Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force											Date: February 2019	
Appropriation/Budget Activity 3600: *Research, Development, Test & Evaluation, Air Force* / BA 2: *Applied Research*					R-1 Program Element (Number/Name) PE 0602202F / *Human Effectiveness Applied Research*							
COST ($ in Millions)	**Prior Years**	**FY 2018**	**FY 2019**	**FY 2020 Base**	**FY 2020 OCO**	**FY 2020 Total**	**FY 2021**	**FY 2022**	**FY 2023**	**FY 2024**	**Cost To Complete**	**Total Cost**
Total Program Element	0.000	126.542	119.018	131.795	0.000	131.795	131.809	137.542	122.565	125.402	Continuing	Continuing
621123: *Learning and Operational Readiness*	0.000	41.340	22.440	22.495	0.000	22.495	21.649	22.814	23.702	24.012	Continuing	Continuing
625328: *Human Dynamics Evaluation*	0.000	22.987	26.068	51.449	0.000	51.449	52.265	53.438	34.814	35.620	Continuing	Continuing
625329: *Sensory Evaluation and Decision Science*	0.000	33.085	36.687	30.726	0.000	30.726	31.259	32.682	33.957	34.392	Continuing	Continuing
627757: *Bioeffects*	0.000	29.130	33.823	27.125	0.000	27.125	26.636	28.608	30.092	31.378	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program conducts applied research in the area of airmen training, airmen system interfaces, bioeffects, and understanding and shaping adversarial behavior. The Learning and Operational Readiness project conducts research to measure, accelerate, and expand the cognitive skills necessary to improve airmen training and mission performance. The Human Dynamics Evaluation project conducts research to advance machine intelligence and operator-aiding technologies by developing and applying airman-focused research for advanced intelligence, surveillance, and reconnaissance (ISR) capabilities and detecting and exploiting human signatures. The Sensory Evaluation and Decision Science project conducts research to revolutionize the manner in which airmen optimize the capabilities of Air Force systems, including remotely piloted aircraft (RPA) and adaptive teams of airmen and machines. The Bioeffects project conducts research on the effects of human exposure to electromagnetic (EM) energy (radio frequency to optical), scalable directed energy weapons, and non-lethal weapons. Efforts in this program have been coordinated through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is $14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
Appropriation/Budget Activity 3600: *Research, Development, Test & Evaluation, Air Force* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602202F / *Human Effectiveness Applied Research*

B. Program Change Summary ($ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	108.784	112.518	122.392	0.000	122.392
Current President's Budget	126.542	119.018	131.795	0.000	131.795
Total Adjustments	17.758	6.500	9.403	0.000	9.403
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	24.500	6.500			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-2.391	0.000			
• Other Adjustments	-4.351	0.000	9.403	0.000	9.403

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2018	FY 2019
Project: 621123: *Learning and Operational Readiness*		
Congressional Add: *Program Increase - learning and operational readiness*	19.150	0.000
Congressional Add Subtotals for Project: 621123	19.150	0.000
Project: 625328: *Human Dynamics Evaluation*		
Congressional Add: *Program Increase - Warfighter physiology program*	0.000	1.500
Congressional Add Subtotals for Project: 625328	0.000	1.500
Project: 625329: *Sensory Evaluation and Decision Science*		
Congressional Add: *Program Increase - Hypoxia research*	4.910	5.000
Congressional Add Subtotals for Project: 625329	4.910	5.000
Congressional Add Totals for all Projects	24.060	6.500

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

Increase in FY 2020 due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force			Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / *Human Effectiveness Applied Research*	Project (Number/Name) 621123 / *Learning and Operational Readiness*	

COST ($ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
621123: *Learning and Operational Readiness*	0.000	41.340	22.440	22.495	0.000	22.495	21.649	22.814	23.702	24.012	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project conducts applied research to measure, accelerate, and expand the cognitive skills necessary to improve airmen training and mission performance. Research is conducted in two focus areas: continuous learning and cognitive modeling. The continuous learning effort creates live, virtual, and constructive (LVC) environments for use in developing revolutionary simulation technologies to increase training capabilities and enhance training effectiveness and efficiency by using learning theory to improve military training and mission performance. Cognitive modeling creates realistic models and simulations of human behavior to advance the understanding of how airmen perform complex tasks.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Title: Continuous Learning	18.158	13.733	13.705
Description: Research enhances distributed mission operations (DMO) and LVC environments and identifies technology requirements for training in live and immersive environments. Continuous learning strategies improve mission training, command and control (C2), intelligence, surveillance and reconnaissance (ISR), and cyber missions. ***FY 2019 Plans:*** Grow persistent readiness assessment and tracking capabilities for optimized airman machine teaming. Establish objective training performance metrics. Continue to develop 5th Gen Cross Domain solution prototypes. Investigate integrated simulations of secure adaptive environments and execute training research studies within multi-domain command and control. ***FY 2020 Plans:*** Initiate validation of objective performance metrics in operationally relevant testbeds. Mature personalized learning technologies. Begin training scenario development and simulated mission rehearsals with focus on contested and degraded operational environments. Execute integrated multi-domain training evaluations to assess modeling and simulation capabilities and limitations. Begin studies to evaluate an optimized mix of live, synthetic, and blended training technologies and architecture standards to determine standards for proficiency based training and readiness assessments. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $0.028 million. Justification for the decrease is described in the plans above.			
Title: Cognitive Modeling	4.032	8.707	8.790
Description: Research explores application of cognitive science for performance improvement by enhancing training in mission-relevant environments (e.g., flight simulators, multi-domain operations).			

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602202F / *Human Effectiveness Applied Research*	**Project (Number/Name)** 621123 / *Learning and Operational Readiness*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
FY 2019 Plans: Transition fatigue models for mobility operations. Demonstrate time-savings for mission planning using model-based processes. Integrate retention-based scheduling system for training into operational learning management system. Demonstrate prototype trainable agent for multi-domain operations. ***FY 2020 Plans:*** Initiate research to extend fatigue models to unmanned aerial vehicles (UAV) and special operations. Begin research to generalize model-based mission planning capabilities to multi-domain command & control (C2) operational planning. Demonstrate multiscale models for real-time cognitive load estimation and prediction in operationally relevant environments. Demonstrate predictive models of toxin-induced cognitive and performance decrements in a laboratory environment. Mature trainable agent research to integrate machine learning to acquire knowledge from operational data. Transition retention-based scheduling system for training. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 increased compared to FY 2019 by $0.083 million. Justification for the increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	22.190	22.440	22.495

	FY 2018	FY 2019
Congressional Add: Program Increase - learning and operational readiness	19.150	0.000
FY 2018 Accomplishments: Conducted Congressionally directed effort		
FY 2019 Plans: Not applicable		
Congressional Adds Subtotals	19.150	0.000

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

None

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force			Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / *Human Effectiveness Applied Research*	Project (Number/Name) 625328 / *Human Dynamics Evaluation*	

COST ($ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625328: *Human Dynamics Evaluation*	0.000	22.987	26.068	51.449	0.000	51.449	52.265	53.438	34.814	35.620	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project conducts applied research to advance machine intelligence, information operations, operator-aiding technologies for advanced and multi-domain integrated intelligence, surveillance and reconnaissance (ISR) capabilities, and Airman bioscience protection technologies. Research is focused in the following areas: human analyst augmentation, human trust and interaction, human signatures, and molecular bioeffects. The human analyst augmentation area develops, integrates, and evaluates human-centric analyst technology to develop cognitive systems engineering solutions for airman data overload, work integration, and mission performance, enhancing operationally effective ISR for the Air Force. This area also includes research to enable and enhance airman-machine teaming for distributed multi-domain operations. The human trust and interaction area seeks to advance human language technologies to benefit military linguists and analysts as well as to understand, quantify, and calibrate trust factors influencing airman interaction with autonomous systems that can be applied to airman-machine teaming in future weapon systems. The human signatures area develops and applies Science & Technology (S&T) to detect and exploit a variety of human-centered signatures, including behavioral and anthropometric aspects of existing and emerging adversaries as well as bio and molecular signatures of airman performance. The molecular bioeffects area conducts research to protect Airmen from toxic chemicals and materials to include nanomaterials and other advanced development materials and to discover novel biomarkers and molecular mechanisms to support personalized training, performance and protection of Airmen cognitive and physical performance using advanced sense, assess and augment technologies.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Title: Future AF Capabilities Applied Research	0.000	0.000	19.666
Description: Investigate, design, and develop science and technologies supporting future Air Force capabilities to provide compelling advantage to the warfighter. To the greatest extent practical, research efforts will utilize modeling and simulation and cross-discipline systems integration (For example: air and space vehicles, avionics, propulsion, materials, human performance, cybersecurity, command, control, communications, computer and intelligence, sensors, electronic warfare, and conventional/ unconventional weapons). The National Defense Strategy and Air Force Science and Technology 2030 Strategy will inform investments over the FYDP. ***FY 2019 Plans:*** In FY 2019, this work is performed under multiple projects and efforts within the following Air Force Science and Technology Programs: 0602102F, Materials; 0602201F, Aerospace Vehicle Technologies; 0602202F, Human Effectiveness Applied			

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602202F / *Human Effectiveness Applied Research*	**Project (Number/Name)** 625328 / *Human Dynamics Evaluation*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Research; 0602203F, Aerospace Propulsion; 0602204F, Aerospace Sensors; 1206601F, Space Technology; 0602602F, Conventional Munitions; 0602605F, Directed Energy Technology; and 0602788F, Dominant Information Science and Methods. ***FY 2020 Plans:*** Continue to investigate and mature science and technology that enables future warfighting concepts to provide leap-ahead capabilities. The National Defense Strategy and Air Force Science and Technology 2030 Strategy focus this science and technology toward, but not limited to, the following capabilities: 1) global persistent awareness; 2) resilient information sharing; 3) rapid, effective decision-making; 4) complexity, unpredictability, and mass; and 5) speed and reach of disruption and lethality. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 increased compared to FY 2019 by $19.666 million. Funding increased due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.			
Title: Human Analyst Augmentation ***Description:*** Conduct research to enhance human components of intelligence, surveillance and reconnaissance (ISR). Develop ability to improve human analytic efficiency and effectiveness with fewer personnel and in increasingly complex mission space. Develop the ability to improve human cognitive performance of the ISR weapon system through improved data exploitation and intelligence content synthesis. Conduct research to optimize multi-domain ISR airman performance. ***FY 2019 Plans:*** Further investigate cognitive mechanisms that underlie analyst's sense making capabilities and develop methodologies to use autonomous agents to assist in the process. ***FY 2020 Plans:*** Develop fundamental design principles and theories in human-machine teaming, human performance, psychological processes, and physiological indicators focused on systems analytics and multi-domain integrated concepts. Design and envision capabilities to improve analytic insight and reasoning, and integrated multi-domain planning and execution. Integrate threat detection, characterization, and tracking algorithms into human-machine teaming systems to improve decision making for multi-domain operational planners. Develop robust and dynamic synthetic intelligence mission data to stimulate, evaluate, and validate software tools for multi-domain operational planners. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $0.001 million. Justification for the decrease is described in the plans above.	8.826	9.692	9.691
Title: Human Trust and Interaction ***Description:*** Conduct research in cross-cultural communication and automated speech translation tools for Air Force missions. Conduct research to address important aspects of trust in airman-machine teams including investigating how an airman	7.618	8.785	8.784

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602202F / *Human Effectiveness Applied Research*	**Project (Number/Name)** 625328 / *Human Dynamics Evaluation*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
knows an autonomous or semiautonomous system is safe to use and whether the system, data, conclusions, and decision recommendations can be trusted. ***FY 2019 Plans:*** Develop initial transparency and trust guidelines for application to semiautonomous vehicles and autonomous agents for analysts. Investigate techniques for translating text to images and images to text. ***FY 2020 Plans:*** Advance and mature human machine teaming trust and transparency standards to semi-autonomous and autonomous applications. Investigate extending translation and natural language processing research to multimedia information extraction. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $0.001 million. Justification for the decrease is described in the plans above.			
Title: Human Signatures ***Description:*** Develop databases of human motion and features collected from air/space platforms. Identify human threat signatures across diverse populations for intelligence, surveillance and reconnaissance (ISR) and force protection applications. Develop and exploit nano, bio, and molecular signatures of airman performance. Develop man-machine interfaces via wearable, affordable, and real-time platforms to assess airman performance. ***FY 2019 Plans:*** Develop methodologies for air quality and physiological monitoring of personnel using machine learning techniques. Develop algorithms to characterize human detections from air based sensors. ***FY 2020 Plans:*** Continue to develop methodologies for air quality and physiological monitoring of personnel using machine learning techniques. Continue to develop algorithms to characterize human detections from air based sensors. Research and develop sensors that detect volatile organic compounds and novel biomarkers to determine Airman readiness. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** Not applicable	6.543	6.091	6.091
Title: Molecular Bioeffects ***Description:*** Protect airman from toxic chemicals and materials and enhance performance capability under demanding training and mission activities through molecular bioscience research. Investigate the underlying molecular-biological mechanisms contributing to airman physical and cognitive performance optimization.	0.000	0.000	7.217

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602202F / *Human Effectiveness Applied Research*	**Project (Number/Name)** 625328 / *Human Dynamics Evaluation*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
FY 2019 Plans: For FY 2019 and prior, this work is performed under Project 627757,Bioeffects, Molecular Bioeffects effort. ***FY 2020 Plans:*** Study the unknown physiological events occurring in pilots using omics technology (i.e., genomics, proteomics, and metabolmics) to predict Airman physical and cognitive states in that operational environment. Refine the development of an Air Force Specific In vitro Screen to enable rapid and accurate assessment of potentially toxic chemicals and materials including nanoparticles. Identify a potential safe and effective fatigue counter measures to improve Airmen performance in physically or mentally intensive operational environment. Conduct studies to predict how networks that form the whole of living organisms will change over time and under varying operationally relevant conditions. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 increased compared to FY 2019 by $7.217 million. Funding increased due to work transferred from Project 627757, Bioeffects, Molecular Bioeffects effort.			
Accomplishments/Planned Programs Subtotals	22.987	24.568	51.449

	FY 2018	FY 2019
Congressional Add: Program Increase - Warfighter physiology program	0.000	1.500
FY 2018 Accomplishments: Not Applicable		
FY 2019 Plans: Conduct Congressionally directed efforts		
Congressional Adds Subtotals	0.000	1.500

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force			Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / *Human Effectiveness Applied Research*	Project (Number/Name) 625329 / *Sensory Evaluation and Decision Science*	

COST ($ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625329: *Sensory Evaluation and Decision Science*	0.000	33.085	36.687	30.726	0.000	30.726	31.259	32.682	33.957	34.392	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project conducts applied research to revolutionize the manner in which airmen optimize the capabilities of Air Force systems, including remotely piloted aircraft (RPA) and adaptive teams of airmen and machines. Research optimizes airman situational awareness and cognitive performance, improves the airman-machine interface, and seamlessly integrates warfighters with their weapon systems across air, space, and cyber domains. Research is conducted in four focus areas: applied neuroscience; human role in semiautonomous systems; battlespace visualization; and battlespace acoustics. The applied neuroscience area develops technologies to enhance airman-airman and airman-machine collaborations and system interactions in distributed decision-making environments. The human role in semiautonomous systems area develops new control/display concepts and technologies to optimize Air Force platform capabilities. The battlespace visualization area advances the science and technology (S&T) associated with collecting, optimizing, displaying, and assimilating sensory information to enhance warfighter decision-making. The battlespace acoustics area researches human-human and human-machine communications to exploit the use of voice and acoustic data in collaborative, net-centric environments while accounting for the effects of acoustic propagation.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Title: Applied Neuroscience	12.161	14.634	14.211
Description: Develop technologies to enhance Airman performance and Airman-machine collaboration in high-stress decision-making environments. Conduct research to predict physiological impacts of extreme, dynamic environments. ***FY 2019 Plans:*** Continue to investigate and refine sensing and assessment technologies/capabilities for sustained and enhanced Airman performance in multiple operationally relevant environments including Airman-Machine Teaming scenarios and multi-domain operations. Validate applicability of biomarker sensor technologies use in operational environments. Continue to investigate augmentation techniques for physical and cognitive performance optimization and stress resilience and apply those techniques in operationally-relevant environments. Continue to explore utility of non-invasive peripheral nerve stimulation and closed-loop stimulation techniques to enhance cognitive performance. Complete development of the next generation aircraft injury exposure criteria for improved aircrew protection. Investigate multi-axis spinal injury modeling during aircraft ejection. Complete investigation of on-board oxygen generating system performance vulnerabilities affecting oxygen production. Complete the development for on-board oxygen generating system contamination database and susceptibility model. Research the development of the next generation of oxygen monitoring system. ***FY 2020 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602202F / *Human Effectiveness Applied Research*	**Project (Number/Name)** 625329 / *Sensory Evaluation and Decision Science*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Validate sensing and assessment technologies/capabilities for sustained and enhanced Airman performance. Support the development of non-invasive off-body sensors for sensing biological and physiological indices of human performance. Continue to explore the utility of non-invasive peripheral nerve stimulation and other neuromodulation techniques to enhance cognitive performance. Identify the biological and physiological markers that predict enhanced cognitive performance in multiple field environments and under various stressors such as fatigue, high exertion, and oxygen deprived environments. Conduct bioinformatics studies on longitudinal data sets to inform cognitive performance augmentation strategies and refine customer decision tools. Research the novel biological and physical effects and safety implications of current and next-generation ejection seats and intense kinetic-energy scenarios involving human safety, to include the modeling & simulation of these effects on the human. Research the breathing and oxygenation systems for aircraft, investigate potential molecular and physiological sensing tools and techniques to ensure warfighter air quality safety and performance. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $0.423 million. Justification for the decrease is described in the plans above.			
Title: Human Role in Semiautonomous Systems ***Description:*** Research new Human-Machine Teaming (HMT) technologies and concepts (e.g., information portrayal, control devices, decision aiding algorithms and adaptive agents) for effective human-machine interaction and teamwork. ***FY 2019 Plans:*** Refine airman-system cooperative decision aids and interfaces that support distributed unmanned system control concepts in limited communication environments. Continue research and development of predictive, look-ahead tools for effects-based mission planning and execution. Continue research on real-time adaptive human-machine teaming/task allocation that includes examining workload and shared situation awareness metrics and the influence of machine aids on airmen problem solving, attention management and task prioritization. Continue research and development of airman-machine interface methods for real-time machine reasoning and negotiating processes. ***FY 2020 Plans:*** Examine novel HMT concepts and metrics in moderate-fidelity laboratory environments characterized by high-consequence, high-uncertainty missions. Examine the impact of novel HMT concepts, interfaces and agents on workload, shared situation awareness, performance, and trust using realistic laboratory environments which parallel operational challenges derived from Air Force operations, specifically focused on Multi-Domain Command & Control. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $0.205 million. Justification for the decrease is described in the plans above.	5.579	6.224	6.019
Title: Battlespace Visualization	6.558	7.457	7.244

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602202F / *Human Effectiveness Applied Research*	**Project (Number/Name)** 625329 / *Sensory Evaluation and Decision Science*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Description: Research the visualization, interaction and understanding of complex information to enhance warfighter decision making. ***FY 2019 Plans:*** Continue exploration of analytic strategies with machine learning techniques to achieve next-generation, automated, data exploitation capability, and develop visual interfaces to enhance decision making. Continue data analytics research focused on human visualization of complex data. Evaluate multi-domain operator system interfaces for integrated defensive and offensive operations. Refine models to predict visibility of objects viewed by humans under both unaided and aided conditions and explore multi-modal model integration. Continue to integrate visualizations of events and their influence on objectives and courses of action for command & control (C2) environments across the air, space and cyberspace domains. ***FY 2020 Plans:*** Select and evaluate analytic strategies with machine learning techniques to achieve next-generation, automated, data exploitation capability, and develop visual interfaces to enhance task performance and decision making. Develop and evaluate integration and tailoring of Explainable Artificial Intelligence (XAI) analytic methods with analytic visual interfaces. Continue data analytics research focused on human visualization of complex data. Test and modify multi-domain operator system interfaces for integrated defensive and offensive operations. Transition model of predicted visibility of objects viewed by humans under both unaided and aided conditions and develop multi-modal model integration. Test and evaluate visualizations of events and their influence on objectives and courses of action for C2 environments across the air, space and cyberspace domains. Conduct multi-sensory research and develop concepts for seamlessly integrating multiple interaction modes, such as visual, auditory, vestibular, and tactile, into integrated work aids. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $0.213 million. Justification for the decrease is described in the plans above.			
Title: Battlespace Acoustics ***Description:*** Conducts research on advanced auditory and communication technologies that mitigate effects of noise and enhance performance in operational environments. ***FY 2019 Plans:*** Continue to conduct research on auditory processing of complex, multi-source acoustic scenes and develop context-aware auditory displays for optimal delivery of real-time information from synthetic teammates, including verbal communication, spatial location and system state. Develop enhanced electro-acoustic characterization techniques for the prediction of auditory protection	3.877	3.372	3.252

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602202F / *Human Effectiveness Applied Research*	**Project (Number/Name)** 625329 / *Sensory Evaluation and Decision Science*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
and performance requirements. Examine and implement techniques for real-time augmentation of auditory reality. Enhance and refine biologically-inspired models of acoustic detection for special operations aviation. ***FY 2020 Plans:*** Conduct research on single sensor perception and multisensory interactions, focusing on multisensory integration and facilitation, as well as multisensory conflict for issues such as spatial disorientation. Determine optimal approaches for information presentation and communication management, incorporating both performance and preference metrics for enhanced decision making. Conduct research on speech identification and production, and develop interfaces and techniques to support effective human-human and human-machine communication. Evaluate emerging hearing enhancement and protection technologies to provide design guidelines for capabilities supporting future operations. Continue to enhance and refine models of acoustic detection for special operations aviation. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $0.120 million. Justification for the decrease is described in the plans above.			
Accomplishments/Planned Programs Subtotals	28.175	31.687	30.726

	FY 2018	FY 2019
Congressional Add: Program Increase - Hypoxia research	4.910	5.000
FY 2018 Accomplishments: Conducted Congressionally directed effort		
FY 2019 Plans: Conduct Congressionally directed efforts		
Congressional Adds Subtotals	4.910	5.000

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force			Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / *Human Effectiveness Applied Research*	Project (Number/Name) 627757 / *Bioeffects*	

COST ($ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
627757: *Bioeffects*	0.000	29.130	33.823	27.125	0.000	27.125	26.636	28.608	30.092	31.378	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project conducts applied research on the effects of human exposure to electromagnetic (EM) energy (direct current (DC) to radio frequency (RF) to optical), scalable directed energy weapons, and non-lethal weapons. This research addresses fundamental physical principles, as well as the psychophysical interaction between directed energy and the individual or groups of individuals. Research is divided into two core focus areas: optical radiation bioeffects and radio frequency radiation (RFR) bioeffects. Optical radiation bioeffects research enhances combat survivability and systems effectiveness through technologies that enable deployed forces to counter optical threats and exploit optical systems for offensive applications. The RFR bioeffects research investigates basic biological mechanisms of RFR, conducts theoretical and empirical dosimetry, conducts research of bioeffects from short and long-term exposures, develops methods to counter RFR threats, and performs research for exploitation of directed energy systems for offensive capabilities.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Title: Optical Radiation Bioeffects	10.395	14.247	15.316
Description: Conduct laboratory experiments and field research on laser bioeffects, enabling military exploitation of laser technology while providing countermeasures for optical hazards/threats. ***FY 2019 Plans:*** Complete initial studies of alternate laser wavelength bioeffects for use in high-energy lasers. Incorporate glare vision effect models in national and Dept of Defense (DoD) standards for definition of protective requirements and glare device effectiveness. Transition risk-based model components for hazard evaluations of laser and broad-band optical systems. Mature generalized dose-response component models for future analysis of emerging laser technologies such as fiber and Diode Pumped Alkali Laser (DPAL) systems. ***FY 2020 Plans:*** Initiate validation and verification experiments for 3-dimensional tissue models of laser exposures. Complete studies of alternate laser wavelength bioeffects for use in high-energy lasers and the assessment of relative hazards. Transition model for probabilistic evaluation of risks from laser exposures on Air Force and DoD laser ranges. Advance dose-response models to include severe retinal and skin optical radiation exposures. Develop metrics for the influence of optical distortion in evaluating developing eye protection technology. Mature models for combining separate images of same retinal or skin area into one image with higher fidelity of injury. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 increased compared to FY 2019 by $0.889 million. Justification for the increase is described in the plans above.			
Title: Radio Frequency Bioeffects	8.952	10.873	11.809

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602202F / *Human Effectiveness Applied Research*	**Project (Number/Name)** 627757 / *Bioeffects*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Description: Conduct laboratory experiments and field research to enable safe exploitation of directed energy technologies for communication, target identification, and weapons development. ***FY 2019 Plans:*** Focus on molecular signatures of Radio Frequency (RF) overexposure to assess acute and chronic bioeffects of RF overexposures in operational situations. Complete scalability matrix for fast thermal gradients exposures for transition from contact to free field application. Continued advancements in fast thermal gradient research. Investigating damage effects of high average power exposures. ***FY 2020 Plans:*** Conduct in vivo measurement of high average power exposures and high peak power microwave exposures to identify and baseline novel bioeffects. Build thermo-acoustic dosimetry techniques for in vivo assessment of high power sources including RF acoustics. Determine acute and chronic bioeffects from emerging sources such as particle beam. Expand in vivo molecular signature of RF exposure to assess acute and chronic bioeffects of RF to inform exposure scenarios. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 increased compared to FY 2019 by $0.936 million. Justification for the increase is described in the plans above.			
Title: Molecular Bioeffects ***Description:*** Protect airman from toxic chemicals and materials and enhance performance capability under demanding training and mission activities through molecular bioscience research. Investigate the underlying molecular-biological mechanisms contributing to airman physical and cognitive performance optimization. ***FY 2019 Plans:*** Complete toxicological analysis of several relevant aerospace fluids, such as hydraulics, coolants, lubricants and jet fuels that may negatively affect high performance aircraft operators. Begin development of an Air Force Specific In Vitro Screen (AFSIVS) to enable rapid and accurate assessment of potentially toxic chemicals and materials including nanoparticles. Conduct studies to develop safe and effective fatigue counter measures to improve Airmen performance in physically or mentally intensive operational environments. Complete initial characterization and toxicity evaluation of particle aerosol in post-detonated areas to define exposure limits for the warfighter. Conduct developmental studies to create an organ on chip technology that enables rapid and accurate assessment of potentially toxic aerospace materials, with special emphasis on advanced acquisition materials that includes nanoparticles. ***FY 2020 Plans:***	9.783	8.703	0.000

Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	**R-1 Program Element (Number/Name)** PE 0602202F / *Human Effectiveness Applied Research*	**Project (Number/Name)** 627757 / *Bioeffects*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2018	FY 2019	FY 2020
Starting in FY 2020, this work will be performed under Project 625328, Human Dynamics Evaluation, Molecular Bioeffects effort. ***FY 2019 to FY 2020 Increase/Decrease Statement:*** FY 2020 decreased compared to FY 2019 by $8.703 million. Funding decreased due to the Molecular Bioeffects effort being transferred to Project 625328, Human Dynamics Evaluation.			
Accomplishments/Planned Programs Subtotals	29.130	33.823	27.125

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.