Exhibit R-2, RDT&E Budget Item Justification: PB 2023 Air Force											Date: April 2022	
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 2021**	**FY 2022**	**FY 2023 Base**	**FY 2023 OCO**	**FY 2023 Total**	**FY 2024**	**FY 2025**	**FY 2026**	**FY 2027**	**Cost To Complete**	**Total Cost**
Total Program Element	0.000	127.160	156.863	135.771	0.000	135.771	118.402	115.918	118.441	121.176	Continuing	Continuing
621123: *Learning and Operational Readiness*	0.000	22.361	18.591	21.164	0.000	21.164	21.492	21.704	22.164	22.647	Continuing	Continuing
625328: *Human Dynamics Evaluation*	0.000	40.124	84.405	28.668	0.000	28.668	26.417	22.117	22.648	23.301	Continuing	Continuing
625329: *Sensory Evaluation and Decision Science*	0.000	37.547	35.783	40.148	0.000	40.148	40.764	41.719	42.606	43.530	Continuing	Continuing
627757: *Bioeffects*	0.000	27.128	18.084	45.791	0.000	45.791	29.729	30.378	31.023	31.698	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program conducts applied research in the area of airmen training, airmen performance sustainment, bioeffects, and understanding and shaping adversarial behavior. The Learning and Operational Readiness project conducts research to increase the agility of training for readiness while advancing learning and performance assessment science and practice. The Biosciences Performance project conducts research to discover, demonstrate, and transition capabilities which optimize and safe-guard Airman physical and cognitive performance allowing for the maximum potential of the multi-domain Airman. The Sensory Evaluation and Decision Science project conducts research to discover, develop, and transition advanced interface technology, decision aiding tools, and situationally-adaptive augmentation methods to seamlessly integrate Airmen and intelligent machines into maximally collaborative warfighting teams. The Bioeffects project conducts novel and operational exposure bioeffects research, exposure effects analysis and national/international exposure standards for the Air Force to enable, sustain, and enhance Airman performance and protection during deployment of directed energy systems.

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 program element would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, and 0602298F.

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 2023 Air Force	Date: April 2022
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 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total
Previous President's Budget	133.877	136.273	0.000	0.000	0.000
Current President's Budget	127.160	156.863	135.771	0.000	135.771
Total Adjustments	-6.717	20.590	135.771	0.000	135.771
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	20.590			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-2.108	0.000			
• Other Adjustments	-4.609	0.000	135.771	0.000	135.771

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2021	FY 2022
Project: 625328: *Human Dynamics Evaluation*		
Congressional Add: *Warfighter Physiology Program*	4.817	0.000
Congressional Add: *Human Motion Assessment*	3.853	0.000
Congressional Add: *Pilot Hypoxia Detection and Notification*	9.538	7.000
Congressional Add: *F-35 Helmet Mounted Display System Tech Refresh and Weight Reduction*	0.000	9.590
Congressional Add: *Special Tactics Support Assessment*	0.000	4.000
Congressional Add Subtotals for Project: 625328	18.208	20.590
Congressional Add Totals for all Projects	18.208	20.590

Change Summary Explanation

Decrease in FY 2021 reflects reprogramming to support Research and Development Projects, 10 U.S.C. Section 2363, an amendment to PL 110-417, 10 U.S.C. Section 2358 and 10 U.S.C. 2805(d)(1)(B).

The FY 2022 President's Budget submittal did not reflect FY 2023 through FY 2026 funding. Therefore, an explanation of the change between the two budget positions for FY2023 cannot be made in a relevant manner.

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force			Date: April 2022
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 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
621123: *Learning and Operational Readiness*	0.000	22.361	18.591	21.164	0.000	21.164	21.492	21.704	22.164	22.647	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project advances research to measure, accelerate, and expand the cognitive skills necessary to improve airmen training and mission performance. The emphasis is on developing technology to enable a more lethal force by delivering revolutionary training and readiness capabilities at the speed of operations. Research is conducted in two focus areas: personalized learning and cognitive modeling. Personalized learning focuses on exploratory application of adaptive proficiency technologies and interactive task learning capabilities to provide more effective, efficient learning that improves mission readiness. Cognitive modeling advances computational and mathematical methods to represent human information processing to facilitate the development of models capable of operating as intelligent teammates, adversaries, or coaches, and cognitive performance prediction systems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Personalized Learning	13.416	11.155	12.698
Description: Research enhances distributed mission operations (DMO) and live-virtual-constructive (LVC) environments through the creation and exploratory application of adaptive proficiency technologies and interactive task learning capabilities, to provide more effective, efficient learning that improves mission readiness. In FY 2021, this effort changed names from Continuous Learning to Personalized Learning. ***FY 2022 Plans:*** Initiate research to evaluate new integrated human and machine personalized learning capabilities in mission-relevant laboratory, testbed, and field environments. Continue development of novel methods for adaptive, multi-objective optimization of instruction, as well as the development of quantitative measures to estimate uncertainty in proficiency measurement and prediction. In collaboration with Cognitive Modeling effort within this project and Multisensory Perception and Communication effort within the Sensory Evaluation and Decision Science Project, initiate research on the integration of multi-modal data to support improved inference, understanding, and decision-making in team-based performance environments. ***FY 2023 Plans:*** Continue research to evaluate integrated human and machine personalized learning capabilities in mission-relevant laboratory, testbed, and field environments. Evaluate adaptive, multi-objective optimization methods in constrained instructional settings. Incorporate uncertainty in proficiency measurement and prediction in laboratory assessments. Initiate research to evaluate the impact of training fidelity related to augmented, virtual, mixed, and extended reality on readiness. Explore methods and			

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force		Date: April 2022
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 2021	FY 2022	FY 2023
standards for assessing transfer of skill for just in time, novel mission training requirements for a peer fight in deployed and austere environments. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** FY 2023 increased compared to FY 2022 by $1.543 million. Funding increase due to added emphasis in personalized learning, and multi-objective instruction and interactive task learning.			
Title: Cognitive Modeling ***Description:*** Research explores application of mathematical and computational modeling to understand the human mind and factors that will enhance or degrade cognitive performance. Simulations of training in mission-relevant environments (e.g., flight simulators, multi-domain operations) will optimize learning strategies during training to increase/accelerate mission readiness. ***FY 2022 Plans:*** Initiate research to track performance by profiling cognitive performance during task execution. Identify mechanisms to predict performance impacts of fatigue countermeasures. Demonstrate technology to track and predict individual fatigue. Continue integration of physiological and cognitive models to predict performance under chemical exposure. Evaluate models that identify and resolve knowledge gaps resulting from learning from text-based instructions. Initiate research on language adaptation in team-based communication in collaboration with Personalized Learning effort within this project and Multisensory Perception and Communication effort within the Sensory Evaluation and Decision Science Project. ***FY 2023 Plans:*** Demonstrate laboratory capability to profile workload and cognitive performance in real time. Evaluate real-time, personalized tracking of fatigue in operationally relevant environments, including impacts of countermeasures. Apply integrated physiology-cognitive models to oxygen deprivation and chemical air contaminants. Demonstrate automated knowledge and skill learning through verbal instruction with knowledge gap resolution in a laboratory-based artificial learning system. Mature mechanisms for adaptation in communication within human-machine teams. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** FY 2023 increased compared to FY 2022 by $1.030 million. Funding increase due to added emphasis in high-cognitive-fidelity models for predictive cognitive performance.	8.945	7.436	8.466
Accomplishments/Planned Programs Subtotals	22.361	18.591	21.164

C. Other Program Funding Summary ($ in Millions)

N/A

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

C. Other Program Funding Summary ($ in Millions)

Remarks

None

D. Acquisition Strategy

Not Applicable

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force			Date: April 2022
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 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
625328: *Human Dynamics Evaluation*	0.000	40.124	84.405	28.668	0.000	28.668	26.417	22.117	22.648	23.301	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project conducts bioengineering and biotechnology research to optimize, safe-guard, and restore the performance of the multi-domain Airman and warfighter in all environments. Research is focused in the areas of 1) cognitive and physiological performance technologies to sustain, augment, and recover operator performance; 2) biotechnology for performance--research in systems biology, synthetic biology, and risk assessment; 3) performance sensing and assessment--technologies to sense and forecast operator state based on physiological, molecular, and environmental signatures related to mission performance; and 4) performance impact of space and flight--elucidate how air and space environments affect processes of life and the ability to maintain homeostasis and develop countermeasures and solutions to sustain, enhance, and restore operator performance.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Performance Sensing and Assessment	5.479	15.953	7.167
Description: Develop technologies to sense and forecast operator state based on physiological, molecular, and environmental signatures related to Airman and warfighter performance. Develop solutions optimized for real-time, minimally-invasive, and autonomous sensing and assessing capabilities to enhance and protect the Airman and the warfighter across the spectrum of operational environments. In FY 2023, this effort changed names from Molecular Sensing and Physiology to Performance Sensing and Assessment. ***FY 2022 Plans:*** Mature Biological Recognition Elements (BRE) development pipeline and optimize for BRE transition to sensor platforms. Develop and test different sensor options (electrochemical, field effect transistors, etc.) for biomarker and Volatile Organic Compounds (VOCs) detection in different operational environments. Incorporate sensor modalities into wearable and injectable sensors. Integration of biological system and their components in sensing platforms. Design, test and evaluate solutions for air quality assessment (sampling, analysis and models). Finalize investigation into Onboard Oxygen Generating System oxygen and flow performance decrements during highly dynamic operating conditions. Conduct Onboard Oxygen Generating System (OBOGS) chemical containment research to assess quality of OBOGS breathing gas under realistic operating conditions. Develop Onboard Oxygen Generating System performance monitor for predicting failure. In FY 2021 and prior years, the OBOGS research is performed under Project 625328/Human Dynamics Evaluation, Aircrew Biodynamics and Protection sub-project. ***FY 2023 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force		Date: April 2022
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 2021	FY 2022	FY 2023
Develop rapid Biological Recognition Element (BRE) selection and optimization strategies. Develop electrochemical and Field Effect Transistors (FET)-based biomarker sensing platforms, including synthetic biology developed components. Optimize sensor form factor for deployment with focus on platform miniaturization. Develop wearable and implantable/biodegradable sensors for continuous biomarker monitoring. Develop platforms to deliver augmentation strategies in an autonomous fashion. Evaluate commercial, off-the-shelf molecular-based sensing technologies for Air Force and Space Force applications. In FY 2023, the research performance of On-board Oxygen Generation System (OBOGS) and implications on human physiology for current and next-generation aircraft is being performed under the Project 625328/Performance Impact of Air and Space sub-project. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** FY 2023 decreased compared to FY 2022 by $8.786 million. Funding decrease due to a reduced emphasis in physiological, molecular, and environmental signatures related to the warfighter's performance.			
Title: Biotechnology for Performance	5.479	15.954	7.167
Description: Conduct research in systems biology, synthetic biology, and physiologic risk assessment research to focus on the underlying mechanisms contributing to individual performance in various operational environments through the integration of genomics, proteomics, metabolomics, and epigenetics. Conduct research to utilize multi-omics technologies to determine the risk associated with exposure to toxic compounds and materials. Resulting research will generate biomarker candidates for sensing personalized predictions of response to stressors and novel interventions to optimize, safeguard, and restore Airman and warfighter performance. In FY 2023, this effort changed names from Systems Biology for Performance to Biotechnology for Performance. ***FY 2022 Plans:*** Explore mechanistically inspired synthetic biology and other performance enhancing technologies to include engineering the microbiome. Generate mechanistic understanding of the effects of stress factors from which to generate biomarkers. Develop advanced physical and in silico models and simulations to predict individualized performance. ***FY 2023 Plans:*** Develop a microfluidic "brain-on-a-chip" platform simulating the dynamic environment and physiologic conditions of brain cells/ tissue to include blood brain barrier oxygen dynamics. Utilize advanced bio-data analytics and bioinformatics processing to analyze baseline multi-omics data collected on large scale research cohort--identify relevant biomarkers, mechanisms of action, and intervention strategies to provide predictive performance assessment algorithms for physical and cognitive augmentation. Identify nasal microbiome strain suitable for peptide delivery to improve stress resilience. ***FY 2022 to FY 2023 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force		Date: April 2022
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 2021	FY 2022	FY 2023
FY 2023 decreased compared to FY 2022 by $8.787 million. Funding decrease due to a reduced emphasis in systems biology, synthetic biology, and physiologic risk assessment research.			
Title: Cognitive and Physiological Performance ***Description:*** Develop technologies in cognitive neuroscience and physical performance to sustain, augment, and recover operator performance and determine performance attributes/metrics for optimal career field alignment. Includes research focused on developing and validating physiological and behavioral assessments of current and predicted cognitive state combined with personalized cognitive performance enhancement techniques and technologies to augment operator performance. In FY 2023, this effort changed names from Cognitive Neuroscience to Cognitive and Physiological Performance. ***FY 2022 Plans:*** Continue research to elucidate the neural mechanisms of neuromodulation and stress on cognitive performance in animal models. Conduct studies of peripheral nerve stimulation effects on various aspects of cognition including learning, attention, and multitasking. Explore methods of addressing physiologic variability between days, people, tasks, and time to improve the accuracy of cognitive state assessments. Perform research to develop methods of assessing fatigue state via physiology, and compare the effects of cognitive interventions on performance during sleep deprivation. Continue development of a novel Brain Machine Interface (BMI) technology to accelerate training for Air Force personnel, such as pilots. ***FY 2023 Plans:*** Conduct evaluation of Brain Machine Interface (BMI) devices optimized for extended reality (XR) applications or alternate Air Force relevant application. Conduct research to determine feasibility to send interpretable information directly to the brain. Conduct longitudinal study evaluating passive sensing technologies for cognitive state assessment. Transition artifact correction algorithms necessary for accurate cognitive state assessment to advanced development projects. Update real-time analytics testbed with additional capabilities and utilize for cognitive probing validation and replication experiments. Finalize research detailing differences between effects of transcranial direct current stimulation (tDCS) and transcutaneous vagal nerve stimulation (tVNS) on brain physiology and structure. Initiate neuromodulation paradigms for cognitive enhancement across Air Force career fields (i.e., piloting; intelligence, surveillance, and reconnaissance (ISR); cyber operations; special operations). ***FY 2022 to FY 2023 Increase/Decrease Statement:*** FY 2023 decreased compared to FY 2022 by $8.787 million. Funding decrease due to a reduced emphasis in predictive and personalized cognitive performance enhancement techniques.	5.479	15.954	7.167
Title: Performance Impact of Air and Space	5.479	15.954	7.167

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force		Date: April 2022
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 2021	FY 2022	FY 2023
Description: Conduct research investigating Airman and warfighter performance degradation resulting from exposure to air and space environments, and seek to understand the fundamental mechanisms driving environmental and operational risks. Develop technologies to mitigate or eliminate the root physiologic causes of these degradations and to ultimately optimize Airman and warfighter performance resulting in the capability to fly faster, higher, and longer than our adversaries. In FY 2023, this effort changed names from Aircrew Biodynamics and Protection to Performance Impact of Air and Space. ***FY 2022 Plans:*** Conduct research to develop and validate lumbar and neck injury criteria. Continue development of computational modeling to predict and assess acute and chronic injury to full aircrew. Conduct research to ascertain injury mechanisms of chronic neck and back pain to aircraft mission durations and vibration effects. Continue research on evaluation of structural integrity of medical transport devices. In FY 2022, the Onboard Oxygen Generating System (OBOGS) research will be performed under Project 625328, effort Human Dynamics Evaluation. ***FY 2023 Plans:*** Conduct research to develop next generation onboard oxygen generation system (OBOGS) technologies. Conduct research to characterize aircrew kinematics, and etiology related to acute and chronic back/neck pain and musculoskeletal injuries. Develop mitigation strategies such as physical conditioning, system design improvements, and interventional strategies to repair post-sortie injury from high-G exposures. Develop human digital engineering algorithms and models for fighter and bomber aircraft system design and human factors analysis applications. In FY 2023, Onboard Oxygen Generating System (OBOGS) research moved from the Project 625328, effort Performance Sensing and Assessment. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** FY 2023 decreased compared to FY 2022 by $8.787 million. Funding decrease due to a reduced emphasis in efforts focused on understanding the root physiologic, environmental, and operational degradations.			
Accomplishments/Planned Programs Subtotals	21.916	63.815	28.668

	FY 2021	FY 2022
Congressional Add: Warfighter Physiology Program	4.817	0.000

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force		Date: April 2022
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	FY 2021	FY 2022
FY 2021 Accomplishments: Conduct Congressionally directed efforts ***FY 2022 Plans:*** Not applicable		
Congressional Add: Human Motion Assessment ***FY 2021 Accomplishments:*** Conduct Congressionally directed efforts ***FY 2022 Plans:*** Not applicable	3.853	0.000
Congressional Add: Pilot Hypoxia Detection and Notification ***FY 2021 Accomplishments:*** Conduct Congressionally directed efforts ***FY 2022 Plans:*** Not applicable	9.538	7.000
Congressional Add: F-35 Helmet Mounted Display System Tech Refresh and Weight Reduction ***FY 2021 Accomplishments:*** Not applicable ***FY 2022 Plans:*** Conduct Congressionally directed efforts	0.000	9.590
Congressional Add: Special Tactics Support Assessment ***FY 2021 Accomplishments:*** Not applicable ***FY 2022 Plans:*** Conduct Congressionally directed efforts	0.000	4.000
Congressional Adds Subtotals	18.208	20.590

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not applicable

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force			Date: April 2022
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 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
625329: *Sensory Evaluation and Decision Science*	0.000	37.547	35.783	40.148	0.000	40.148	40.764	41.719	42.606	43.530	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project conducts research to discover, develop, and transition advanced interface technology, decision aiding tools, and situationally-adaptive augmentation methods to seamlessly integrate Airmen and intelligent machines into maximally collaborative warfighting teams. Advanced technologies will enhance how Airmen fight via improved team interactions and adaptive information throughput. Airman-Machine interaction design is critical for achieving mission success and maintaining meaningful human control in highly complex, uncertain, and rapidly evolving environments.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Collaborative Interfaces and Teaming	10.138	9.661	10.840
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 2022 Plans:*** Develop and test multiple interface designs for teaming solutions based on research on swift trust development, and effective teaming methods between human operators in a Joint All Domain Command and Control (JADC2) context; develop a multi-domain playbook for JADC2 operators; conduct research and experimentation focused on human-machine-teaming (HMT) and collaborative interface design among mixed human-human and human-machine teams; conduct research on trust development within mixed human-synthetic agent teams; conduct research on human implications of machine learning and run-time assurance technologies; conduct research focused on development of software architectures and platforms to enable HMT for pilot-vehicle interfaces, Unmanned Aerial System (UAS) teaming, base defense, and air battle management. ***FY 2023 Plans:*** Develop and validate the effects of multiple interface designs for teaming solutions based on research on swift trust development and effective teaming methods between human operators in a Joint All Domain Command and Control (JADC2) context; expand a multi-domain playbook for JADC2 operators to include Air, Space and Cyber effects; conduct research and experimentation focused on human-machine-teaming (HMT) and collaborative interface design among mixed human-human and human-machine teams in applied and simulated domains; conduct research on trust development within mixed human-synthetic agent teams; conduct research on human implications of machine learning and run-time assurance technologies; conduct research focused on development of software architectures and platforms to enable human-machine-teaming (HMT) for pilot-vehicle interfaces in operationally relevant scenarios, Unmanned Aerial System teaming, base defense, and air battle management; apply research			

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
methodologies to conduct operator-centric field evaluations of fielded automation/autonomy systems; synthesize guidelines for engendering trust in human-human and human-machine teams. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** FY 2023 increased compared to FY 2022 by $1.179 million. Funding increase due to added emphasis in areas such as Human-Machine Teaming technologies, and collaborative interface designs in applied and simulated domains.			
Title: Multisensory Perceptions and Communication	14.268	13.597	15.256
Description: Multisensory Perception and Communication focuses on identifying and exploiting the underlying sensory and cognitive mechanisms mediating human perception and communication in order to inform the development of multimodal interfaces and speech/language technologies. Research will examine sensory processing, multisensory integration, and human communication processes in simple and complex environments to identify the barriers to effective information transmission and inform the development of technologies to overcome, or exploit, those barriers in order to enhance Airmen performance. ***FY 2022 Plans:*** Conduct research examining impact of communication interruption on task performance and refine a prototype real-time interruption system for human-machine communication; evaluate impact of communication management technologies used in real-world operations; develop laboratory and web-based toolkit and tablet-based applications for studying communication and perception for use in remote and in-house experimentation; generate and test model of perception of real-world sounds in complex environments for developing tools supporting perceptual disruption; establish new testbed for neurophysiological studies of multisensory perception and multimodal display research; conduct research on multimodal contribution to automatic speech recognition and machine translation; develop new algorithms for real-time speech synthesis for speech displays; conduct experiments on speech perception in complex environments to improve operational communication; develop program for research in visual and auditory attention monitoring to inform advanced multimodal interfaces; measure, model, and simulate operational acoustic environments for use in training and interface research and development; address requests for direct support from operational community. ***FY 2023 Plans:*** Conduct behavioral research on team communication; collect operationally-relevant speech databases; develop new models of dialogue processes; build and integrate algorithms from these models into an existing communication interface for identifying intelligent interruption capability; identify characteristics of effective/ineffective communication to inform prototype miscommunication identification system; evaluate these capabilities in operationally-relevant testbeds. Build and evaluate new communication management technologies and explore new domain-specific features and form factors; test in operational exercises with military and civilian operational communities. Evaluate Augmented and Virtual reality (AR/VR) capabilities for providing information through additional perceptual channels (visual, haptic/tactile along with speech communications); for			

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force		Date: April 2022
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
distributed, collaborative tasks, supporting multi-capable airmen. Develop multimodal symbologies and evaluate, with subject matter experts from flight community and Special Forces, in simulation and real-world operating environments with appropriate environmental/task complexity. Collect behavioral and neurophysiological data, use to refine real-time model of attention and processing capacity, integrate into operational testbeds to evaluate as driver for adaptive interfaces. Evaluate new technologies focused on perceptual and communication disruption in field tests. Continue to address requests for direct support from operational community. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** FY 2023 increased compared to FY 2022 by $1.659 million. Funding increase due to added emphasis in areas such as cognitive mechanisms mediating human perception and communication, and evaluation of Augmented and Virtual reality capabilities for training and collaborative tasks.			
Title: System Analytics	13.141	12.525	14.052
Description: System Analytics studies the macro-cognition of the Airman using computational tools to accomplish mission objectives, encompassing interactions between operators, analytics, and environment. The goal of this research area is to describe, assess, and design for effective integration of analytics into mission systems. ***FY 2022 Plans:*** Advance development of theory-driven, evidence-based approaches to integrate new analytics (including decision aids, algorithms, automation, autonomy, and artificial intelligence/machine learning technologies) into human-machine systems in complex operational environments. Lines of effort will emphasize maturation and transition of research in systems analytics assessment, dynamic wide area discovery and exploitation, meaning making in the information environment, applied operational analytics, joint integrated Intelligence, Surveillance, and Reconnaissance (ISR), and human language technology. Efforts will include increased investment in evaluation of conversational artificial intelligence, exploitation of publicly available information, and explain-ability and ISR applications of topological data analytics. ***FY 2023 Plans:*** Focus on the goal of accelerating design and assessment of mission relevant, Airman-centric data analytics capabilities at speed and scale. Research activities are aligned under two enduring Lines of Effort (LOEs). The Analytic-enabled Cognition LOE seeks to quantify the impact of analytics on thinking and reasoning in order to tailor capabilities to the context-specific cognitive requirements of Airmen. The Sense-making at Scale LOE seeks to design analytics to enhance sense-making and mitigate data overload in order to enable Airmen to rapidly extract meaning from complex, uncertain, multi-dimensional data sources. Planned areas of increased investment include cognitive and physiological performance assessment, development of analytics for insider threat identification, and decision support for joint all domain mission planning and execution. Areas of decreased investment			

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force		Date: April 2022
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 2021	FY 2022	FY 2023
and transition to 6.3 will encompass single-INT analytics studies, data visualization for wide area monitoring, and technologies for intelligence requirement management. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** FY 2023 increased compared to FY 2022 by $1.527 million. Funding increase due to an added emphasis in areas such as the analytics on thinking and reasoning in order to tailor capabilities to cognitive requirements of Airmen, and computational tools to accomplish mission objectives.			
Accomplishments/Planned Programs Subtotals	37.547	35.783	40.148

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not applicable

Exhibit R-2A, RDT&E Project Justification: PB 2023 Air Force			Date: April 2022
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 2021	FY 2022	FY 2023 Base	FY 2023 OCO	FY 2023 Total	FY 2024	FY 2025	FY 2026	FY 2027	Cost To Complete	Total Cost
627757: *Bioeffects*	0.000	27.128	18.084	45.791	0.000	45.791	29.729	30.378	31.023	31.698	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project conducts applied research on the effects of human exposure to electromagnetic energy (direct current to radio frequency to optical, scalable directed energy weapons, and non-lethal weapons. This research addresses fundamental physical principles, as well as the biophysical interaction between directed energy and the individual or groups of individuals. Research is divided into two core focus areas: novel directed energy bioeffects and mechanisms and directed energy modeling, simulation, and analysis. The research enhances combat survivability and systems effectiveness through technologies that enable deployed forces to counter optical threats and exploit optical systems for offensive applications. In addition, basic biological investigations into the mechanisms associated with high peak power and high average power radio frequency exposure allow for the exploitation of directed energy systems for offensive capabilities while protecting the warfighter from adversarial use of radio frequency technologies. The novel directed energy bioeffects mechanisms research examines the physical, physiological, and neural interactions of electromagnetic energy with tissues to understand dose-response effects as well as reveal the means to cause or prevent a specific effect. The directed energy modeling, simulation, and analysis research is focused on new software components that represent and optimize concepts of directed energy system employment from the Airman standpoint. These components are matured for future transition and application for engagement-to-mission level simulations in which directed energy weapons are employed.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Title: Novel Directed Energy Bioeffects and Mechanisms	9.495	6.329	16.027
Description: Conduct laboratory experiments to provide fundamental knowledge of mechanisms of interaction of directed energy with molecules, cells, tissues, organs, and whole organisms in support of military directed energy systems. Conduct laboratory experiments to understand the mechanistic and behavioral effects of novel weapon incidents to the Airman and to understand the effects of protection strategies on Airman performance.			
FY 2022 Plans: Continue multiple parameterization, validation and verification experimental studies which examine high peak power microwave, high energy laser, and other emerging directed energy weapon concepts in order to assure valid modeling of real-world concerns. Initiate studies to further understanding of superthreshold effects on critical tissues including dynamic tissue characteristics under superthreshold insult. Develop methodologies to validate representation of directed energy vision effects within the Modeling and Simulation environment. Collect data that leads to more refined exposure limits for militarily relevant environments. Examine postulated second-order effects for their impact on military missions. Examine mechanisms emerging from subcellular and cellular level response to radio frequency and optical radiation. Participate in activities that further development of directed energy bioeffects policy and standards to maximize safe use of the technology.			
FY 2023 Plans:			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
Continue collection and transition of data from multiple parameterization, validation and verification experimental studies to candidate products that support high peak power microwave, high energy laser, and other emerging directed energy weapon concepts in order to assure valid modeling of real-world concerns. Continue studies to further the understanding of suprathreshold effects on critical tissues including dynamic tissue characteristics under suprathreshold insult. Develop methodologies to represent human vulnerabilities and vision effects within the modeling and simulation environment. Examine mechanisms emerging from subcellular and cellular level response to radio frequency and optical radiation. Perform research that underpins enhanced assessment of operational exposures to battlefield directed energy environments. Provide research data and expertise to activities that further the development of directed energy policy and exposure standards to maximize interoperability and safe use of technology. ***FY 2022 to FY 2023 Increase/Decrease Statement:*** FY 2023 increased compared to FY 2022 by $9.698 million. Funding increase due to added emphasis in novel and experimental directed energy efforts to better understand dynamic tissue characteristics that support high peak power microwave, high energy laser, and other emerging directed energy weapon concepts.			
Title: Directed Energy Bioeffects Modeling, Simulation and Analysis	17.633	11.755	29.764
Description: Conduct physics-level modeling and simulations to represent and optimize directed energy bioeffects to include direct, scalable, and collateral effects. ***FY 2022 Plans:*** Expand content of component level models to support future transitions of digital human representations to tactical wargaming and models. Translate new data from relevant biological experiments to establish engineering to mission-level models supporting severity of outcome in system risk assessments. Initiate new approaches for utilizing high performance computing for better characterizing uncertainty in quantitative models for bioeffects analysis. Extend advanced multi physics models to contain accurate representations of newly-discovered or postulated mechanisms of directed energy biological activity. ***FY 2023 Plans:*** Advance dose-response models to include probability of injury as a function of depth within the skin. Mature approaches for utilizing high performance computing to quantify the uncertainty within multi-physics bioeffect simulations of directed energy engagement. Extend prototype approaches for surrogating physics-level simulations through machine learning applications. Develop advanced three-dimensional digital anatomical models for use within physics-level software, and leverage these models against empirical datasets for advanced validation purposes. ***FY 2022 to FY 2023 Increase/Decrease Statement:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2021	FY 2022	FY 2023
FY 2023 increased compared to FY 2022 by $18.009 million. Funding increase due to added emphasis in directed energy bioeffects modeling, simulation and analysis efforts, and efforts such as supporting severity of outcome in system risk assessments.			
Accomplishments/Planned Programs Subtotals	27.128	18.084	45.791

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not applicable