounds) within uncertain, degraded acoustic conditions; extending and protecting auditory and cognitive performance; human performance in automated, mixed-initiative (human control-machine control) environments; communications in hearing-degraded conditions; visual scanning and target detection; Soldier emotion and fatigue states; integration across multiple sensory modalities; perceptual-motor behavior; collaborative (team) and independent multi-task, multi-modal, multi-echelon Soldier-system performance - all cast against the influx of emerging transformation-driven technological solutions and opportunities. Technical barriers include lack of methods for describing, measuring, modeling, analyzing and managing the interplay of these phenomena due to the dynamic nature of human behavior and to the situational complexity and ambiguity that characterize operations in the future force. 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 and enable neuroengineering. 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 cognitive and perceptual processes. In the area of translational neuroscience, which is the transition of basic neuroscience research to relevant applications, 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 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.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** 74A / *Human Engineering*

Work in this Project supports key Army needs and provides the technical underpinnings to several PEs to include PE 0601104A (University and Industry Research Centers) / Project H09 (Robotics Collaborative Technology Alliance) and PE 0602716A (Human Factors Engineering Technology) / H70 (Human Factors Engineering System Development).

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

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 2019	FY 2020	FY 2021
Title: Translational Neuroscience ***Description:*** Integrating neuroscience with traditional approaches to understanding Soldier behavior to enable systems designs that maximize Soldier performance.	3.713	-	-
Title: Human System Integration ? Cybernetics ***Description:*** Apply 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.	5.070	-	-
Title: Continuous Multi-Faceted Soldier Characterization for Adaptive Technologies ***Description:*** This effort will investigate technologies that provide the foundation for future Army systems to adapt to individual Soldier?s states, behaviors, and intentions in real-time. Enable high fidelity, continuous prediction that can account for continuous changes in Soldier?s physical, cognitive, and social states, such as stress, fatigue, task difficulty, trust, and situational awareness.	4.116	-	-
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.	1.251	-	-
Title: Novel Forms of Joint Human-Intelligent Agent Decision Making ***Description:*** This effort will develop novel 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	0.974	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** 74A / *Human Engineering*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
group performance, emphasizing deep learning approaches that function under conditions of limited, mismatched, or dynamic data.			
Accomplishments/Planned Programs Subtotals	15.124	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) 74F / *Pers Perf & Training*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
74F: *Pers Perf & Training*	-	5.385	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	5.385

Note

In Fiscal Year (FY) 2020 this Project was realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA4 Training and Human Science Research

A. Mission Description and Budget Item Justification

This Project provides the funding to develop 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.

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

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 2019	FY 2020	FY 2021
Title: Personnel Measures ***Description:*** Basic research to develop innovative theories, models, and methods to improve personnel assessment, training, and leader development.	1.845	-	-
Title: Climate, Readiness, and Resilience ***Description:*** Basic research that will provide a better understanding of individual, unit, and organizational behavior and performance within the context of complex organizational and operational environments.	3.540	-	-
Accomplishments/Planned Programs Subtotals	5.385	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** 74F / *Pers Perf & Training*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
AA1: *ILIR - AMC*	-	0.000	10.443	11.007	-	11.007	11.232	11.454	11.580	11.697	0.000	67.413

Note

In Fiscal Year 2020 (FY20) this Project was realigned from:
Program Element (PE) 0601101A In-House Laboratory Independent Research
* Project 91A ILIR-AMC

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.

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

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

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 2019	FY 2020	FY 2021
Title: Edgewood Chemical Biological Center (ECBC)	-	0.885	1.021
Description: Basic research in chemistry, biology, biotechnology, and aerosols for creating the science base needed for countering improvised explosive devices (IEDs), obscurants, and defeating targets.			
FY 2020 Plans: Conduct fundamental research in rational molecular synthesis, abiotic structures, nanoparticles, and self-organizing systems; synthetic biology and design and construction of new biological parts, devices, and systems; aerosol sciences and behaviors of aerosols and reaerosolization processes; and the mathematics involved in data processing and interpretation.			
FY 2021 Plans:			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Armaments Research, Development and Engineering Center (ARDEC) ***Description:*** Funds basic research in weapons component physics, explosives synthesis/detection, and the fundamental science base of area denial. ***FY 2020 Plans:*** Conduct innovative basic research that would ultimately result in new more powerful and less sensitive explosives to enhance lethality, lighter and advanced structural materials for guns and weapon platforms, new materials and sensors for area denial, and more lethal, multipurpose, and compact warheads. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	1.327	1.475
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 2020 Plans:*** Conduct basic research to improve understanding and the establish the underlying physics supporting the Army ground vehicle community in such areas as; semi- , fully-, and multiple autonomous vehicle operation and control, ground vehicle cybersecurity threat detection algorithms and resilience, lightweight materials and additive manufacturing, active protection and signature management, advanced combustion engine thermal control, soft soil mobility modeling, cognitive loading and crew station design, advanced energy storage materials, corrosion modeling, and early detection mechanisms. ***FY 2021 Plans:*** Will 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	-	1.118	1.260

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Natick Soldier Research, Development and Engineering Center (NSRDEC) ***Description:*** This effort funds basic research in food sciences, textiles, and lightweight materials with potential for individual protection. ***FY 2020 Plans:*** Create an understanding of fibers of liquid crystals confined in polymer matrices for fiber quality, phase transition characteristics of the liquid crystals, and temperature responsive behavior to inform the future development of lightweight "smart" textiles that efficiently respond to external stimuli. Conduct fluid structure interface modeling of a braided cord using cyber-physical fluid dynamics and molecular-tagging-velocimetry techniques to gain understanding of the physical relationship between fluid flow features and the unsteady forces exhibited by braided cords undergoing gallop oscillations for informing the design of gliding parachute systems. Investigate human control schemes of a swarm of robotic agents in a three-dimensional (3D) environment to elucidate how humans perceive and guide small swarms of semi-autonomous agents across a range of conditions for determining the most effective and intuitive control schemes for efficient human-machine combat teaming. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	1.009	1.149
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 2020 Plans:*** Enhance optical nonlinearities using materials with dielectric constant near zero for sensor protection; will study collisional broadening of rubidium vapor by low-density contaminant gases to detect aging in atomic clocks; investigate use of mutual	-	2.282	2.447

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
information to detect dependencies between random processes to improve radar tracking in noisy environments; explore how chaos appears in optimal communication systems and how performance may be improved for wireless datalinks in noisy environments; explore nested plasmonic resonances in a hybrid nanoantenna for laser protection. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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 2020 Plans:*** Conduct analytical and experimental study of induced flow effects on coaxial rotor wake and performance; explore use of advanced measurement techniques such as volumetric particle image velocimetry to measure time resolved unsteady flow phenomena in rotor wakes; explore advanced grid generation techniques and higher-order flow solvers to enable automated high-fidelity solutions for complex geometry full vehicle configurations. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	1.227	1.372
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.	-	2.121	2.283

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
FY 2020 Plans: Conduct research on resource-aware algorithms based on artificial intelligence for performing content summarization, awareness to autonomous node placement, and multimodal selection for resource information delivery at the tactical edge. Conduct research utilizing an innovative approach to collecting visual data in order to mimic a biological vision system that navigates using ultraviolet and visible light to ultimately determine if the addition of the ultraviolet spectrum is better for navigation than navigating with the visible spectrum alone. Conduct research on the Manganese Oxide structure and bonding mechanisms through the addition of Sulphur doping to formulate, synthesize, and characterize Sulphur doped Manganese Oxide materials for potential use in robust cathode materials. ***FY 2021 Plans:*** Will 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 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: FY 2020 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	0.474	-
Accomplishments/Planned Programs Subtotals	-	10.443	11.007

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA1 / *ILIR - AMC*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) AA2 / *ILIR - SMDC*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
AA2: *ILIR - SMDC*	-	0.000	0.941	0.988	-	0.988	1.007	1.039	1.051	1.051	0.000	6.077

A. Mission Description and Budget Item Justification

Work in this Project supports basic research at the Space and Missile Defense Command / Army Strategic Command Technical Center (SMDC/ARSTRAT 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 0602307A (Advanced Weapons Technology).

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: SMDC In-house Laboratory Independent Research (ILIR)	-	0.912	0.988
Description: This effort provides In-house Laboratory Independent Research (ILIR) at the United States Army Space and Missile Defense Command (USASMDC). 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 2020 Plans: Improve diode coherence for direct-diode High Energy Laser concepts. Explore concepts for scaling both spectrally beam combined and coherently beam combined direct-diode approaches. Establish methods for adaptive optics branch point, speckle, as well as scintillation measurements and compensation for atmospheric turbulence compensation.			
FY 2021 Plans: Will perform laser modeling of other atomic transition line parameters to determine if efficient lasing is possible; model laser cavity parameters, and expand laser spectroscopy to include improved plasma parameters; develop 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			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
conditions, solar loading, and terrain parameters; investigate 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: FY 2020 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	0.029	-
Accomplishments/Planned Programs Subtotals	-	0.941	0.988

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
AA3: *Single Investigator Basic Research*	-	0.000	97.703	103.455	-	103.455	107.062	110.540	111.856	113.008	0.000	643.624

Note

In Fiscal Year 2020 (FY20) this Project was realigned from:
Program Element (PE) 0601102A Defense Research Sciences
* Project H57 Single Investigator Basic Research

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 science, 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.

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

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 2019	FY 2020	FY 2021
Title: Basic Research in Life Sciences	-	11.890	11.240
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			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021

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 2020 Plans:

Use spectral-domain optical coherence tomography to reveal fine details of brain hemodynamic (blood flow) signals and clarify the correlation between these two observable quantities and the level and spatial distribution of neural activity in the living brain with electrophysiology and optogenetic (using light) manipulation, that in the long term may lead to new avenues for the treatment of brain injuries, training methods for the future soldier, or methods to establish direct, remote control for future combat vehicles, in line with the Soldier Lethality and Next Generation Combat Vehicle Army Modernization Priorities. Determine whether key intracellular regulators can be inactivated by forming a self-seeding aggregate and whether such a protein aggregate can then attract other proteins, thereby inactivating them as well, that in the long term may enable new methods for preventing, detecting, and treating Post-Traumatic Stress Disorder. Employ genetics and molecular biology methods to create a comprehensive glycan library where the glycans are bound to a biotin-labelled polymer, and utilize the new system to target the depletion or enrichment of specific microbial species from a given community of organisms and determine the effect of these changes in the composition of a mock community of skin bacteria, that in the long term may lead to more effective methods for portable water purification, insect resistance, and wound healing. Genetically engineer novel green fluorescent protein ?protomers? that will utilize engineered electrostatic interactions to explore whether proteins can be programmed to self-assemble into a range of useful higher order structures similar to synthetic polymers but with the information rich properties of proteins, that in the long term may enable Army-relevant applications ranging from protective materials to chemical detection and decontamination systems. Integrate sociological and psychological theory on status, influence, and attentional control with biological measurements, to create a method for predicting or simulating how threat impacts team performance and communication impedance, which in the long term may provide a new paradigm for training Soldiers and assessing individual and squad capabilities in more realistic simulated environments where decisions must be made rapidly in the face of the rapidly changing battlefield dynamics.

FY 2021 Plans:

Will 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; 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

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
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 2020 to FY 2021 Increase/Decrease Statement:*** Planned program progression.			
Title: Basic Research in Chemical Sciences ***Description:*** This effort fosters basic research to achieve advanced energy control, improved threat detection, and novel responsive materials for Soldier protection. Research efforts will lead to: light-weight, reliable, compact power sources, more effective, lower vulnerability propellants and explosives for tailored precision strikes with minimum collateral damage, new approaches for shielding the Soldier and Army platforms from ballistic, chemical, and biological threats, and reducing signatures for identification by the enemy, and advance warning of explosive, chemical, and biological weapons and dangerous industrial chemicals. ***FY 2020 Plans:*** Use a combined experimental-computational approach to develop mechanistic descriptions of catalysis by metal nanostructures when excited by photon or other non-thermal energy sources to determine the most efficient photoelectrocatalysis approaches for driving chemical conversion at metal nanoparticle surfaces, that in the long term may enable the development of lower-weight power storage and generation in support of the Army Modernization Priorities of Future Vertical Lift and Soldier Lethality. Develop two innovative single-molecule approaches to define the catalytic kinetics and dynamics of living polymerization reactions in real time, at the single-polymer level, and down to single-monomer resolution, that in the long term may enable new polymer structures with novel properties ranging from protective coatings on vehicles and aircraft to more rapid and cost-effective manufacturing methods, in support of the Army Modernization Priorities of Future Vertical Lift, Next Generation Combat Vehicle, and Soldier Lethality. Synthesize a unique set of fluorescent ester probe catalysts with variable mobility and reactivity within the structured pore space and investigate reactions of these porous catalysts at the single particle level using advanced imaging and spectroscopic techniques, that in the long term will provide a novel catalyst design to enable new fuel cells and chemical neutralization methods in support of the Army Network and Soldier Lethality Army Modernization Priorities. Develop a first-principles framework for predicting the structure of molecular interfaces and designing molecular interfaces with enhanced properties that in the long term may enable new methods for chemical manufacturing, such as energetic materials, in support of the Army Modernization Priorities of Long-Range Precision Fires, Air and Missile Defense, and Soldier Lethality. ***FY 2021 Plans:***	-	16.515	17.926

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal Change of scope.			
Title: Basic Research in Physics	-	16.519	18.181
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 2020 Plans:*** Create and demonstrate novel linear and nonlinear supersymmetry-enabled optical materials and structures that in the long term may enable a new generation of invisibility technologies and secure optical communications through low-power switching and wave-length conversion techniques, all of which are in direct support of the Army Network and Future Vertical Lift Army Modernization Priorities. Electrically induce topological superconductivity in a single material system to explore the related electronic phases that comprise and enable this possibility, that in the long term will enable low-power electronics, coding, communications, and logistical support applications orders of magnitude more powerful than is possible with conventional computers, thereby in direct support of the Army Network Modernization Priority. Create new cold atom platforms to host anyons and exotic emergent excitations which are expected to be key building blocks in topological quantum memory, quantum computer architectures, and robust quantum interferometry schemes that in the long term may reveal new states of quantum matter with applications ranging from sensors and computers with orders of magnitude greater sensitivity and power than conventional systems. Develop new algorithms and applications for the realization of nearer-term quantum computers (QCs) that are inspired by underlying physical principles rather than the traditional methods using only pure mathematical techniques, and subsequently perform quantum supremacy experiments, that if successful will directly support the Army Network Modernization Priority as a			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
successful QC and will enable coding, communications, and logistical support applications orders of magnitude more complex than is possible with conventional computers. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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 2020 Plans:*** Investigate quantum hydrodynamic (forces exerted by fluids) charge transport in heterostructure of two dimensional (2D) materials including monolayer and bilayer graphene, 2D superconductors and atomically thin hexagonal boron nitride (hBN) and its interaction with electromagnetic radiation spanning from radio frequencies to terahertz (THz) frequencies, and to realize novel Radio Frequency (RF) and THz device concepts based on quantum hydrodynamic behaviors. Establish approaches to achieve background-limited photo-detection in mid-infrared spectral regimes using colloidal metal nanoparticle based artificial materials and microcavity enhanced thermal effects. Pursue use of carbon nanotubes and 2D materials within microcavities to achieve room temperature exciton-polariton lasers with orders of magnitude reduced threshold current densities compared to normal photon laser regimes. Develop a new biomolecule capable of sensing and modulating the local electric field at specific locations inside a single cell, controlled by optical input and providing optical output. Develop a new liquid scanning, non-invasive, microwave	-	6.242	7.464

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
microscopy methodology capable of measuring the electrical interactions between intracellular organelles at high spatial and temporal resolution. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Basic Research in Materials Sciences ***Description:*** Research that provides innovations in materials design and process through the elucidation of fundamental relationships linking composition, microstructure, defect structure, processing and properties of materials. Revolutionary materials provide support for the Army in firepower, mobility, communications, personnel protection, infrastructure and installations, and will directly affect virtually all mission areas. ***FY 2020 Plans:*** Establish the feasibility of using newly developed nuclear magnetic diffraction techniques to obtain atomic resolution structural and functional information about nanocrystalline membrane proteins. Utilize nuclear magnetic resonance to identify the phase transitions in metallic liquids, the conditions under which they occur, and the influence they have on mechanical properties. This knowledge could be utilized to develop advanced processing methods for high performance lightweight metallic alloys. Synthesize and characterize novel nano-structured hybrid inorganic-organic crystals and understand how the variations in organic spacer and chalcogen elements affect the excitonic effects to achieve tuning of extraordinary physical properties. Investigate recently identified aramid nanofibers (ANFs) as a reinforcing material. ***FY 2021 Plans:*** Will 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	-	11.792	13.191

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Basic Research in Mechanical Sciences ***Description:*** This effort focuses on improved understanding of propulsion and combustion for improved efficiency and fuel flexibility, energetics initiation for insensitive munitions, fluid dynamics for rotorcraft, complex dynamic systems for novel sensors, energy generation and multi-dimensional systems, and solid mechanics especially at high strain rates in composite materials for novel armor and protection systems. ***FY 2020 Plans:*** Couple machine learning control with sparse identification of nonlinear dynamics to create novel flow regimes and generate interpretable models of their underlying physics, providing the potential to create, understand and control new types of flows. Create an experimental microscopy method for probing sub-surface sample volumes in opaque and scattering condensed phases via Raman and Laser Induced Fluorescence (LIF) spectroscopy which will provide chemical reaction information on opaque reacting materials in-situ. Determine the dependency of size, microstructure, and surface chemistry on the mechanics of neat nanocellulose thin films from a molecular viewpoint, and establish design principles for maximizing the performance of these nanostructured materials under microballistic impact. Extend underlying physics of wheeled locomotion and general intrusion on complex terrain by extending Resistive Force Theory (RFT) to faster intruding motions and conducting rapid localized granular intrusion experiments. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	6.076	7.301
Title: Basic Research in Computing Sciences	-	6.199	7.446

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** Establish new scientific understandings in learning and modeling of adversarial mental states and decision processes for driving cyber deception schemes and to build an integrated framework of deception composition and projection methods to successfully manipulate adversaries' mental state and decision-making process to our advantage. Create a novel computational framework for the modeling and analysis of multisensory neural information processing. Integrate information from multimodal brain data toward enhanced brain-computer communications. Establish computational method and data structures for fast and efficient tensor factorization. Such systems can scale to large number of modes and can efficiently process multi-way data which arrive in a streaming fashion. Devise efficient techniques for tensor factorization which are necessary for a large number of Army applications, including but not limited to dimensionality reduction and clustering in machine learning, latent parameter estimation and source separation. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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 2020 Plans:***	-	12.955	14.411

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Expand current methods for obtaining consensus in distributed setting, typically limited to linear control and constraints to deal with temporal and non-linear constraints. Extend traditional linear methods to carry out optimization computation, allowing for distributed learning on top of distributed consensus and control. The results should have an impact on research in Internet of Battlefield Things. Create a framework for effective use of crowdsourcing? a technique that has gained popularity in Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) applications, where the wisdom of crowds is harnessed by taking into account the cognitive ability of each individual person in the crowd. Design algorithms to route data to their destination, using locally available information, which is optimal with respect to the use of available resources by using coding techniques throughout their span. Design networks to enable distributed trust services using Blockchain methodologies, which are robust to impairments in connectivity and to asymmetries in computational capabilities at the nodes. Predict dynamic human behaviors through mapping physical movements and shared mental models. Extend the boundaries of cognitive science into shared mental models within multi-team systems. This includes theoretical advancements based on iterative experimental and computational modeling towards the development of a predictive model of team dynamics in isolated, high stress, and complex environments. ***FY 2021 Plans:*** Will 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 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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.	-	5.086	6.295

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
FY 2020 Plans: Create new mathematical tools and methods for performing complex, multi-system analysis and modeling to enhance soldier and weapon-system performance. Central to this effort is the development of mathematical principles and practical algorithms for stochastic analysis and control, numerical computation of infinite-dimensional systems, analysis and control of biological systems, and modeling of irregular geometric and social phenomena. Develop new methodologies for the mechanistic modeling of biological systems, particularly by utilizing fields of mathematics, such as differential geometry, algebra, topology, and Bayesian statistics, not traditionally brought to bear on biological problems, as well as hybrid methods optimizing mechanistic, and data-driven approaches. Uncover fundamental principles and relationships in biological structure, function, and development using mathematical modeling. Of special interest are robustness and resilience, stochasticity, neurobiology, and biological timekeeping. Develop modeling techniques specifically for describing the collective behavior of smaller scale heterogeneous elements, as well as solving the related inverse problem. These improved methods combined with the understanding of modeling will allow greater fidelity and more efficient studies of any biological system, and will be especially transformational for the Army in understanding circadian rhythms, Post Traumatic Stress Disorder (PTSD), and traumatic injury. Create methods to analyze, control, and model stochastic differential equations which include separable methods for stochastic partial differential equations. Investigate geometric structures to create techniques for large-scale limit laws, asymptotic analysis, and solutions in optimal control. Develop innovative geometric and topological data modeling frameworks, with a particular focus on bridging the scientific gap between current topological data analysis methods and practical statistical inference, and machine learning techniques. Develop data-based and non-smooth analytical techniques for modeling complex, spatio-temporal dynamical systems that provide explanatory, as well as predictive results. Create models and computational methods for material-related issues in layered and two dimensional geometries, energetic crystals, and porous media that include geometric methods for multiscale computation, octree discretizations for massively parallel architectures, new quasi-continuum material models for sharp interfaces, and methods for ordered material incommensurability.			
FY 2021 Plans: Will 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			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: FY 2020 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	4.429	-
Accomplishments/Planned Programs Subtotals	-	97.703	103.455

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
AA4: *Training and Human Science Research*	-	0.000	20.792	21.871	-	21.871	22.284	22.801	23.059	23.060	0.000	133.867

Note

In Fiscal Year (FY) 2020 this Project was realigned from:
Program Element (PE) 0601102A Defense Research Sciences
* Project 74A Human Engineering
* Project 74F Pers Perf & Training

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, with a focus on researching how optimal methods for information exchanged between Soldiers and intelligent technologies including human performance in automated, mixed-initiative (human control-machine control) environments; visual scanning and target detection; performance-related Soldier state changes; integration across multiple sensory modalities; 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

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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.

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

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 2019	FY 2020	FY 2021
Title: Translational Neuroscience	-	3.646	3.965
Description: This effort integrates neuroscience with traditional approaches to understanding Soldier behavior to enable systems designs that maximize Soldier performance. ***FY 2020 Plans:*** Identify multimodal neural correlates of vigilance in Army-relevant tasks; create novel methods for exploration and understanding of relationships between performance and long-term longitudinal neural data; and understand interactions between properties of visual scene and improved performance at real-world target detection tasks. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Human System Integration	-	5.115	5.403
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 2020 Plans:*** Create methods for modeling and understanding critical aspects of closed-loop human-system interactions; establish machine learning approaches to improve effective human-agent collaborations within Army-relevant crew station environments; create			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
learning interfaces that mitigate performance decrements due to heterogeneous human-agent interactions; and identify approaches to understand effects of individual agent performance on hybrid team performance. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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?s states, behaviors, and intentions in real-time. Enable high fidelity, continuous prediction that can account for continuous changes in Soldier?s physical, cognitive, and social states, such as stress, fatigue, task difficulty, trust, and situational awareness. ***FY 2020 Plans:*** Establish just-in-time modeling approaches to adapt individualized level of appropriate risk in single-human single-agent interaction; create algorithmic forecasting approaches for anticipating changes in Soldier state; and generate novel metrics of team interactions and performance though multifaceted environmental and social data. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	4.055	4.361
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.	-	1.070	1.330

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
FY 2020 Plans: Identify behavioral and physiological correlates of positive and negative gamification feedback mechanisms for adaptive individualized training. ***FY 2021 Plans:*** Will identify methods to utilize immersive technologies and individual differences to improve training for spatial tasks and efficient navigation. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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, emphasizing deep learning approaches that function under conditions of limited, mismatched, or dynamic data. ***FY 2020 Plans:*** Create interaction and algorithmic mechanisms for human reward shaping of reinforcement learning algorithms to develop collaborative and interpretable agent behavior. ***FY 2021 Plans:*** Will study techniques to reduce data requirements for autonomous systems by incorporating knowledge from humans using natural interactions. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	0.760	1.000
Title: Science of Measurement of Individuals and Collectives ***Description:*** This research investigates advanced psychometric theory and measurement of Soldiers and teams to maximize talent management. ***FY 2020 Plans:*** Conduct research in computational psychometrics to identify promising approaches to develop valid simulation-based tests; conduct research on spatial skills and abilities related to navigation in 3-dimensions (3D) and complex terrain. ***FY 2021 Plans:***	-	2.658	2.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
Will conduct research to identify individual contribution to performance within a group; conduct research to develop new integrative framework of implicit personality; conduct research in psychometric models for sensor data sources (e.g., data streams). ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Decrease related to research moved into the new "Context of Behavior in Military Environments" effort.			
Title: Context of Behavior in Military Environments ***Description:*** This basic research effort investigates an integrative theory to understand and model the contextual drivers of individual and group performance. ***FY 2021 Plans:*** Will conduct research studying a theory of event-based leadership and identify contextual factors impacting individual and group decision making. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Continues work from the ?Science of Measurement of Individuals and Collectives" effort.	-	-	0.912
Title: Understanding Multilevel and Organizational Dynamics ***Description:*** This basic research effort investigates advanced methods and models to understand the relationship of human states, traits, and behaviors on individual, group, and organizational dynamics. ***FY 2020 Plans:*** Conduct research to investigate approaches for unobtrusive measurement of team performance in unconstrained, outdoor environments; conduct research to understand and model unit-based learning and knowledge diffusion in organizations. ***FY 2021 Plans:*** Will conduct research on mathematical algorithms for composing teams and assessing team performance; conduct research to understand and model social contagion of motivation within groups. (e.g., how does motivation spread among group members). ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Decrease related to research moved into the new "Formal and Informal Learning and Development" effort.	-	2.557	1.900
Title: Formal and Informal Learning and Development ***Description:*** This basic research effort studies a holistic model to understand and inform individual and group learning across assignments, platforms, and contexts throughout the career span.	-	-	1.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
FY 2021 Plans: Will conduct research on adaptive performance to identify predictors and barriers to behavior change and learning; conduct research to develop an integrated framework of self-regulated learning behaviors, motivation, and attitudes related to individual and group informal learning. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Continues work from the "Understanding Multilevel and Organizational Dynamics" effort.			
Title: FY 2020 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	0.931	-
Accomplishments/Planned Programs Subtotals	-	20.792	21.871

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army										Date: February 2020		
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 2019**	**FY 2020**	**FY 2021 Base**	**FY 2021 OCO**	**FY 2021 Total**	**FY 2022**	**FY 2023**	**FY 2024**	**FY 2025**	**Cost To Complete**	**Total Cost**
AA5: *Biotechnology and Systems Biology*	-	0.000	5.748	6.089	-	6.089	6.213	6.338	6.409	6.473	0.000	37.270

Note

In Fiscal Year (FY) 2020 this Project was realigned from:
Program Element (PE) 0601102A Defense Research Sciences
* Project H44 Adv Sensors Research

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.

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

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 2019	FY 2020	FY 2021
Title: Engineered Biotechnology (previously titled: Biological and Bio-derived Materials and Devices)	-	2.326	2.619
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 2020 Plans: Establish a framework using computational models and iterative biopanning of investigated microbial interactions to identify biologically enabled device and process specific consortia; extend fundamental understanding of microbial communities using			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
systems biology techniques for agile bioprocessing; and identify responses of engineered bacteria to surfaces of electronic materials for adhesion, release, signaling and survival. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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 2020 Plans:*** Identify synthetic biology routes to engineer robust host organisms with sense-and-respond genetic circuits; utilize synthetic biology techniques to investigate the use of biological processes to synthesize hierarchical materials from biologically available small molecules; and create biological tools to explore and understand the feasibility of dynamic, bio-hybrid materials. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	3.161	3.470
Title: FY 2020 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 Plans:***	-	0.261	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638			
Accomplishments/Planned Programs Subtotals	-	5.748	6.089

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

N/A

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
AA6: *Robotics and Mobile Energy*	-	0.000	21.700	22.794	-	22.794	22.948	23.406	23.666	23.904	0.000	138.418

Note

In Fiscal Year (FY) 2020 this Project was realigned from:
Program Element (PE) 0601102A Defense Research Sciences
* Project F20 Adv Propulsion Rsch
* Project F22 Rsch In Veh Mobility
* Project H45 Air Mobility
* Project H66 Adv Structures Rsch
* Project T63 Robotics Autonomy, Manipulation, & Portability Rsh
* Project H47 Applied Physics Rsch

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; and 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), PE 0601104A (University and Industry Research Centers).

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

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

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
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 2020 Plans:*** Increase understanding of liquid-gas interactions at extreme environmental conditions, articulating blade mechanisms, and additive chemistry in heat activated polymers. This research enables novel pathways for increased performance, reliability and survivability of platform propulsion systems. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	0.864	1.226
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 2020 Plans:*** Determine ignition chemistry of extremely low ignition quality fuels to determine mechanisms for assisted ignition. Understand tribological materials for extreme low viscosity fuels to advance the materials for lower wear and scuffing, and novel light-weight/ reliable coatings that can overcome higher thermo-mechanical stress. Increase understanding of aeroelasticity at high pressure ratio conditions to increase aero-damping to mitigate excitation or resonance. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:***	-	3.827	3.700

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
Nominal change of scope.			
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. ***FY 2020 Plans:*** Establish concepts for efficient conversion of ambient energy to electrical energy; understand, design, fabricate, prepare and characterize advanced catalysts for sustainable energy, and to enhance carbon monoxide oxidation and water splitting using infrared radiation; and determine the feasibility of using radioisotopes and nuclear isomers to access energy storage, without fission, that would enable greatly enhanced mission duration beyond that of current batteries and with reduced size and weight. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	1.051	1.236
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 2020 Plans:*** Identify novel structures that will enable the realization of advanced air vehicle architectures, and increase the fundamental understanding of dynamic phenomena important to novel air vehicle design. ***FY 2021 Plans:***	-	1.225	1.540

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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 2020 Plans:*** Create additively manufactured nanocomposites with engineered interfacial properties using ?structural? polymers and novel structural morphing concepts to enable high vibration damping. Establish control theories for active-matter systems that self-organize to desirable emergent properties. Identify new materials and mechanical processes to enable reconfigurable and structurally adaptive platforms. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal Change in Scope	-	0.826	1.000
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 2020 Plans:*** Identify methods to enhance robotic situational awareness in mission-relevant and hybrid teaming contexts. Understand mechanisms to efficiently share and exchange situational awareness with robotic and human team members. Create methods to increase robotic operational tempo under supervised and unsupervised autonomous operating conditions. Explore impacts and	-	1.201	1.515

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
methods to mitigate sporadic network connectivity, including fail-safe and fail-over paradigms in human-in-the-loop and human-on-the-loop scenarios. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Intelligent Systems ***Description:*** Pursue research in autonomous systems that supports and unburdens Soldiers in a flexible, robust, survivable and comprehensive manner. This work addresses the cognitive requirements of humans and (non-human) agents, both hardware and software based, operating individually or in collaboration, on the battlefield. Emphasis is placed on perception, reasoning, and collaboration techniques that can apply to and transfer between a broad range of systems (i.e., adaptive communication and data collection networks; crowd-sourcing and information retrieval software agents; and predictive and explanatory decision support systems). ***FY 2020 Plans:*** Establish methods to enable the teaming of intelligent systems with Soldiers through the exploration of techniques for online learning from human example, coordinated intelligent exploration of complex environments and online semantic labeling for shared understanding. Investigate perceptual and intelligence methods to enable an autonomous system to conduct op-tempo operations in military relevant environments. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	5.967	6.246
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.	-	2.827	3.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
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 2020 Plans:*** Establish control methods to increase vehicle endurance and energy efficient operations, including new energy aware autonomous behaviors, as well as novel concepts to enable cooperative multi-domain maneuver capabilities in mission-relevant environments. Identify novel vehicle configurations and materials that enable significant enhancements to small unmanned aerial system range, endurance, payload, and maneuverability, including emerging actuation concepts. Incorporate uncertainty quantification physics into flight dynamic models. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal scope change			
Title: Air Mobility	-	2.333	2.556
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 2020 Plans:*** Conduct experimental investigation of active flow control technology for hub/pylon drag reduction; conduct experimental measurements of hovering rotor wake to better understand vortex instabilities and identify flow physics that leads to these; apply high-fidelity computational tools for fundamental flow physics studies of interactional aerodynamics and rotor wakes, and their effects on steady/unsteady air loads and performance of rotors and complete aircraft configurations. ***FY 2021 Plans:*** Will 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			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
computational aero-science investigations using numerical methods including work on validating the physical assumptions forming the building blocks of the underlying theory. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Advanced Mathematical Algorithms for Improved Vehicle Efficiency ***Description:*** Research in support of advanced military mobility technologies with emphasis on Terramechanics (vehicle-terrain interaction), and complex vehicle dynamics and simulation. This includes developing the data and underlying models to simulate and predict autonomous vehicle mobility in soft soil and complex organic terrain under a variety of environments. Research is directed at understanding advanced mathematical and computational methodologies using state-of-the-art analytical and empirical procedures. ***FY 2020 Plans:*** Review and quantify the effectiveness and efficiency of the multi-scale computational algorithms for modeling a military ground vehicle traversing over fine soil particles to their true size and geometry; expand and apply deep learning algorithms for generating Go/NoGo maps to other geographic regions; expand human cognitive models based on use cases and human roles (e.g., driver, gunner, etc.) for integration into autonomy modeling and operational use case evaluation software. Examine how these algorithms support shared control relative to complete human operators. Also identify high performance computing demands on these models and algorithms. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	0.594	0.775
Title: FY 2020 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 Plans:***	-	0.985	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638			
Accomplishments/Planned Programs Subtotals	-	21.700	22.794

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
AA7: *Mechanics and Ballistics*	-	0.000	34.139	36.048	-	36.048	37.451	38.202	38.633	39.021	0.000	223.494

Note

In Fiscal Year (FY) 2020 this Project was realigned from:
Program Element (PE) 0601102A Defense Research Sciences
* Project 53A Battlefield Env & Sig
* Project H42 Materials & Mechanics
* Project H43 Research In Ballistics
* Project H44 Adv Sensors Research
* Project H67 Environmental Research
* Project VR9 Surface Science Research

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.

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** AA7 / *Mechanics and Ballistics*

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); 0602146A (Networks C3I Technology); 0602147A (Long Range Precision Fires); PE 0602141A (Lethality Technology), PE 0602143A (Soldier Lethality Technology).

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

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 2019	FY 2020	FY 2021
Title: Protection Sciences	-	5.139	5.451
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 mechanisms through increased understanding of wave propagation through tissue, and the resulting deformation and damage of tissue during ballistic and blast events. ***FY 2020 Plans:*** Perform ballistic model experiments on lightweight metal alloys and brittle materials to deepen understanding of fundamental ballistic events, failure and fracture mechanics, and high strain rate behavior; identify the physics and mechanics of materials with electromagnetic fields and forces that fluctuate on timescales of influence during an impact event; conduct experiments to understand stress wave propagation and dispersion through biological constituents to identify regions more susceptible to damage, and design next-generation Personal Protective Equipment that mitigates damage to these regions. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Microscopic/Nanostructural Materials	-	2.971	3.241
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.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
FY 2020 Plans: Design, characterize, and conduct ballistic experiments of a high-strength, multi-phase alloy with targeted precipitates to produce a maximum transformation volume so that once the penetrator forms shear bands in the high strength material, the deformation cannot be accommodated by lateral cracking, and short-circuit the transition to plugging failure. Identify next generation ceramic material synthesis techniques by using multi-modal diamond particle sizes and novel powdered silicon-carbon mixtures to hot-press high diamond content (60?90%) diamond / silicon-carbon composites rapidly in an inert atmosphere. ***FY 2021 Plans:*** Will investigate nanostructured materials properties achieved through novel processing routes for potential use in and transition to vehicle armor and lethality applications. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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 2020 Plans:*** Extend the large-scale atomistic simulations combined with virtual diffraction to Iron-Nickel-Zirconium; investigate via Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), and Atom Probe Tomography analyses on the shock-recovered samples to study deformation mechanisms, texture evolution and their contribution to failure process; identify novel modeling strategies that link molecular dynamics simulations to continuum models of microfibril structure within single fibers of ultrahigh molecular weight polyethylene (UHMWPE). Understand the influence of chemistry and structure on the rate dependent mechanical response of crosslinked polymer networks. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	3.096	3.389
Title: Materiel Research and Processing Using High Energy Fields	-	2.254	2.480

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 Plans:*** Exploit field-assisted processing methods to tailor phases that demonstrate improvements in mechanical and functional behavior (such as fracture resistance). Create new models at multiple length scales (including molecular and mesoscale) to simulate the evolution of microstructural features under the application of energy fields and perform validation using customized experimental apparatus. ***FY 2021 Plans:*** Will 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 will be 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: One Dimensional (1D) and Two Dimensional (2D) Materials and Processing Research	-	1.286	1.622
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 2020 Plans:*** Identify synthesis methods for novel 2D polymer molecules assembled with intermolecular hydrogen bonding to create graphene-like materials with enhanced toughness relative to graphene. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Nominal change of scope.			
Title: Bio-enabled Precision Materials Synthesis and Assembly	-	1.523	1.817
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 2020 Plans:*** Identify methods for genetic control over biological organisms, with particular focus on diatoms, to develop new pathways for hierarchically structured materials with nanoscale resolution of features to control optical, structural and reactive performance for potential application in adaptive coatings. Create generalized molecular and coarse grained computational tools for copolymers made from a diverse range of synthetic and bio-derived monomeric feedstocks enabling design and optimization of complex copolymers with tunable micro-structure, mechanical, or functional performance. ***FY 2021 Plans:*** Will 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 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Launch and Flight of Gun Launched Projectiles as well as Missiles	-	2.846	3.190
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 2020 Plans:*** Link multi-physics (fluids, thermal, structures, dynamics and controls) tools to computationally investigate high-speed flight phenomena (interactions with shocks and vortices, aero-thermal, aero-optical) and improve munition maneuverability and survivability. Formulate theory and algorithms for flight control and estimation exploiting understanding of unique dynamics and constraints to guide advanced munitions in denied environments. Conduct time resolved analysis of inelastic and plastic			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
deformation of brittle materials under 1D strain and combined loading in conjunction with computational modeling. Understand the neural mechanisms of movement initiation and directional control. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Energetic Materials Research ***Description:*** Expand and confirm physics based models and validation techniques to enable design of novel insensitive propellants/explosives with tailored energy release for revolutionary future force survivability and weapons effectiveness. ***FY 2020 Plans:*** Synthesize new energetic ingredients for use in rocket and gun propellants with properties/performance equal to or greater than nitroglycerine, identify stand-alone energetic ingredients which have detonation pressure exceeding that of the explosive used in current reactive armor, and create new melt cast ingredients and formulations with performance exceeding that of Composition B. Use non-traditional physics-based approaches to synthesize, explore stabilization routes and characterize performance of disruptive-type materials and energetic reaction processes, including extended solids, structural reactive materials and enhanced yield energetics. Determine response of newly developed ingredients to dynamic compression and correlate findings with numerical simulations for validation and verification. Conduct numerical simulations to aide in understanding the kinetic rates of newly developed propellants and propulsion technologies (ramjet). ***FY 2021 Plans:*** Will 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	-	3.350	3.651

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
in FY20; continue numerical simulations that aide in understanding the kinetic rates of newly developed propellants and propulsion technologies. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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 2020 Plans:*** Understand urban land surface energy budget and radiative transfer processes at the Dense Urban Area Meteorological Sensor Array (MSA) testbed and couple radiative transfer module to Atmospheric Boundary Layer Environment (ABLE) model for high resolution urban modeling; understand thermal and momentum flux of sloping surfaces under stratification to better treat physical processes in complex and urban terrain; implement new approaches for quantifying uncertainty in forecast model output, and adequately expressing the uncertainty for decision support tools; implement machine learning techniques as a method to increase the performance of low-resource forecast models in the presence of increasing volumes of sensor data; examine new methodologies for predicting environmental impacts on acoustic vector sensing; quantify the effects of variations in humidity, ozone, and ultraviolet radiation on the transport and chemical evolution of ambient aerosols with an emphasis on processes occurring in dense-urban environments. Create physics algorithms for atmospheric optical communication link budget models that simulate optical turbulence effects upon link quality and maximum data rate among ground terminals, airborne platforms, and low earth orbit (LEO) platforms. Utilize instrumented Unmanned Air Systems multi-rotors for microscale model initialization in data sparse environments; implement Machine Learning techniques to accurately and efficiently identify the atmospheric state from large datasets. ***FY 2021 Plans:*** Will 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	-	3.846	4.130

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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 2020 Plans:*** Create numerical methods and algorithms to enable new high-fidelity computer models of materials, with uncertainty of model predictions and incorporating some non-deterministic aspects of microstructure characterization, capable of taking advantage of large-scale computing environments; create new and extend existing computational methodologies to advance the state-of-the-art of at-scale models of materials, from the electronic scale through atomistic- and meso-scale to macro-scale, to take full advantage of state-of-the-art large-scale computing environments in order to expedite design of new materials for Army applications. Implement models that describe transport in electronic materials for improved design of electronic and electrochemical interfaces in materials and devices. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:***	-	3.262	3.540

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Nominal change of scope.			
Title: Environmental Quality ***Description:*** This effort conducts research on innovative environmentally-friendly technologies that support the warfighter focusing on pollution prevention technologies. ***FY 2020 Plans:*** Synthesize and characterize a possible new class of layered coatings as a possible replacement to chrome. Understand the bio-optics of light scattering pigmentary nanoparticles that provide visible and infrared coloration for improved Green Coatings. Create materials and coatings to protect and reduce maintenance of military clothing and textile items. Create the underlying science base for making energetics with a reduction of hazardous materials in the processing of energetics. Perform basic research on the possible clean synthesis of energetic polymers for the reduction of hazardous chemicals in processing. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	0.859	1.107
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 2020 Plans:*** Understand and characterize chemical and biochemical phenomena occurring at or near solid surfaces and material interfaces, to include the effects of binding energy, reactions, transport and deposition; understand the interactions between chemical reactions and transport processes on surfaces; develop the theory and conduct modeling of processes at complex surfaces; and conduct experiments focused on the systematic understanding of surface structure, morphology and surface group properties. ***FY 2021 Plans:***	-	2.157	2.430

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Will 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 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: FY 2020 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	1.550	-
Accomplishments/Planned Programs Subtotals	-	34.139	36.048

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
AA8: *Sensing and Electromagnetics*	-	0.000	8.582	9.066	-	9.066	9.567	9.759	9.868	9.968	0.000	56.810

Note

In Fiscal Year (FY) 2020 this Project was realigned from:
Program Element (PE) 0601102A Defense Research Sciences
* Project 31B Infrared Optics Rsch
* Project H44 Adv Sensors Research
* Project H47 Applied Physics Rsch
* Project H52 Equip For The Soldier

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.

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

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 2019	FY 2020	FY 2021
Title: Photonic Materials and Device Research	-	0.886	1.000
Description: Conduct research into novel material and device structures operable throughout the electromagnetic spectrum from long wave infra-red (LWIR) to ultraviolet (UV) including sources, detectors, and integrated photonic devices to increase situational awareness in open and complex terrains; allow assured communication, improve target detection, identification, and discrimination; and create new device functionalities while reducing size, weight, and power requirements. ***FY 2020 Plans:*** Understand the growth and properties of semi-polar and non-polar aluminum gallium nitride alloys including the polarization of light emission, n-type and p-type doping of the alloys, and the generation of defects associated with heteroepitaxial (one kind of			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
crystal is grown upon the surface of a different type) growth techniques; and perform fundamental studies on chip-scale integrated photonic sub-wavelength structures with the goal of identifying critical features for optical phase delay radio frequency (RF) beamforming and enhancement of surface interactions electromagnetic field for possible on-chip sensing. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal Scope change.			
Title: Advanced Materials Research ***Description:*** This effort conducts research in modeling, fabrication, and characterization of semiconductor materials and structures that leads to revolutionary device functionality in sensing, low power electronics, quantum networks, and power generation. This effort investigates novel complex crystal structures that can lead to devices with performance beyond normal semiconductor transistors, including neuromorphic computing structures and topological insulator based heterostructure with low operating voltage. ***FY 2020 Plans:*** Create topological insulators applicable for ultra-low power devices for Army electronics; identify complex crystal structures for new device concepts beyond traditional semiconductor transistors for high performance electronics including neuromorphic computing structures with low operating voltage; understand the fundamental physics of electron transport along and across material interfaces to achieve new electronic/optoelectronic device functionalities; identify the performance of semiconductor materials specifically designed to reduce leakage currents in infrared sensors; identify the proximity superconductor effect in semiconductors; and validate modeling of charge carrier dynamics at a semiconductor-electrolyte interface of energy generating materials. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:***	-	2.638	2.750

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Nominal change of scope.			
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 RF propagation and exploitation in complex clutter environments for improved RF and radar sensing. ***FY 2020 Plans:*** Create robust machine learning tools and agile inference in resource constrained environment; create full-wave electromagnetic scalar and vector Helmholtz solvers for extremely large (up to a trillion elements) quasistatic magnetic- and electric-field sensing problems; establish wideband direction-of-arrival methods for multiple acoustic targets with reflectors and reconstruct individual waveforms using a single acoustic particle velocity sensor; and understand and create new radar data-driven approaches for forming three-dimensional high-frequency millimeter wave synthetic aperture radar (SAR) imagery using limited positional information. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	1.543	1.713
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 communications 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 RF devices and sensors. ***FY 2020 Plans:*** Develop models that investigate ion transport in three-dimensional (3D) electrode structures; identify the interactions of electromagnetic fields with plasmonic electrocatalytic materials; vary the density of carbon vacancies in silicon carbide and characterize changes to signal and leakage currents; and advance three-dimensional fabrication techniques for piezoelectric	-	1.500	1.665

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
materials and integration strategies for thin film piezoelectrics to enable tunable, adaptable RF MEMS devices and inertial sensors to address challenges with spectrum management and operation. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Fundamentals for Precision Measurement for Contested Environments ***Description:*** This effort explores new materials, novel device architectures, and unique processing techniques to successfully maintain communication and information sharing protocols in GPS-denied, actively jammed, or austere environments. ***FY 2020 Plans:*** Design, simulate and establish fabrication process to investigate environmentally stable electro-optic air-ring resonator using specialized metamaterial approach as a component for GPS-denied timing applications. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	0.535	0.710
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 2020 Plans:*** Design and synthesize homogenous multilayer composites of carbon nanotubes using layer-by-layer assembly to systematically elucidate the effect of carbon nanotube dimensions on their function as electromagnetic radiation absorbers and broaden the	-	1.090	1.228

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
frequency range of carbon nanotube microwave absorption. Utilize full wave electromagnetic simulations to predict geometric and periodic design patterns for printed hybrid nanocomposites of magnetic nanoparticles and graphene to enhance electromagnetic absorption and inform the design of lightweight Soldier protective platforms. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: FY 2020 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	0.390	-
Accomplishments/Planned Programs Subtotals	-	8.582	9.066

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
AA9: *Information and Networking*	-	0.000	39.112	41.035	-	41.035	41.452	42.282	42.753	43.184	0.000	249.818

Note

In Fiscal Year (FY) 2020 this Project was realigned from:
Program Element (PE) 0601102A Defense Research Sciences
* Project 305 ATR Research
* Project H47 Applied Physics Rsch
* Project H48 Battlespace Info & Comm Rsc

A. Mission Description and Budget Item Justification

This Project supports basic research to enable intelligent and survivable command and 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 produce help identifying 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), 0602143A (Soldier Lethality Technology) and 0602145A (Next Generation Combat Vehicle Technology).

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

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

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 2019	FY 2020	FY 2021
Title: Communications in Complex Dynamic Networks	-	5.366	5.475

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 Soldiers' 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. ***FY 2020 Plans:*** Create models for the structure and processes associated with social, information, and communication networks, and composite networks thereof, with the communication networks potentially comprising unconventional communication channels (e.g., incoherent optical communications and low-radio-frequency channels) with features that can be exploited to enable operation in complex dynamic environments. Utilize simulated and experimentally collected data to identify adaptive methods to control the evolution of these networks and to optimize network performance. Create methods for the simulated and experimental assessment of the novel communications and networking modeling and control approaches by exploiting, e.g., low-complexity approximations or high-performance computing resources, and apply such methods to the evaluation of the proposed approaches. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** This is a nominal change in scope.			
Title: Data to Knowledge to Support Decision Making (Information Mediation)	-	4.850	5.221
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			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
of individual Warfighters and units through the integration of cognitive augmentation and course of action recommender technologies. ***FY 2020 Plans:*** Understand the characteristics of complex systems behavior and reasoning given heterogeneous exascale networked sensing and actuating information-sources and ensemble machine-learning models; identify methods to estimate Soldier state through use of wearable sensors and personal devices; quantify and understand the propagation of uncertainty given intelligent predictive representations and create theoretical models that enable machine learnable risk quantification for decision making. ***FY 2021 Plans:*** Will 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 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 2020 to FY 2021 Increase/Decrease Statement:*** This is a nominal change in scope.			
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 2020 Plans:*** Create communications and networking models and methodologies that provide physics-based security guarantees through the exploitation of fundamental characteristics of entanglement. Identify algorithms that provide information-theoretic guarantees on security for conventional networks and develop associated theoretical performance characterizations. Establish ultraviolet networking protocols that optimize network performance while satisfying bounded probability of adversarial detection by exploiting atmospheric absorption effects. Create methodologies and algorithms for non-invertible intrusion detection systems in resource	-	4.610	5.029

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
constrained environments. Understand cyber deception methods for contested tactical networks to effectively mask current and future operations by exploiting machine learning and game-theoretic approaches. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** This is a nominal change in scope.			
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 2020 Plans:*** Identify or create natural language processing (NLP), social terrain modeling, multimodal data analytics, and soldier-centric informatics to support human-agent interaction, situational awareness, and decision-making. Leverage machine learning, ontological, morphological, rule-based, and other evolutionary approaches to using human language technologies (HLT), computational linguistics, social theory, and informatics for naturalistic communication and shared understanding between Soldiers and systems. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:***	-	0.890	1.226

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
This is a nominal change in scope.			
Title: Advanced Computing Architectures and Algorithms ***Description:*** Investigate advanced computing and high performance computing (HPC) networking architectures, memory/storage architectures, algorithms and visualization techniques to support advanced battle command applications for Command, Control, Communications, Computers, and Intelligence (C4I) systems. ***FY 2020 Plans:*** Identify memory and processor architecture needed to simulate and characterize performance characteristics of advanced computer systems; establish methods to use neuromorphic processors and heterogeneous architectures using innovative programming techniques beyond machine learning; advance mathematical algorithms and models devoted to scalable and temporal data analytics for machine learning, real-time detection, increased, and predictive analytics to increase Soldier effectiveness, situational awareness, and decision-making. ***FY 2021 Plans:*** Will 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 learning agents to optimize a diverse set of properties (e.g., security, efficiency, etc.) while maintaining communication integrity in mobile networks. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** This is a nominal change in scope.	-	3.502	3.891
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 2020 Plans:*** Establish networking approaches and algorithms that configure physical and cyber network properties to leverage multiple communication modalities and obscure the location and nature of information on the network while providing enhanced network adaptiveness. Create the framework for integrating conventional radio-frequency communications with unconventional spectrum	-	5.753	6.372

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
usage to enhance network adaptability and provide resilience to adversarial jamming and detection. Identify methodologies and algorithms for automated resilience for tactical cyber physical systems. Understand both signature-based intrusion detection and anomaly detection methods for cyber physical systems. Identify methods of assigning dynamic risk scores for tactical systems based on mission and phase of mission to enhance the overall resilience of the entire tactical system. Formulate methods for augmenting situational awareness by leveraging and navigating the social terrain in complex environments. Establish the principles of distributed and hybrid approaches for combining model-based and data-driven approaches, to detect anomalies in the environment, devices, and systems in a manner that is aware of and helpful to learning operating parameters, security considerations, and mission goals. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** This is a nominal change in scope.			
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 2020 Plans:*** Understand the implications of training deep networks from sparsely labeled data under time constraints; identify learning approaches with statistically mismatched data. Create the framework for enhanced natural, intuitive, multimodal, and bi-directional communication between Soldiers, agents, and systems. Improve computational methods for capturing knowledge and intent	-	3.600	3.981

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
from information in military environments. Create methods for online discovery and adaptation of semantic models in dynamic environments. Use human input to improve learning algorithms that provide improved decision-making with less data and in less time. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** This is a nominal change in scope.			
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 2020 Plans:*** Create machine learning approaches to obtain real-time scene understanding and situational awareness from multimodal visible and infrared imaging sensors distributed on multiple heterogeneous aerial and ground platforms to support Next Generation Combat Vehicle engagement scenarios; identify point-of-need at the edge image data exploitation methods in the absence of remote, back-end networking support; and refine computational vision approaches for enhanced scene understanding in visually degraded environments. ***FY 2021 Plans:*** Will 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	-	1.874	2.231

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 2020 to FY 2021 Increase/Decrease Statement:*** This is a nominal change in scope.			
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 2020 Plans:*** Identify innovative electronic device structures based on surface conduction phenomena in diamond; understand the utility of ferromagnetic material for developing conformal low frequency antennas by exploring host materials with high permeability, embedded with meta-material cells that enhance the permeability for efficient operation at desired frequencies; create the growth techniques for chalcogenide-based topological insulator and topological crystalline insulator materials to understand the structural, electronic and unique transport properties of these specialized materials; and create pyroelectric materials with multiple compositions to enable stacking of materials and efficiently extract energy from a pulsed thermal source for both wireless power and data transfer. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** This is a nominal change in scope.	-	1.635	1.947
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

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
matter interfaces, including optical cavities, nanophotonics, and high density atomic systems. This effort also explores quantum algorithms for entanglement distribution. ***FY 2020 Plans:*** Understand atomic systems confined to optical cavities for strengthened light-matter interactions; create an understanding of Rydberg atomic systems for high-sensitivity electrometry and deterministic quantum memories; understand the interactions between optical nanofibers and atomic systems; and identify techniques for quantum frequency conversion from ultraviolet to telecommunications wavelengths, solid-state qubit candidates, and quantum algorithms. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** This is a nominal change in scope.			
Title: FY 2020 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	1.776	-
Accomplishments/Planned Programs Subtotals	-	39.112	41.035

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
AB1: *Basic Res in infect Dis, Oper Med and Combat Care*	-	0.000	32.126	33.167	-	33.167	33.856	35.272	35.675	36.042	0.000	206.138

Note

In Fiscal Year (FY) 2020 this Project was realigned from:
Program Element (PE) 0601102A Defense Research Sciences
* Project ET6 BASIC RESCH IN CLINICAL & REHABILITATIVE MED
* Project S13 Sci BS/Med Rsh Inf Dis
* Project S14 Sci BS/Cbt Cas Care Rs
* Project S15 Sci BS/Army Op Med Rsh
* Project T64 Sci BS/System Biology And Network Science

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).

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 2019	FY 2020	FY 2021
Title: Damage Control Resuscitation	-	1.622	1.729
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 2020 Plans: Identify candidate key additives for improving platelet storage that delay or inhibit the biochemical processes that lead to platelet death during storage. Investigate correlations between biochemical changes in blood clotting system to clinical markers of acute traumatic coagulopathy. Perform studies of stem cells to determine the growth / environmental conditions which minimize their ability to create lethal blood clots when administered into the bloodstream. Continue use of cell culture screening of drugs that			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
protect cells from the effects of blood loss and oxygen deprivation. Characterize the response of tissue capillaries to hemorrhagic shock. Understand the utility of stem cells and the proteins they secrete for possible application as treatments for traumatic hemorrhage. Initiate mathematical modeling for predicting success of resuscitation strategies for traumatic injuries. ***FY 2021 Plans:*** Will 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; perform basic research studies to identify candidate components for engineered plasma to reverse impaired blood clotting that occurs subsequent to severe trauma. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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 2020 Plans:*** Characterize composite cell/tissue scaffolds and stem cells as potential candidates for a viable skin substitute. Elucidate the mechanisms of impaired extremity wound healing caused by bone-muscle composite injury in a rodent model. Will identify wound healing agents that limit injury progression by stabilize necrotic tissue and/or resolving dysregulated inflammation in wounds. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Funding realigned to support Pre-hospital Tactical Combat Casualty Care and Prolonged Field Care.	-	1.458	0.709
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 2020 Plans:***	-	0.865	1.489

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Increased funding for minimally invasive control of non-compressible injury and crush injury.			
Title: Traumatic Brain Injury ***Description:*** This effort conducts basic research in poly-trauma (multiple injuries)/Traumatic Brain Injury (TBI) model, mechanisms of cell death, and the discovery of novel drugs and medical procedures to mitigate the effects of TBI ***FY 2020 Plans:*** Establish framework 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 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	1.330	1.427
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 2020 Plans:*** Define changes that occur within the capillaries when perfused with oxygen-carrying blood substitutes. Characterize stem cell ability to mitigate organ failure following traumatic injury in rodent models. ***FY 2021 Plans:***	-	0.993	2.769

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Increase due to realignment of funds from the Clinical and Rehabilitative Medicine to Prolonged Care effort.			
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. ***FY 2020 Plans:*** Characterize cellular and vital organ bioeffects from exposures to various sources of directed energy to include: acoustic/sonic waves, lasers, microwaves and other relevant radiofrequency threats. Identify and characterize risk factors that contribute to increased risk for musculoskeletal injury during Basic Combat Training (BCT). Create whole body blast animal models that can inform blast injury criteria for next generation bomb suit and blast exposure health hazard assessment criteria. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	2.664	2.519
Title: Physiological Health	-	3.672	5.139

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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 2019	FY 2020	FY 2021
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 2020 Plans:*** Understand the role of nutrition support for metabolic recovery; understand regulation of mineral transport by inflammation; discover Central Nervous System (CNS) correlates of chronic sleep restriction and recovery; define field-based impact of sleep on operational performance; investigate non-invasive brain stimulation for enhancing operational performance. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Increased funding for Soldier Performance Augmentation research area.			
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 2020 Plans:*** Establish animal models for basic mechanisms of injuries from exposure to heat that degrade health and performance and those factors that accelerate improved recovery. Identify physiological and host response signatures for performance degradation following toxic chemical exposures. Identify small molecule biomarkers for accurate assessment of exposures to toxic chemicals or hazardous environmental materials. Identify microbiome perturbations after exposure to environmental chemicals which can modulate adverse health effects of the host. ***FY 2021 Plans:***	-	1.056	1.158

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Physiological 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 2020 Plans:*** Advance, refine, and maintain animal models for PTSD. Facilitate rapid through-put evaluation of candidate compounds for prevention/ treatment of PTSD. Facilitate development of new analytic techniques to be used in Systems Biology research for obtaining an understanding of the underlying biological processes for both PTSD onset and maintenance and combat stress resolution for those exposed to trauma in which resolution of symptoms occurred without intervention. Continue identify neuro-biomarkers to optimize recovery from adverse performance-limiting outcomes of traumatic stress. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	2.026	1.809
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 2020 Plans:***	-	6.405	6.078

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
Formulate and analyze triazine class compounds intended for oral administration in humans. Create analysis methods for projected pyrimidinylguanidine class of compounds (a newly discovered family of similar chemical compounds that are active against malaria parasites in animal models). Determine mode of action of primaquine-like compounds used to prevent or treat malaria. Create methods for projected clinical trials and to assess drug distribution and efficacy in experimental animals and humans. Identify and assess new lead candidates from additional chemical classes for treatment and prevention of malaria. Fabricate newly discovered malaria proteins (artificially produced via genetic engineering) to characterize their ability to prevent malaria in experimental animals. Identify new formulations or delivery methods of malaria proteins for inclusion into malaria vaccines. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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 2020 Plans:*** Characterize previously identified antigens (substances derived from the agent which stimulate immune systems to produce antibodies) from ETEC, Shigella and Campylobacter which together are responsible for most of the cases of diarrhea in deployed Warfighters. Characterize various types of ETEC, Shigella and Campylobacter to inform vaccine development efforts. Understand previously identified indicators of vaccine effectiveness (correlates of protection) in animal models of bacterial diarrhea to predict protection from disease. ***FY 2021 Plans:*** Will 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	-	1.572	1.679

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
proteins produced in response to and against bacterial diarrheal diseases; characterize diarrhea-associated bacteria to inform future development of prophylactics against bacterial diarrheal diseases. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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 2020 Plans:*** Formulate new attenuated (weakened) dengue viruses for use in dengue human challenge trials as part of vaccine testing and studying virus induced host damage and immune cell mediated protection. Characterize immune cells and antibodies in samples from humans in novel inactivated virus/ live attenuated virus vaccinations against dengue. Conduct computer based assessments of human immune responses to dengue vaccination and dengue infection. Identify and characterize vaccine technologies to produce antibody products that might be used to prevent or treat disease by lethal viruses such as Hantaviruses, South American and African Hemorrhagic viruses. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	1.682	1.788
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 2020 Plans:***	-	1.583	1.675

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
Identify unique biological markers (e.g., proteins, genes) and technology that can be used to produce improved detection tools that can identify multiple pathogens in a vector population and help to inform vector control countermeasures and risk assessment tools. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Clinical and Rehabilitative Medicine ***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. ***FY 2020 Plans:*** Create candidate products to treat severe burn injury for skin regeneration and reduced scarring. Create animal pain models, discover novel pain treatment targets and identify biomarkers that predict pain phenotype and analgesic efficacy. Understand and characterize the pattern of molecules that impact immune response in the eye after injury to understand the timing of clinical impacts. Characterize cellular mechanisms leading to vision dysfunction. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Funds realigned to the Prolonged Field Care effort.	-	1.196	-
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 2020 Plans:*** Refine and test computational models to understand blood-clotting processes and assess the effects of changes in clot formation, blood flow, and injury severity on trauma-induced coagulopathy (when the blood's clotting ability is impaired); will refine and	-	3.056	3.199

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
test algorithms to predict the risk of musculoskeletal stress-fracture injury in Warfighters during basic combat training; refine computational algorithms to improve the understanding of vaccine-induced immune responses during viral infection, to provide insight into molecular mechanisms of protection; improve and extend algorithms to predict biomarkers indicative of toxic chemical exposure and organ damage; create algorithms to understand the mechanisms involved in hearing loss; utilize new deep-learning algorithms to extract knowledge from big datasets, in order to identify brain activity during sleep that may be indicative of PTSD, and more efficiently assess pharmacological properties of drug candidates. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: FY 2020 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Funding transferred in accordance with Title 15 USC ?638	-	0.946	-
Accomplishments/Planned Programs Subtotals	-	32.126	33.167

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
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*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
AB2: *Protection, Maneuver, Geospatial, Natural Sciences*	-	0.000	16.844	17.737	-	17.737	18.569	19.169	19.382	19.383	0.000	111.084

Note

In Fiscal Year (FY) 2020 this Project was realigned from:
Program Element (PE) 0601102A Defense Research Sciences
* Project 52C Mapping & Remote Sens
* Project T22 Soil & Rock Mech
* Project T23 Basic Res Mil Const
* Project T24 Signature Physics And Terrain State Basic Research
* Project T25 Environmental Science Basic Research

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.

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

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 2019	FY 2020	FY 2021
Title: Mapping, remote sensing, signature physics and terrain state	-	3.656	4.015
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 2020 Plans:			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
Explore new analytical approaches of automated learning to a wide class of spatially-enabled data to discover hidden but important patterns. Fundamental research in this effort also investigates emergent properties of multimodal observations and novel collection strategies. ***FY 2021 Plans:*** Will investigate 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 will also include validation of computational models to infer mechanisms of collective motion that initiate social contagion. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
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. ***FY 2020 Plans:*** Determine the fundamental mechanisms for material concealment; develop novel damage theories for protective materials; investigate fundamental responses of snow, ice, and soil to dynamic loads; and investigate acoustic and infrasound to enhance geophysical environment predictions. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.	-	4.502	4.878
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 2020 Plans:***	-	1.614	1.886

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
Identify and quantify fundamental scientific principles that support complex autonomous/semi-autonomous Engineer operations and 3D printing, maximize infrastructure resilience and adaptability through new, innovative infrastructure materials. ***FY 2021 Plans:*** Will investigate the interfacial transition zone (ITZ) chemical and mechanical properties of concrete materials with the inclusion of biomimetic adhesive polymer inspired by marine organisms; will explore polymer functionality that gives rise to stimulus-responsive reactions. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope.			
Title: Biological, Chemical and Physical Sciences ***Description:*** Explore novel approaches of innovative data analytics, bio-inspired materials, and chemical experimentation to understand basic principles of biological and chemical mechanisms, organisms, and natural processes of the environment. ***FY 2020 Plans:*** Explore and inform the effects of permafrost thaw on biogeochemical processes of the microbiome using state-of-the-art metabolite analysis to relate measured processes to landscape scale effects and impacts on future Army operations. Investigate the fundamental divergence of chemical signaling in isolated populations of slender glass lizards to increase basic understanding of chemical signal evolution, and determine if chemical signaling can inform future Army applications in communications. ***FY 2021 Plans:*** Will 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 2020 to FY 2021 Increase/Decrease Statement:*** Nominal change of scope	-	6.704	6.958
Title: FY 2020 SBIR/STTR Transfer ***Description:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 Plans:*** Funding transferred in accordance with Title 15 USC ?638 ***FY 2020 to FY 2021 Increase/Decrease Statement:***	-	0.368	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020	FY 2021
Funding transferred in accordance with Title 15 USC ?638			
Accomplishments/Planned Programs Subtotals	-	16.844	17.737

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) ET6 / *BASIC RESCH IN CLINICAL & REHABILITATIVE MED*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
ET6: *BASIC RESCH IN CLINICAL & REHABILITATIVE MED*	-	4.403	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	4.403

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AB1 Basic Res in Infect Dis, Oper Med and Combat Care

A. Mission Description and Budget Item Justification

This Project supports basic research on experimental models that are developed to support in-depth trauma research studies. This Project includes studies to understand the healing of burned or traumatically injured tissues including eye, bone, nerve, skin, muscle, organs and composite tissues. Such efforts will minimize lost duty time and provide military medical capabilities for post-evacuation restorative and rehabilitative care.

Work in this Project complements and is fully coordinated with PE 0602787A (Medical Technology).

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

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

Work in this Project is performed by the United States Army Medical Research Materiel Command (USAMRMC), Fort Detrick, MD.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Clinical and Rehabilitative Medicine	4.403	-	-
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.			
Accomplishments/Planned Programs Subtotals	4.403	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** ET6 / *BASIC RESCH IN CLINICAL & REHABILITATIVE MED*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) F20 / *Adv Propulsion Rsch*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
F20: *Adv Propulsion Rsch*	-	3.544	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	3.544

Note

In Fiscal Year (FY) 2020 this Project was realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA6 Robotics and Mobile Energy

A. Mission Description and Budget Item Justification

This Project fosters research to increase the performance of small air-breathing engines and power-trains to support improved system mobility, reliability, and survivability for air and/or ground vehicles; and ultimately serves to reduce the logistics cost burden for the future force. Problems addressed include the need for greater fuel efficiency and reduced weight in these propulsion systems. Technical barriers to advanced propulsion systems are the inadequacy of existing materials to safely withstand higher temperature demands, the lack of capability to accurately simulate the flow physics and the mechanical behavior of these systems, including the engine and drive train. The Army is the lead Service in these technology areas and performs basic research in propulsion, as applicable to rotorcraft as well as tracked and wheeled vehicles. Technical solutions are being pursued through analysis, code generation, and evaluations to improve engine and drive train components and investigate advanced materials. Component level investigations include compressors, combustors, turbines, energy sources and conversion, injectors, pistons, cylinder liners, piston rings, gears, seals, bearings, shafts, and controls.

Work in this Project provides the technical underpinnings for PE 0602211A (Aviation Technology).

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

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 2019	FY 2020	FY 2021
Title: Vehicle Propulsion & Power Research	3.544	-	-
Description: Basic research investigating engine and drivetrain technologies for Army manned-and-unmanned vehicles. Research investigates concepts and theories to provide enhanced tools, methods, and innovative concepts to enable improvements in propulsion power density, energy efficiency, reliability, and lifecycle cost for increased performance and capabilities in future Army systems.			
Accomplishments/Planned Programs Subtotals	3.544	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** F20 / *Adv Propulsion Rsch*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) F22 / *Rsch In Veh Mobility*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
F22: *Rsch In Veh Mobility*	-	0.749	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	0.749

Note

In Fiscal Year (FY) 2020 this Project was realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA6 Robotics and Mobile Energy

A. Mission Description and Budget Item Justification

This Project conducts research in support of advanced military vehicle technology with emphasis on advanced propulsion, 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.

Work in this Project provides the theoretical underpinnings for PE 0602601A (Combat Vehicle and Automotive Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Advanced Mathematical Algorithms for Improved Vehicle Efficiency	0.749	-	-
Description: Research in support of advanced military mobility technologies with emphasis on Terramechanics (vehicle-terrain interaction), and complex vehicle dynamics and simulation. Research is directed at understanding advanced mathematical and computational methodologies using state-of-the-art analytical and empirical procedures.			
Accomplishments/Planned Programs Subtotals	0.749	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** F22 / *Rsch In Veh Mobility*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) H42 / *Materials & Mechanics*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
H42: *Materials & Mechanics*	-	11.851	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	11.851

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA7 Mechanics and Ballistics

A. Mission Description and Budget Item Justification

This Project conducts basic research in materials science, which includes research into key phenomena enabling the creation and production of revolutionary materials that will provide higher performance, lighter weight, lower cost, improved reliability, and environmental compatibility for Army unique applications. The current methodology of using materials to gain added functionality for Army systems is to use a layered approach, whereby each layer provides added capability (e.g., ballistic, chemical/biological, signature, etc.), but ultimately makes the system too heavy and too expensive. Technical solutions are being pursued through understanding the fundamental aspects of chemistry and microstructure that influence the performance and failure mechanisms of ceramics, advanced polymer composites, and advanced metals, with the goal of creating hierarchically organized materials systems that possess multifunctional attributes at greatly reduced weight and cost. These advanced materials will enable revolutionary lethality and survivability technologies for the future.

Work in this Project supports key Army needs and provides the technical underpinnings for several PEs to include PE 0602105A (Materials Technology) / Project H84 (Materials) and PE 0602786A (Warfighter Technology) / H98 (Clothing & Equipment Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Microscopic/Nanostructural Materials ***Description:*** Devise new materials and design capabilities based upon fundamental concepts derived at the microscopic and nanostructural levels for the future force.	3.050	-	-
Title: High Deformation Rate Materials ***Description:*** Develop the fundamental understanding necessary to design, process, and characterize materials specifically intended for high loading-rate applications, as in armor and armaments.	3.164	-	-
Title: Materiel Research and Processing Using High Energy Fields	2.365	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H42 / *Materials & Mechanics*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: Explore interactions between materials and intense energy fields (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.			
Title: 1-Dimensional (1D) and 2-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.	1.597	-	-
Title: 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 thermodynamics and govern reactions, thereby providing completely new pathways for materials discovery.	1.675	-	-
Accomplishments/Planned Programs Subtotals	11.851	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) H43 / *Research In Ballistics*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
H43: *Research In Ballistics*	-	11.420	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	11.420

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA7 Mechanics and Ballistics

A. Mission Description and Budget Item Justification

This Project seeks to improve the understanding of the chemistry and physics controlling the propulsion, launch, and flight of gun-launched projectiles and missiles, and to understand the interaction of these weapons with armored targets. This research results in basic new knowledge, which allows the formulation of more energetic propellants, more accurate and non-lethal (NL)/lethal projectiles and missiles, and advanced armors for increased survivability of Army combat systems. This Project supports the Office of the Secretary of Defense Advanced Energetics Initiative to mature the fundamental technologies required to transition the next generation of energetic materials into field use.

Work in this Project supports key Army needs and provides the theoretical underpinnings for PE 0602618A (Ballistics Technology) / Project H80 (Survivability and Lethality Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Advanced Energetics Initiative ***Description:*** Expand and confirm physics based models and validation techniques to enable design of novel insensitive propellants/explosives with tailored energy release for revolutionary future force survivability and weapons effectiveness.	3.475	-	-
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.	2.900	-	-
Title: Armor Research ***Description:*** Develop fundamental knowledge of mechanisms that can be exploited to ensure the next generation of lightweight and efficient armor technologies.	3.687	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H43 / *Research In Ballistics*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Humans in Extreme Ballistic Environments Research ***Description:*** Provide physics-based discovery of novel protection mechanisms through increased understanding of wave propagation through tissue, and the resulting deformation and damage of tissue during ballistic and blast events.	1.358	-	-
Accomplishments/Planned Programs Subtotals	11.420	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army										Date: February 2020		
Appropriation/Budget Activity 2040 / 1					R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*				Project (Number/Name) H44 / *Adv Sensors Research*			
COST ($ in Millions)	**Prior Years**	**FY 2019**	**FY 2020**	**FY 2021 Base**	**FY 2021 OCO**	**FY 2021 Total**	**FY 2022**	**FY 2023**	**FY 2024**	**FY 2025**	**Cost To Complete**	**Total Cost**
H44: *Adv Sensors Research*	-	9.681	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	9.681

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA5 Biotechnology and Systems Biology
* Project AA7 Mechanics and Ballistics
* Project AA8 Sensing and Electromagnetics

A. Mission Description and Budget Item Justification

This Project supports basic research to produce future generations of sensors with capabilities beyond those currently being employed. Technical barriers include the fundamental speed and bandwidth limitations of current materials and devices, the efficiency of current algorithms, current computing architectures, organic material lifetimes, the understanding of the fundamental concepts of quantum cryptography, and the spatial resolution of current radio frequency (RF) sensors. The technical approach is to exploit large-scale electromagnetic (EM) models to predict and explain target and clutter scattering behavior, and research new digital and image processing modules and algorithms, beam propagation and material models of nonlinear optical effects, remote sensing and intelligent system distributive interactive simulations, and battlefield acoustic signal processing algorithms for improved, hazardous material detection and sensor data feature and information fusion under, unique sensor development, and survivable sensor systems. This Project also funds research in the development of biologically inspired materials for use as sensors as well as for power generation and storage; and physics-based multi-scale models for electronic, optical, mechanical, and chemical materials. Payoffs include high-data-rate military communications, improved radar signal processing techniques that will allow existing systems to improve spatial resolution, improved ultra-wideband radar technology for detection of explosives including mine detection, through-the-wall sensing and improved robotics perception, improved sensor approaches and signal processing techniques for enhanced acoustic/seismic sensing systems in noisy environments, distributed sensor data fusion in ad hoc networks, improved cryptography techniques, improved understanding of the physics and atomic properties of materials, and improved capabilities in hazardous material and event sensing.

Work in this Project supports key Army needs and provides the theoretical underpinnings to PE 0602786A (Warfighter Technology) / Project H98 (Clothing & Equipment Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Improving Sensor Research	1.559	-	-
Description: Create more survivable and secure sensors and displays, and investigate new magnetic- and electric-field sensor technologies for personnel, activity, and improvised explosive device (IED) detection. Develop novel algorithms and			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H44 / *Adv Sensors Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
electromagnetic models to investigate RF propagation and exploitation in complex clutter environments for improved RF and radar sensing.			
Title: Multi-scale Modeling for Novel Materials ***Description:*** Explore and develop multi-scale modeling techniques to support fundamental studies of electronic and structural materials 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 research that leverages 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 VS2 (Multi-scale Materials Modeling Centers).	2.867	-	-
Title: Biological and Bio-inspired Materials and Devices Research ***Description:*** Create synthetic biological materials for devices and sensors that can be used by the Army to improve force protection and reduce logistical burden.	2.026	-	-
Title: Living Materials ***Description:*** Research the concept of responsive materials imparting living functions for operation in Army relevant environments thus enabling 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.	3.229	-	-
Accomplishments/Planned Programs Subtotals	9.681	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) H45 / *Air Mobility*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
H45: *Air Mobility*	-	2.410	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	2.410

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102 Defense Research Sciences
* Project AA6 Robotics and Mobile Energy

A. Mission Description and Budget Item Justification

This Project supports basic research in aerodynamics for manned and unmanned rotary wing aircraft. The goal of this effort is to develop improved tools and methods to analyze, evaluate, and assess rotorcraft-unique aerodynamic properties in conventional helicopter and tilt-rotor aircraft. The efforts in this Project will result in a better understanding of rotorcraft aeromechanics and will result in improved performance, safety and, ultimately, improved combat effectiveness of the manned and unmanned rotorcraft in the future force. This Project supports the future force by providing research into technologies that can improve tactical mobility, reduce logistics footprint, and increase survivability for rotary wing aircraft.

Work in this Project provides the theoretical underpinnings for PE 0602211A (Aviation Technologies).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Rotary Wing Aerodynamics	2.410	-	-
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.			
Accomplishments/Planned Programs Subtotals	2.410	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H45 / *Air Mobility*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) H47 / *Applied Physics Rsch*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
H47: *Applied Physics Rsch*	-	5.700	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	5.700

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA6 Robotics and Mobile Energy
* Project AA8 Sensing and Electromagnetics
* Project AA9 Information and Networking

A. Mission Description and Budget Item Justification

This Project performs basic research on electronic materials and structures as well as technologies in energy harvesting and energetic materials, batteries and fuel cells to enable higher performance and more efficient electronic systems. This includes nanoelectronic devices for low-power and high-frequency applications; sensors, emissive nonlinear and nanophase electrodes, and electronic materials; advanced battery materials, thermoelectric devices, photovoltaic devices, as well as more efficient fuel cells for hybrid power; and the manipulation of cold atoms on a chip for improved gyroscopes and accelerometers for inertial navigation units in global positioning system (GPS)-denied environments, very sensitive gravitational sensors for detecting underground facilities, low-phase noise precision oscillators for low-velocity Doppler radar, and ultra-stable atomic clocks for GPS-denied environments, as well as for future space-based timing applications. These investigations will also impact the development of power sources and specialty electronic materials for the Army's future force, including improved wide band gap semiconductor performance for more electric platforms, nanomaterials for batteries and fuel cells, quantum dots for increased photovoltaic efficiency and advanced radar systems. Technical barriers affecting performance, weight, cost, and power consumption will be addressed.

Work in this Project supports key Army needs and provides the technical underpinnings to PE 0602705A (Electronics and Electronic Devices) / Project H94 (Electronics & Electronic Devices).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Nanoelectronic Devices and Sensors	1.513	-	-
Description: Conduct research on advanced battery materials; fuel cells and reformers for Soldier and vehicle power; electronic materials structures and defects in high-temperature, wide-bandgap semiconductors for high-power electronic and photonic applications; materials for advanced nano- and micro-devices; and integration of nano-energetics and Micro-Electro-Mechanical Systems (MEMS) for fusing and micro-robotic applications.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H47 / *Applied Physics Rsch*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Fundamentals for Energy Efficient Electronic Components ***Description:*** This effort addresses the power draw of RF front ends for communication and the digital back-end from electronic materials. This work explores new materials with inherently higher energy efficiencies, while improving upon the current state-of-the-art. These materials will be used in conjunction with advances in circuits and systems to provide improvements in power efficiencies, linearity and noise at the subsystem level which are unique needs of the military. Conduct materials, components, and multi-scale modeling research that will lead to advances in energy storage, harvesting, conversion, and efficiency for a wide range of Army applications such as Soldier and vehicle power, microgrids, communications, radar and electronic warfare.	1.860	-	-
Title: Fundamentals for Precision Measurement for Contested Environments ***Description:*** Develop new materials, novel device architectures, and unique processing techniques to successfully maintain communication and information sharing protocols in GPS-denied, actively jammed, or austere environments.	0.576	-	-
Title: Fundamentals for Alternative Energy ***Description:*** Explore novel concepts in energy generation and capture, and 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.	1.751	-	-
Accomplishments/Planned Programs Subtotals	5.700	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) H48 / *Battlespace Info & Comm Rsc*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
H48: *Battlespace Info & Comm Rsc*	-	31.363	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	31.363

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA9 Information and Networking

A. Mission Description and Budget Item Justification

This Project supports basic research to enable intelligent and survivable command and 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 supports the Army's Network Science initiative and addresses the areas of information assurance, signal processing for wireless battlefield communications, document and speech machine translation, and intelligent systems for C4I. Major barriers to achieving the goals are the 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 lower echelons, 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, new low-density languages, and information warfare threats. These C4I technologies must accommodate heterogeneous security infrastructures and information exchange/security mechanisms between multiple levels of security. The intelligent systems for C4I research focuses on providing the agent technology capabilities that will produce 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 technical underpinnings to PE 0602783A (Computer and Software Technology) / Project Y10 (Computer/ Information Science Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Communications in Complex Dynamic Networks	1.066	-	-
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.			

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H48 / *Battlespace Info & Comm Rsc*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Data-to-Knowledge to Support Decision-Making ***Description:*** Design and implement 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.	4.960	-	-
Title: Information Protection for 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. .	3.810	-	-
Title: Naturalistic Behavior for Shared Understanding and Explanation with Intelligent Systems ***Description:*** Establishes formal methods for bridging language barriers in tactical environments, incorporating state-of- the-art techniques in machine translation and natural language processing.	1.144	-	-
Title: Advanced Computing Architectures and Algorithms ***Description:*** Investigate advanced computing and high performance computing (HPC) networking architectures, memory/storage architectures, algorithms and visualization techniques to support advanced battle command applications for C4I systems.	4.118	-	-
Title: Quantum Information Sciences ***Description:*** Perform research to enable quantum networks, which necessitates research in efficient light / matter interfaces and long-lived, robust quantum memories. Additionally, the study of quantum techniques for sensing and ultra-precise navigation, timing, and communications will be undertaken. Conventional techniques for sensing magnetic fields, gravity, and timing have reached a plateau in their performance, and will be severely impacted in future contested-battlefield environments. This research brings new insights regarding the use of quantum science to enhance Warfighter effectiveness.	5.304	-	-
Title: Experimental Methods in Network Science ***Description:*** Supports in-house Network Science studies in conjunction with the Network Sciences Collaborative Technology Alliance and Distributed Analytics and Information Science for United States / United Kingdom (U.S. / U.K.) Coalition Operations Information.	2.173	-	-
Title: Assured Operations in the Physical, Social and Cyber Domain	4.594	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H48 / *Battlespace Info & Comm Rsc*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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 developed 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.			
Title: Mobile Network Modeling ***Description:*** This research focuses on techniques that enable predictions of performance and stability of large, complex communications networks. It takes into account the impact of Soldiers' 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.	1.039	-	-
Title: Machine Learning for Intelligent Agent and Human Decision Making ***Description:*** This effort will research 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 will include methods for learning and decision making that occur under short time frames and constrained resources (computation, power, spectrum and networks).	3.155	-	-
Accomplishments/Planned Programs Subtotals	31.363	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) H52 / *Equip For The Soldier*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
H52: *Equip For The Soldier*	-	1.177	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	1.177

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA8 Sensing and Electromagnetics

A. Mission Description and Budget Item Justification

This Project supports basic research to achieve technologies for the Soldier of the future. This research is focused on core technology areas which include mathematical modeling, physical and cognitive performance, polymer science/textile technology, nanotechnology, biotechnology, and combat ration research. Research efforts are targeted at enhancing the mission performance, survivability, and sustainability of the Soldier by advancing the state-of-the-art in the sciences underlying human performance, clothing, and protective equipment to defend against battlefield threats and hazards such as ballistics, chemical agents, lasers, environmental extremes, and ration shortfalls.

Work in this Project provides theoretical underpinnings for PE 0602786A (Warfighter Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Equipment for the Soldier	1.177	-	-
Description: This Project supports basic research to achieve technologies that support the Soldier of the future. Research areas include mathematical modeling, physical and cognitive performance, polymer science/textile technology, nanotechnology, biotechnology, and combat rations.			
Accomplishments/Planned Programs Subtotals	1.177	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) H57 / *Single Investigator Basic Research*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
H57: *Single Investigator Basic Research*	-	98.050	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	98.050

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA3 Single Investigator Basic Research

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. 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 science, 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.

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Basic Research in Life Sciences	5.865	-	-
Description: Pursues 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 pursues fundamental studies in molecular and systems biology, and genetics, ii) neurosciences research investigating the physiology underlying perception, neuro-motor output, and potential methods of monitoring cognitive states during activity, iii) biochemistry research focuses on studies in structural and cell biology, metabolic processes, and biophysics, iv) research in microbiology pursues studies in microbial physiology, ecology, and evolution, v) social science research aims to elucidate the social, cultural, and other influences to human actions, and vi) auditory and signal processing research to map the cognitive implications of multisensory information integration.			
Title: Basic Research in Environmental Sciences	0.300	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H57 / *Single Investigator Basic Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: Environmental Sciences research explores the properties of Earth materials and chemical species to discover how they interact with their environments and respond to external forces. Knowledge of the fundamental properties of these materials, from the atomistic to the landscape scale, and their interactions with the atmosphere, hydrosphere, and biosphere are relevant to Army operations, infrastructure, and stewardship. Fundamental research lays the foundation to provide future new Army capabilities, including the remote characterization of land surfaces, trafficability of ground vehicles, and new methods for waste management and remediation.			
Title: Basic Research in Chemical Sciences ***Description:*** Basic research to achieve advanced energy control, improved threat detection, and novel responsive materials for Soldier protection. Research efforts will lead to: light-weight, reliable, compact power sources, more effective, lower vulnerability propellants and explosives for tailored precision strikes with minimum collateral damage, new approaches for shielding the Soldier and Army platforms from ballistic, chemical, and biological threats, and reducing signatures for identification by the enemy, and advance warning of explosive, chemical, and biological weapons and dangerous industrial chemicals.	13.573	-	-
Title: Basic Research in Physics ***Description:*** Focuses on 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.	18.650	-	-
Title: Basic Research in Electronics and Photonics ***Description:*** Pursues 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.	7.095	-	-
Title: Basic Research in Materials Sciences ***Description:*** Research that provides innovations in materials design and process through the elucidation of fundamental relationships linking composition, microstructure, defect structure, processing and properties of materials. Revolutionary materials provide support for the Army in firepower, mobility, communications, personnel protection, infrastructure and installations, and will directly affect virtually all mission areas.	8.453	-	-
Title: Basic Research in Computing Sciences	6.720	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H57 / *Single Investigator Basic Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: 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, situation awareness, command and control, as well as on the overall performance of weapon, intelligence, transportation and logistics systems.			
Title: Basic Research In Network Sciences ***Description:*** 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.	12.344	-	-
Title: Basic Research in Mechanical Sciences ***Description:*** Focuses on improved understanding of propulsion and combustion for improved efficiency and fuel flexibility, energetics initiation for insensitive munitions, fluid dynamics for rotorcraft, complex dynamic systems for novel sensors, energy generation and multi-dimensional systems, and solid mechanics especially at high strain rates in composite materials for novel armor and protection systems.	6.620	-	-
Title: Basic Research in Mathematical Sciences ***Description:*** Pursue 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.	5.695	-	-
Title: Basic Research in Simulation and Training ***Description:*** Advances in simulation and training require basic research to understand neuronal changes that occur in the brain during successful and unsuccessful simulations and training. An interdisciplinary approach involving chemistry, computer science, engineering, mathematics, physics, and network science will be required to understand the molecular, cellular, developmental, structural, functional, and computational aspects of the brain during learning, simulation, and training. It will be necessary to determine how neural circuits develop and are arranged physiologically in individuals to produce cognitive computations during simulation and training. This research will also include extensive studies to discover and map the neural circuitry that enables cognitive adaptation, and the dynamic mechanisms of neural network modification need to be established.	2.060	-	-
Title: Expeditionary Materials Processing Science	5.212	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H57 / *Single Investigator Basic Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: Basic research coupling materials, innovative design, and manufacturing science to enable conversion of resources for meeting an expeditionary Army?s requirements. This research will enable predictive material-to-materiel models for high-confidence, certifiable article production, high-fidelity expeditionary and versatile material-to-materiel processing capabilities, and a new generation of materials responsive to applied field for shape shifting and phase transformation.			
Title: Basic Research in Social Sciences ***Description:*** Social science research focuses on generating fundamental understanding of how social dynamics unfold, taking into account individual-level biophysiological factors contributing to social interaction (e.g., genetics, health, cognition, perception), group processes (e.g., interpersonal forces that determine influence, power, conformity), and the impacts of social institutions (e.g., economic processes, legal/governance structures, religious/belief systems, kin networks), with attention to the interconnections among these levels of analyses, and to the physical and natural environments in which human social dynamics are situated. This scientific understanding will improve situational awareness for Warfighters and analysts, improving efficacy of decision-making to achieve mission objectives.	5.463	-	-
Accomplishments/Planned Programs Subtotals	98.050	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) H66 / *Adv Structures Rsch*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
H66: *Adv Structures Rsch*	-	3.116	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	3.116

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA6 Robotics and Mobile Energy

A. Mission Description and Budget Item Justification

This Project funds basic research for improved tools and methods to advance structural health monitoring capabilities and enable condition-based maintenance for sustainment of rotorcraft and ground vehicles. This research also enables the design and use of composite structures that can better address the cost, weight, performance, and dynamic interaction requirements of future platforms identified by the Army Modernization Strategy. Ultimately, these technologies result in safer, more affordable vehicles with a greatly reduced logistics footprint. This Project is a collaborative Army and National Aeronautics and Space Administration (NASA) effort that includes structures technology research into: structural integrity analyses; failure criteria; inspection methods which address fundamental technology deficiencies in both metallic and composite Army rotorcraft structures; use of composite materials in the design and control of structures through structural tailoring techniques; rotorcraft aeroelastic modeling and simulation; helicopter vibration (rotating and fixed systems); and the design and analyses of composite structures with crashworthiness as a goal. The problems in structural modeling are inaccurate structural analysis and validation methods to predict durability and damage tolerance of composite and metallic rotorcraft structures and inadequate structural dynamics modeling methods for both the rotating and fixed system components to address reliability issues for future aircraft. The technical barriers include a lack of understanding of failure mechanisms, damage progression, residual strength, high-cycle fatigue, the transfer of aerodynamic loads on the rotor to the fixed system, and impact of these unknown loads on aircraft components. Technical solutions are focused on: advanced fatigue methodologies for metallic structures, improved composites technology throughout the vehicle, long-term investigation of integrated stress-strength-inspection, advanced methods for rotor system vehicle vibratory loads prediction, improved methods to predict vehicle stability, and improved analyses to address Army Aviation requirements. These advancements will extend service life, reduce maintenance costs, enhance durability, and reduce the logistics footprint of existing and future Army vehicles. This is the only basic research Project supporting investigations for rotorcraft and ground vehicle structures within the Department of Defense.

Work in this Project supports key Army needs and provides the technical underpinnings to PE 0602211A (Aviation Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Air Vehicle Structures & Dynamics Research	2.128	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H66 / *Adv Structures Rsch*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: Conduct basic research in advanced analytical methodologies and techniques for understanding and predicting the health and performance of rotorcraft structures. Develop and experimentally validate technologies, models, and approaches to increase the reliability, useful life, or performance of components in vertical takeoff and landing systems.			
Title: Reconfigurable Platform Mechanics & Propulsion ***Description:*** Conduct basic research in reconfigurable platform mechanics and propulsion science technologies to enable high-speed Vertical Take-off and Landing (VTOL). Investigate reconfigurable technologies for improved performance, stability and handling qualities across different flight regimes in all operational environments.	0.988	-	-
Accomplishments/Planned Programs Subtotals	3.116	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) H67 / *Environmental Research*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
H67: *Environmental Research*	-	1.065	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	1.065

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA7 Mechanics and Ballistics

A. Mission Description and Budget Item Justification

This Project focuses basic research on innovative technologies for industrial pollution prevention (P2) that directly supports the Army production base and weapon systems and also addresses non-stockpile chemical warfare (CW) site remediation. Work in pollution prevention invests in next generation manufacturing, maintenance, and disposal methods that will result in significantly reducing the usage of hazardous and toxic substances and their associated costs. The goal is to decrease the overall life-cycle costs of Army systems by 15-30% through the application of advanced pollution prevention technologies. Non-stockpile CW efforts include establishing the ecotoxicity of CW compounds, environmental fate and effect of CW compounds in soils and biodegradation of CW compounds. Pollution prevention thrusts include: environmentally acceptable, advanced, non-toxic processes to manufacture lightweight alternative structural materials to enhance weapon system survivability; clean synthesis of more powerful and improved energetic compounds to eliminate the use of hazardous materials and minimize the generation of wastes; and surface protection alternatives to hazardous paints, cadmium, chromium, and chromate conversion metal and composite surfaces.

Work in this Project complements and is fully coordinated with the Army Environmental Requirements Technology Assessment (AERTA) requirements and contains no duplication with any effort within the Military Departments.

The cited work provides the technical underpinnings for PE 0602618A (Ballistics Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Industrial Pollution Prevention	1.065	-	-
Description: This effort conducts research on innovative environmentally-friendly technologies that support the warfighter (focusing on pollution prevention technologies).			
Accomplishments/Planned Programs Subtotals	1.065	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** H67 / *Environmental Research*

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) S13 / *Sci BS/Med Rsh Inf Dis*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
S13: *Sci BS/Med Rsh Inf Dis*	-	10.237	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	10.237

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AB1 Basic Res in infect Dis Oper Med and Combat Care

A. Mission Description and Budget Item Justification

This Project fosters basic research leading to medical countermeasures for naturally occurring diseases impacting military operations. Basic research for this Project provides an understanding of the mechanisms that make organisms infectious and mechanisms that render the human body's response effective, preventing diseases caused by infectious agents. Understanding the biological characteristics of infectious organisms also enables the development of point-of-care and laboratory-based diagnostic tools (used to identify the nature and cause of a particular disease). Understanding of disease transmission by insects and other organisms helps in developing new interventions to prevent transmission of such diseases. Infectious disease threats from malaria, diarrhea, and dengue (a severe debilitating disease transmitted by mosquitoes), common where Warfighters are stationed across all Unified Combatant Commands, are the highest priorities for basic research.

Work in this Project complements and is fully coordinated with PE 0602787A (Medical Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

The cited 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 2019	FY 2020	FY 2021
Title: Basic Research on drugs and vaccines against parasitic diseases	5.813	-	-
Description: Malaria, which can cause fatal and chronic disease, is the most significant military infectious disease threat. This effort seeks to better understand the biology of malaria and leishmaniasis (a skin-based disease transmitted by sand flies predominantly exhibited as skin sores) parasites and to gain the necessary foundation for discovering medical countermeasures to protect military personnel from infection. Because the malaria parasite becomes resistant to drugs over time, it is necessary to continually search for parasite weaknesses that can be exploited by different drugs and vaccines. This effort seeks to better understand small molecule therapeutics and prophylactics, to overcome drug resistant organisms and identify new proteins in the design of candidate vaccines for various types of malaria including the severe form (caused by Plasmodium falciparum) and the less severe but relapsing form (caused by Plasmodium vivax).			
Title: Bacterial Disease Threats	1.442	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** S13 / *Sci BS/Med Rsh Inf Dis*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: This effort is to better understand the biology of bacterial organisms and their effects on humans and how to prevent/ treat diarrhea (a significant threat during initial deployments).			
Title: Viral Threats Research ***Description:*** This effort is to better understand highly lethal or incapacitating viruses, including those that cause hemorrhagic diseases (viral infection that causes severe internal bleeding) such as dengue hemorrhagic fever (life-threatening form of disease caused by the Dengue virus, transmitted by mosquitoes) and Hemorrhagic fever with renal syndrome (HFRS)(caused by hantavirus infection resulting in internal bleeding; transmitted by exposure to rodents or their droppings). Basic research includes understanding risk to the Warfighter of contracting a viral disease based on its prevalence in the respective area of operations, viral biology (structure, function, life cycle of the virus and its ecological factors), the disease process, and disease interaction (symptomology) with the human body.	1.539	-	-
Title: Vector Identification and Control ***Description:*** This effort conducts research to investigate the biology of biting arthropods (i.e. mosquitoes and sand flies) and other vectors (organisms that transmit disease) and their control. This effort also expands identification of infectious disease pathogens in vectors and disease surveillance capabilities in the field. This research will help to direct new interventions into preventing disease transmission.	1.443	-	-
Accomplishments/Planned Programs Subtotals	10.237	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) S14 / *Sci BS/Cbt Cas Care Rs*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
S14: *Sci BS/Cbt Cas Care Rs*	-	4.957	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	4.957

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AB1 Basic Res in Infect Dis, Oper Med & Combat Care

A. Mission Description and Budget Item Justification

This Project supports basic research to understand the fundamental mechanisms of severe trauma to advance treatment and surgical procedures to save lives and improve medical outcomes for the Warfighter. Experimental models are being developed to support in-depth trauma research studies. This project includes basic research studies of new concepts for control of severe bleeding, studies of predictive indicators and decision aids for life-support systems; studies to identify potential new therapeutics to heal and repair burned or traumatically injured hard and soft tissues of the eye, face, mouth, and extremities; and studies to elucidate the physiological basis of combat-related traumatic brain injury (TBI). Such efforts will minimize lost duty time and provide military medical capabilities for far- forward medical/surgical care of injuries.

Work in this Project complements and is fully coordinated with PE 0602787A (Medical Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

The cited 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 2019	FY 2020	FY 2021
Title: Damage Control Resuscitation ***Description:*** This effort conducts studies to define and identify cellular processes and metabolic (biochemical activity) mechanisms associated with blood clotting to understand the relationships between the human immune processes and bleeding in trauma.	1.467	-	-
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.	1.301	-	-
Title: Combat Critical Care Engineering	0.784	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** S14 / *Sci BS/Cbt Cas Care Rs*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: This effort conducts basic science studies of vital sign (e.g. heart rate, blood pressure, blood oxygen concentration) responses to trauma as predictors of medical outcomes and as a basis for developing life-saving interventions. This effort also conducts basic science studies to support development of technologies to preserve function of vital organs following traumatic injury.			
Title: Traumatic Brain Injury ***Description:*** This effort conducts basic research in poly-trauma (multiple injuries)/TBI model, mechanisms of cell death, and the discovery of novel drugs and medical procedures to mitigate the effects of TBI.	1.217	-	-
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.	0.188	-	-
Accomplishments/Planned Programs Subtotals	4.957	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) S15 / *Sci BS/Army Op Med Rsh*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
S15: *Sci BS/Army Op Med Rsh*	-	6.306	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	6.306

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AB1 Basic Res in Infect Dis, Oper Med & Combat Care

A. Mission Description and Budget Item Justification

This Project fosters basic research on physiological and psychological factors that limit Warfighter effectiveness and on characterization of health hazards generated by military systems that result as a consequence of military operations; includes research on the neurobehavioral aspects of post-traumatic stress; develops concepts for medical countermeasures to prevent or mitigate the effects of muscle and bone injury to include reducing the effects of sleep loss and other stressors on Warfighter performance. The hazards of exposure to directed energy, repetitive use, fatigue, heat, cold, and altitude are also investigated under this Project.

Work in this Project complements and is fully coordinated with PE 0602787A (Medical Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

The cited 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 2019	FY 2020	FY 2021
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.	2.180	-	-
Title: Physiological Health ***Description:*** This effort conducts research on the physiological mechanisms of sleep, fatigue, and nutrition on Soldier performance, readiness and well-being. Also, efforts will contribute to human health and performance optimization and enhancement.	1.988	-	-
Title: Environmental Health and Protection	1.102	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** S15 / *Sci BS/Army Op Med Rsh*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
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.			
Title: Psychological 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.	1.036	-	-
Accomplishments/Planned Programs Subtotals	6.306	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
T14: *BASIC RESEARCH INITIATIVES - AMC (CA)*	-	39.000	66.350	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	105.350

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 2019	FY 2020
Congressional Add: Basic Research Program Increase	35.000	-
FY 2019 Accomplishments: Basic Research Program Increase		
Congressional Add: Counter UAS Technology	3.000	-
FY 2019 Accomplishments: Counter UAS Technology		
Congressional Add: UAV fuel systems enhancements	1.000	-
FY 2019 Accomplishments: UAV fuel systems enhancements		
Congressional Add: Propulsion Technology	-	10.000
FY 2020 Plans: Propulsion Technology		
Congressional Add: Ballistic and Materials Technology	-	10.000
FY 2020 Plans: Ballistic and Materials Technology		
Congressional Add: Flexible LED Lighting	-	5.350
FY 2020 Plans: Flexible LED Lighting		
Congressional Add: Military Waste Stream Conversion	-	5.000
FY 2020 Plans: Military Waste Stream Conversion		
Congressional Add: Multi-layer and dynamically responsive macromolecular composites	-	5.000

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
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 2019	FY 2020
FY 2020 Plans: Multi-layer and dynamically responsive macromolecular composites		
Congressional Add: Advanced hemostat products ***FY 2020 Plans:*** Advanced hemostat products	-	2.000
Congressional Add: Multi-fuel ignition, chemistry and control strategies for unmanned aircraft systems hybrid propulsion ***FY 2020 Plans:*** Multi-fuel ignition, chemistry and control strategies for unmanned aircraft systems hybrid propulsion	-	9.000
Congressional Add: Transmission electron microscope ***FY 2020 Plans:*** Transmission electron microscope	-	20.000
Congressional Adds Subtotals	39.000	66.350

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) T22 / *Soil & Rock Mech*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
T22: *Soil & Rock Mech*	-	4.561	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	4.561

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AB2 Protection, Maneuver, Geospatial, Natural Sciences

A. Mission Description and Budget Item Justification

This Project fosters basic research to correlate the effects of the nano- and micro-scale behavior on the macroscale performance of geological and structural materials to provide a foundation for the creation of future revolutionary materials and to revolutionize the understanding of sensor data within heterogeneous geological systems. This research encompasses geologic and structural material behavior, structural systems, and the interaction with dynamic and static loadings. Research includes underlying physics and chemistry that control the mechanics and electromagnetic behavior of geological and structural materials, new techniques that provide measurements at the fundamental scale, and fundamental theories for relating nano- and micro-scale phenomena to macro-scale performance.

Work in this Project provides the basis for applied research in PE 0602784A (Military Engineering Technology), Project T40 (Mobility/Weapons Effects Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Military Engineering Basic Research ***Description:*** Conduct fundamental research to determine how physical and chemical characteristics of materials affect their interactions with environment.	2.195	-	-
Title: Materials Modeling for Force Protection ***Description:*** Conduct fundamental research on material interactions at the micro- and nano-scales to determine how they affect macroscale properties	2.366	-	-
Accomplishments/Planned Programs Subtotals	4.561	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** T22 / *Soil & Rock Mech*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) T23 / *Basic Res Mil Const*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
T23: *Basic Res Mil Const*	-	1.777	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	1.777

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AB2 Protection, Maneuver, Geospatial, Natural Sciences

A. Mission Description and Budget Item Justification

Work in the Project fosters basic research and supports facilities research initiatives. The objective of Army installations basic research is to investigate, identify, and quantify the fundamental scientific principles that can be used to predict or influence the development of high performance facilities and sustainable installations, both fixed and contingency. Such basic research provides the requisite long term cost effective training and sustainment platforms for Army mission accomplishment. These efforts provide basic research leading to improved design in a range of facilities to optimize facility mission performance, enhance facility security, reduce design and construction errors and omissions, reduce resource requirements, and reduce the environmental burdens over the facility's life. This Project provides leap-ahead technologies to solve military-unique problems in the planning, programming, design, construction, and sustainment of deployed facilities, and energy and utility infrastructure.

Work in this Project provides the basic research basis for applied research in PE 0602784A (Military Engineering Technology) / Projects T41 (Military Facilities Engineering Technology) and T45 (Energy Technology Applied to Military Facilities).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Facilities Research	1.777	-	-
Description: Conduct fundamental research on innovative infrastructure technologies to optimize facility mission performance, through enhanced security and reduction in resource requirements, design errors and omissions, and environmental burdens.			
Accomplishments/Planned Programs Subtotals	1.777	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** T23 / *Basic Res Mil Const*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) T24 / *Signature Physics And Terrain State Basic Research*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
T24: *Signature Physics And Terrain State Basic Research*	-	1.719	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	1.719

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AB2 Protection, Maneuver, Geospatial, Natural Sciences

A. Mission Description and Budget Item Justification

This Project supports basic research to increase knowledge in the areas of terrain state and signature physics. It investigates the knowledge base for understanding and assessing environmental impacts critical to battlespace awareness. Projects include fundamental material characterization, investigation of physical and chemical processes, and examination of energy and mass transfer applicable to predicting state of the terrain, which control the effects of the environment on targets and target background signatures and mobility, in support of the materiel development community. The terrain state area of terrestrial sciences investigates weather-driven terrain material changes and the sensing and inferring of subsurface properties. The signature physics area of terrestrial sciences focuses on understanding the dynamic changes to electromagnetic, acoustic, and seismic signatures, and energy propagation in response to changing terrain state and near surface atmosphere.

Work in this Project provides a foundation for applied research in PE 0602784A (Military Engineering Technology) / Project 855 (Topographical, Image Intel and Space) and T42 (Terrestrial Science Applied Research).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Analysis for Signal and Signature Phenomenology	1.719	-	-
Description: Conduct fundamental research to examine the effects of environmental parameters on electromagnetic, acoustic, and seismic signatures as well as energy propagation with regard to terrain state and near surface atmosphere.			
Accomplishments/Planned Programs Subtotals	1.719	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** T24 / *Signature Physics And Terrain State Basic Research*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) T25 / *Environmental Science Basic Research*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
T25: *Environmental Science Basic Research*	-	6.621	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	6.621

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AB2 Protection, Maneuver, Geospatial, Natural Sciences

A. Mission Description and Budget Item Justification

This Project supports basic research to investigate fundamental scientific principles and phenomena necessary to ensure efficient development of the technologies needed to address Army sustainment issues in the restoration, compliance, conservation, and non-industrial pollution prevention areas. These efforts include: investigating and monitoring contaminated sites, including chemical contamination and unexploded ordnance (UXO) detection and discrimination; better characterization of contaminants through improved risk-based assessment; destruction, containment, or neutralization of organics resulting from military activities in water, soil, and sediments; adhering to applicable federal, state, and local environmental laws and regulations; monitoring and controlling noise generation and transport; protecting and enhancing natural and cultural resources; reducing pollution associated with military activities; and the study of ecosystem genomics and proteomics in support of the Army's Network Science initiative.

Work in this Project provides a fundamental basis for applied research in PE 0602720A (Environmental Quality Technology) / Project 048 (Industrial Operations Pollution Control Technology), Project 835 (Military Medical Environmental Criteria), and Project 896 (Base Facilities Environmental Quality).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 2019	FY 2020	FY 2021
Title: Environmental and Ecological Fate of Explosives, Energetics, and Other Contaminants ***Description:*** Conduct fundamental research to examine the effects of Army relevant compounds on the environment	3.403	-	-
Title: Fundamental Understanding of Explosives, Energetics and UXO in the Environment ***Description:*** Conduct fundamental research to increase the understanding of the physical and chemical characteristics of insensitive munitions	1.053	-	-
Title: Training Land Natural Resources	1.234	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** T25 / *Environmental Science Basic Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Description: Conduct fundamental research on the molecular interactions of plants and animals with environmental stimuli.			
Title: Network Science ***Description:*** Conducted fundamental research to examine the behavior of environmental networks to inform data models and algorithms	0.931	-	-
Accomplishments/Planned Programs Subtotals	6.621	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army											Date: February 2020	
Appropriation/Budget Activity 2040 / 1					R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*				Project (Number/Name) T63 / *Robotics Autonomy, Manipulation, & Portability Rsh*			
COST ($ in Millions)	**Prior Years**	**FY 2019**	**FY 2020**	**FY 2021 Base**	**FY 2021 OCO**	**FY 2021 Total**	**FY 2022**	**FY 2023**	**FY 2024**	**FY 2025**	**Cost To Complete**	**Total Cost**
T63: *Robotics Autonomy, Manipulation, & Portability Rsh*	-	9.246	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	9.246

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AA6 Robotics and Mobile Energy

A. Mission Description and Budget Item Justification

This Project supports basic research in areas that expands the autonomous capabilities, utility, and portability of small robotic systems for military applications, with a focus on enhanced intelligence, biomimetic functionality, and robust mobility, to permit these systems to serve as productive tools for dismounted Soldiers. It enables future systems to support and unburden Soldiers by integrating technologies with an understanding of cognitive and physical needs, and the missions of the humans and (non-human) agents operating on the battlefield. The ability of the Warfighter to command a suite of small unmanned systems (e.g., air, ground, and hybrid vehicles) reduces exposure of the Soldier to harm and improves the efficiency by which a dismounted unit achieves tactical objectives such as securing a targeted zone. Example missions requiring enhanced autonomy, manipulation, and man-portability include rapid room clearing and interior structure mapping; detection of human presence, chemical/biological/nuclear/radiological/explosive (CBNRE), and booby-traps; surveillance; and subterranean passage detection and exploration. Because of their relatively small size, light weight, and service in dismounted environments, small unmanned systems have unique challenges in perception, autonomous processing, mobility mechanics, propulsive power, and multi-functional packaging that transcend similar challenges associated with large unmanned systems. The Army Futures Command conducts research in related disciplines, including machine perception, intelligent control, biomimetic robotics, manipulator mechanics, and propulsive power and drives to foster the development of technologies for lightweight, small-volume, robotics applications for harsh environments. Machine perception research includes the exploration of lightweight ultra-compact sensor phenomenology and the maturation of basic machine vision algorithms that enable small unmanned systems to more fully understand their local environment. Intelligent control research includes the maturation of autonomous processing capabilities and the advancement of artificial intelligence techniques that lead to reliable autonomous behavior in a large-displacement, highly-dynamic environment and permit unmonitored task performance. Research in biomimetic robotics and manipulator mechanics includes the advancement of mechatronic and biomimetic appendages to enable agile high-speed locomotion, dexterous task-performance, and environmental-manipulation; and the maturing of nonlinear control algorithms to support robust, stable mobility. Propulsion power research includes investigations of engine cycles and alternative hybrid energy conversion techniques to provide compact, lightweight, quiet, low-emission, high-density power sources that support highly-portable unmanned systems capable of performing long-endurance missions.

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** T63 / *Robotics Autonomy, Manipulation, & Portability Rsh*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Robotics Autonomy and Human Robotic Interface Research ***Description:*** In-house research with a focus on enabling robust autonomous mobility for small robotic systems, including autonomous operations in Global Positioning System (GPS) denied areas, planning, behaviors, intelligent control, and the interface of perception technologies to accomplish Army missions in the area of unmanned systems.	1.869	-	-
Title: Intelligent Systems ***Description:*** Pursue in-house research that supports and unburdens Soldiers in a flexible, robust, survivable and comprehensive manner. This work will address the cognitive requirements of humans and (non-human) agents, both hardware and software based, operating individually or in collaboration, on the battlefield. Emphasis will be placed on perception, reasoning, and collaboration techniques that can apply to and transfer between a broad range of systems (such as: adaptive communication and data collection networks; cyber defense, crowd-sourcing and information retrieval software agents; and predictive and explanatory decision support systems).	5.827	-	-
Title: Unmanned Air Vehicle Research ***Description:*** Conduct basic research focused on topics that contribute to the body of knowledge required to create future intelligent unmanned aerial vehicles that can effectively team with manned aircraft. Emphasis will be placed upon topics of control and aeromechanics that will expand the flight envelope for unmanned systems, manipulation of objects, and specialized topics relating to perception, reasoning, and creation of a common model of the surrounding environment and planning for behaviors in adversarial environments at high tempo..	1.550	-	-
Accomplishments/Planned Programs Subtotals	9.246	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) T64 / *Sci BS/System Biology And Network Science*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
T64: *Sci BS/System Biology And Network Science*	-	2.722	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	2.722

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102A Defense Research Sciences
* Project AB1 Basic Res in infect Dis Oper Med and Combat Care

A. Mission Description and Budget Item Justification

This Project fosters research investigations through a systematic approach using iterative computer simulation with mathematical modeling and biological information to analyze and refine biological studies. Information gained from these studies has the potential to provide a better understanding of the overall biological system and its molecular network of interactions, leading to improved early strategic decision-making in the development of preventive and treatment solutions to diseases. This approach establishes a model for application of computational biology processes and knowledge of biological networks to discover medical products that prevent and/or treat diseases or medical conditions.

The cited work provides theoretical underpinnings for PE 0602787A (Medical Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

The cited 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 2019	FY 2020	FY 2021
Title: Network Sciences Initiative	2.722	-	-
Description: This basic research effort involves the use of mathematical models and algorithms to extract medical information from large-scale datasets (generated from the study of cellular genetic makeup, protein structures and function, and whole organism responses) to improve understanding, prevention, diagnostics, and treatments of post-traumatic stress disorder (PTSD), uncontrolled bleeding, infectious diseases, hard-to-diagnose pulmonary disease, and exposure to environmental stressors and hazards.			
Accomplishments/Planned Programs Subtotals	2.722	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** T64 / *Sci BS/System Biology And Network Science*

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army			Date: February 2020
Appropriation/Budget Activity 2040 / 1	R-1 Program Element (Number/Name) PE 0601102A / *Defense Research Sciences*	Project (Number/Name) VR9 / *Surface Science Research*	

COST ($ in Millions)	Prior Years	FY 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total	FY 2022	FY 2023	FY 2024	FY 2025	Cost To Complete	Total Cost
VR9: *Surface Science Research*	-	2.259	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	2.259

Note

In Fiscal Year (FY) 2020 this Project is being realigned to:
Program Element (PE) 0601102 Defense Research Sciences
* Project AA7 Mechanics and Ballistics

A. Mission Description and Budget Item Justification

This Project fosters basic research to establish and maintain a core capability to enable a molecular level understanding of properties and behaviors of materials relevant to the Army; by developing understanding and ability to manipulate nanostructured materials as a means to tune properties which meet desired performance requirements; by advancing the scientific understanding of surface properties and interfacial dynamics of complex materials; and by providing scalable processes grounded in a molecular understanding of materials. This Project funds basic research 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.

The cited work provides the theoretical underpinnings for PE 0602622A (Chemical, Smoke and Equipment Defeating Technology).

Funding has been realigned to reflect the FY20 financial restructure and Army Modernization Priorities.

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 (U.S.) Army Futures Command (AFC).

B. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Surface Science Research	2.259	-	-
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.			
Accomplishments/Planned Programs Subtotals	2.259	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2021 Army		Date: February 2020
Appropriation/Budget Activity 2040 / 1	**R-1 Program Element (Number/Name)** PE 0601102A / *Defense Research Sciences*	**Project (Number/Name)** VR9 / *Surface Science Research*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A