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Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Air Force **Date:** May 2021

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>
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COST (\$ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	0.000	128.434	133.877	136.273	0.000	136.273	-	-	-	-	-	-
621123: <i>Learning and Operational Readiness</i>	0.000	19.315	22.361	18.591	0.000	18.591	-	-	-	-	-	-
625328: <i>Human Dynamics Evaluation</i>	0.000	51.449	46.841	63.815	0.000	63.815	-	-	-	-	-	-
625329: <i>Sensory Evaluation and Decision Science</i>	0.000	30.545	37.547	35.783	0.000	35.783	-	-	-	-	-	-
627757: <i>Bioeffects</i>	0.000	27.125	27.128	18.084	0.000	18.084	-	-	-	-	-	-

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 Human Dynamics Evaluation 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 and application of advanced chemicals/materiel in air superiority platforms and warfighting 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 PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601SF, 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.

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B. Program Change Summary (\$ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	134.795	115.222	119.441	0.000	119.441
Current President's Budget	128.434	133.877	136.273	0.000	136.273
Total Adjustments	-6.361	18.655	16.832	0.000	16.832
• Congressional General Reductions	0.000	-0.245			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	18.900			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.373	0.000			
• SBIR/STTR Transfer	-2.121	0.000			
• Other Adjustments	-4.613	0.000	16.832	0.000	16.832

Congressional Add Details (\$ in Millions, and Includes General Reductions)

	FY 2020	FY 2021
Project: 625328: <i>Human Dynamics Evaluation</i>		
Congressional Add: <i>Warfighter Physiology Program</i>	0.000	5.000
Congressional Add: <i>Human Motion Assessment</i>	0.000	4.000
Congressional Add: <i>Pilot Hypoxia Detection and Notification</i>	0.000	9.900
Congressional Add Subtotals for Project: 625328	0.000	18.900
Project: 625329: <i>Sensory Evaluation and Decision Science</i>		
Congressional Add: <i>Program increase - Advanced technology development</i>	2.923	0.000
Congressional Add Subtotals for Project: 625329	2.923	0.000
Congressional Add Totals for all Projects	2.923	18.900

Change Summary Explanation

FY 2022 increased by \$16.832 million due to increased emphasis on human effectiveness.

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Exhibit R-2A, RDT&E Project Justification: PB 2022 Air Force										Date: May 2021		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>				Project (Number/Name) 621123 / <i>Learning and Operational Readiness</i>			
COST (\$ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
621123: <i>Learning and Operational Readiness</i>	0.000	19.315	22.361	18.591	0.000	18.591	-	-	-	-	-	-

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 2020	FY 2021	FY 2022
Title: Personalized Learning	11.589	13.416	11.155
<p>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.</p> <p>In FY 2021, this effort is renamed from Continuous Learning to Personalized Learning.</p> <p>FY 2021 Plans: Continue to mature emerging technologies for the Readiness Product Line by advancing proficiency-based training through persistent, high resolution human and system measurement and secure multi-classification-level training integration. Balance the applied research portfolio with exploratory research in novel methods for adaptive, multi-objective instruction and interactive task learning, as well as the development of quantitative measures to estimate uncertainty in proficiency measurement and prediction.</p> <p>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.</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement:</p>			

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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 621123 / <i>Learning and Operational Readiness</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2020	FY 2021	FY 2022
FY 2022 decreased compared to FY 2021 by \$2.262 million. Funding decrease due to reduced emphasis in personalized learning, and multi-objective instruction and interactive task learning.				
<p>Title: Cognitive Modeling</p> <p>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.</p> <p>FY 2021 Plans: Continue research and development toward the maturation of emerging technologies addressing training and airman cognitive state sensing and assessment needs. Initiating maturation of models of physiology with computational cognitive models to predict cognitive performance under low-oxygen and chemical exposure conditions. Continue maturation of framework for rapidly developing high-fidelity representations of human cognitive behavior and performance. Continue research and development of high-cognitive-fidelity models capable of broader social interactions within Air Force relevant environments.</p> <p>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.</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: FY 2022 decreased compared to FY 2021 by \$1.508 million. Funding decrease due to reduced emphasis in high-cognitive-fidelity models for predictive cognitive performance.</p>		7.726	8.945	7.436
Accomplishments/Planned Programs Subtotals		19.315	22.361	18.591
C. Other Program Funding Summary (\$ in Millions)				
N/A				
Remarks				
None				
D. Acquisition Strategy				
N/A				

UNCLASSIFIED

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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 625328 / <i>Human Dynamics Evaluation</i>
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COST (\$ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
625328: <i>Human Dynamics Evaluation</i>	0.000	51.449	46.841	63.815	0.000	63.815	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

This project develops technologies to sense, assess, and augment Airman physical and cognitive performance by conducting biological/bioengineering research focused in the areas of 1) cognitive science, 2) systems biology and performance, and 3) molecular sensing and physiology. Cognitive sciences develops and validates assessments of current and predicted cognitive states combined with personalized cognitive performance enhancement techniques and incorporation of technologies to augment these states. Systems biology for performance integrates the full spectrum of biosciences to discover the underlying mechanisms of airman performance. Molecular sensing and physiology will utilize real-time non-invasive physiological and environmental monitoring to assess the biological state of the airman for the purposes of maintaining and enhancing airman performance. Project also conducts research to predict physiological impacts of extreme, dynamic aerospace environments on aircrew safety, and performance.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2020	FY 2021	FY 2022
<p>Title: Future AF Capabilities Applied Research</p> <p>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).</p> <p>The National Defense Strategy and Air Force Science and Technology (S&T) Strategy will inform investments over the FYDP.</p> <p>FY 2021 Plans: Starting in FY 2021, this work is performed in PE 0602020F, Future AF Capabilities Applied Research, Project 620200, Enterprise Transformational Applied Research, Transformational Capability Incubator effort.</p> <p>FY 2022 Plans: Not applicable</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: Not applicable</p>	18.933	0.000	0.000
<p>Title: Human Analyst Augmentation</p>	10.289	0.000	0.000

UNCLASSIFIED

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B. Accomplishments/Planned Programs (\$ in Millions)		FY 2020	FY 2021	FY 2022
<p>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.</p> <p>FY 2021 Plans: In FY 2021, Human Analyst Augmentation work will be performed under the System Analytics effort and the Collaborative Interfaces and Teaming effort in Project 625329, Sensory Evaluation and Decision Science.</p> <p>FY 2022 Plans: Not applicable</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: Not applicable</p>				
<p>Title: Human Trust and Interaction</p> <p>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 knows an autonomous or semiautonomous system is safe to use and whether the system, data, conclusions, and decision recommendations can be trusted.</p> <p>FY 2021 Plans: In FY 2021, Human Trust and Interaction work will be transferred to the System Analytics effort in Project 625329, Sensory Evaluation and Decision Science.</p> <p>FY 2022 Plans: Not applicable</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: Not applicable</p>		8.826	0.000	0.000
<p>Title: Molecular Sensing and Physiology</p> <p>Description: Provides advanced science and technology solutions for the characterization and exploitation of novel molecular biosignatures attributed to physiological stress and utilizing these biosignatures to sense and assess the physiological state of airmen within their associated operational environments. Goal of this research is to sustain and/or augment airmen performance and alert the airmen and their commanders when they are trending toward sub-optimal performance so that intervention strategies</p>		6.136	6.985	15.953

UNCLASSIFIED

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B. Accomplishments/Planned Programs (\$ in Millions)		FY 2020	FY 2021	FY 2022
<p>can be implemented to restore mission effectiveness. Research performance of On-board Oxygen Generation System (OBOGS) and implications on human physiology for current and next-generation aircraft.</p> <p>FY 2021 Plans: Research biological recognition elements (BRE) for biosignature detection. Investigate new biosignatures in non-invasive biofluids. Develop reliable, wearable sensors for near real-time detection in non-invasive physiological fluids and sensors for hydration monitoring in Air Force environments. Evaluate and down select sensors for an aircrew fatigue management system.</p> <p>FY 2022 Plans: Mature BRE (Biological Recognition Elements) development pipeline and optimize for BRE transition to sensor platforms. Develop and test different sensor options (electrochemical, field effect transistors, etc.) for biomarker and VOCs (Volatile Organic Compounds) 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 OBOGS oxygen and flow performance decrements during highly dynamic operating conditions. Conduct OBOGS chemical containment research to assess quality of OBOGS breathing gas under realistic operating conditions. Develop OBOGS 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.</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: FY 2022 increased compared to FY 2021 by \$8.968 million. Funding increase due to an added emphasis in molecular sensing and the design, test and evaluate solutions for air quality assessment.</p>				
<p>Title: Systems Biology for Performance</p> <p>Description: Investigates the underlying molecular-biological mechanisms contributing to airman physiological and cognitive performance optimization. Provide airman protection from performance degradation and/or enhance performance capability under demanding training and mission activities through molecular bioscience research.</p> <p>FY 2021 Plans: Apply biotechnology to investigate methods for engineering the microbiome for enhancing airman performance. Explore synthetic biology techniques to enable performance modification and resiliency. Develop mathematical models to predict system biology performance. Develop advanced organ and tissue human models for mechanistic assessments.</p> <p>FY 2022 Plans:</p>		7.265	6.985	15.954

UNCLASSIFIED

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B. Accomplishments/Planned Programs (\$ in Millions)		FY 2020	FY 2021	FY 2022
<p>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.</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: FY 2022 increased compared to FY 2021 by \$8.968 million. Funding increase due to an added emphasis in systems biology performance efforts, and the development of advanced physical and in silico models and simulations to predict individualized performance.</p>				
<p>Title: Cognitive Neuroscience</p> <p>Description: Conduct research to develop and validate assessments of current and predicted cognitive states, enabling the development of personalized cognitive performance enhancements (e.g., neuromodulation, nutrition, physiological training, recovery approaches), supported by a foundational understanding of neurological mechanisms.</p> <p>FY 2021 Plans: Refine neuromodulation animal models for use in predicting human cognitive performance to include molecular predictors. Integrate inclusion of stress models on cognitive performance. Validate transcranial Direct Current Stimulation (tDCS) in operational environments and contexts. Expand Signature Tracking for Optimized Nutrition and Training (STRONG) Laboratory research to outside units for assessing program effectiveness. Complete a flexible domain package of cognitive workload assessment. Continue to develop algorithms for faster, predictable decision making capabilities. Initiate exploration of brain-machine interface research to enhance human state assessment, decision making, and trust. Explore use of bioinformatics to predict changes in cognitive neuroscience. Deliver enhanced lumbar spinal injury criteria and advance spinal injury prediction. Continue development of Multi-Axis Neck Injury Criteria (MANIC) model neck injury criteria transfer functions. Continue development of 5th and 95th percentile computational human ejection models to include expanded aircrew populations. Conduct current trainer aircraft on-board oxygen generation system (OBOGS) test & evaluations. Begin other fighter and new trainer aircraft OBOGS test & evaluation. Finalize and integrate innovative single/dual-breathing machine simulator development.</p> <p>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 technology to accelerate training for Air Force personnel such as pilots.</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement:</p>		0.000	6.985	15.954

UNCLASSIFIED

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B. Accomplishments/Planned Programs (\$ in Millions)		FY 2020	FY 2021	FY 2022
<p>FY 2022 increased compared to FY 2021 by \$8.968 million. Funding increase due to and added emphasis in cognitive neuroscience and performance efforts, and novel Brain Machine Interface technology to accelerate training for Air Force personnel.</p> <p>Title: Aircrew Biodynamics and Protection</p> <p>Description: Conduct research to predict physiological impacts of extreme, dynamic aerospace environments (e.g., aircrew ejection, high altitude, high-G flight) on aircrew safety and performance. Research and develop novel innovative protective and safety devices related to aircraft ejection systems and flight safety equipment. Assess existing Air Force and Department of Defense safety standards and criteria for neck/spinal injury.</p> <p>FY 2021 Plans: Deliver enhanced lumbar spinal injury criteria and advance spinal injury prediction. Continue development of Multi-Axis Neck Injury Criteria model neck injury criteria transfer functions. Continue development of 5th and 95th percentile computational human ejection models to include expanded aircrew populations. Conduct current trainer aircraft OBOGS test & evaluations. Begin other fighter and new trainer aircraft OBOGS test & evaluation. Finalize and integrate innovative single/dual-breathing machine simulator development.</p> <p>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.</p> <p>In FY 2022, the OBOGS research will be performed under Project 625328/Human Dynamics Evaluation sub-project.</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: FY 2022 increased compared to FY 2021 by \$8.968 million. Funding increase due to an added emphasis in aircrew biodynamics and aircrew protection efforts, and efforts such as computational modeling to predict and assess acute and chronic injury to full aircrew.</p>		0.000	6.986	15.954
Accomplishments/Planned Programs Subtotals		51.449	27.941	63.815
		FY 2020	FY 2021	
Congressional Add: Warfighter Physiology Program		0.000	5.000	

UNCLASSIFIED

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	FY 2020	FY 2021
FY 2020 Accomplishments: Not Applicable		
FY 2021 Plans: Conduct Congressionally directed efforts		
Congressional Add: Human Motion Assessment	0.000	4.000
FY 2020 Accomplishments: Not applicable		
FY 2021 Plans: Conduct Congressionally directed efforts		
Congressional Add: Pilot Hypoxia Detection and Notification	0.000	9.900
FY 2020 Accomplishments: Not applicable		
FY 2021 Plans: Conduct Congressionally directed efforts		
Congressional Adds Subtotals	0.000	18.900

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not applicable

UNCLASSIFIED

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COST (\$ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
625329: Sensory Evaluation and Decision Science	0.000	30.545	37.547	35.783	0.000	35.783	-	-	-	-	-	-

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 2020	FY 2021	FY 2022
<p>Title: Applied Neuroscience</p> <p>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.</p> <p>FY 2021 Plans: In FY 2021, Applied Neuroscience work will performed under the Cognitive Neuroscience effort and the Aircrew Biodynamics and Protection effort in Project 625328, Human Dynamics Evaluation.</p> <p>FY 2022 Plans: Not applicable</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: Not applicable</p>	13.195	0.000	0.000
<p>Title: Collaborative Interfaces and Teaming</p> <p>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.</p> <p>FY 2021 Plans: Execute the following: research on swift trust development and effective teaming methods between human operators in an MDC2 context; research on trust in software code; experiments to test visualizations and displays using HMT simulations, research and experimentation focused on HMT and collaborative interface design among mixed human-human and human-machine teams;</p>	5.616	10.138	9.661

UNCLASSIFIED

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B. Accomplishments/Planned Programs (\$ in Millions)		FY 2020	FY 2021	FY 2022
<p>research on intelligent agent development and testing; conduct research focused on development of software architectures and platforms to enable HMT for pilot-vehicle interfaces, Unmanned Aerial System (UAS) teaming, and Air Battle Management.</p> <p>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 teaming, base defense, and air battle management.</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: FY 2022 decreased compared to FY 2021 by \$0.476 million. Funding decrease due to reduced emphasis described in plans above.</p>				
<p>Title: Battlespace Visualization</p> <p>Description: Research the visualization, interaction and understanding of complex information to enhance warfighter decision making.</p> <p>FY 2021 Plans: In FY 2021, Battlespace Visualization work will be performed under the Multisensory Perceptions and Communication effort within this Project.</p> <p>FY 2022 Plans: Not applicable</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: Not applicable</p>		5.824	0.000	0.000
<p>Title: Battlespace Acoustics</p> <p>Description: Conducts research on advanced auditory and communication technologies that mitigate effects of noise and enhance performance in operational environments.</p> <p>FY 2021 Plans:</p>		2.987	0.000	0.000

UNCLASSIFIED

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B. Accomplishments/Planned Programs (\$ in Millions)		FY 2020	FY 2021	FY 2022
<p>In FY 2021, Battlespace Acoustics work will be performed under the the Multisensory Perceptions and Communication effort within this Project.</p> <p>FY 2022 Plans: Not applicable</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: Not applicable</p>				
<p>Title: Multisensory Perceptions and Communication</p> <p>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.</p> <p>FY 2021 Plans: Initiate research examining impact of communication interruption on task performance and develop a prototype real-time system; Plan study examining relative contribution of vocabulary and language rhythms and sounds on human interruption strategies; Initiate new behavioral/neurophysiological studies of multisensory perception and multimodal display research; Initiate program on multimodal contribution to automatic speech recognition and machine translation; Initiate lab experiments on perceptual jamming; Continue experiments on speech perception in complex environments; Plan new research in spatial attention monitoring; Measure and model acoustic signatures for aircraft and operational environments.</p> <p>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</p>		0.000	14.268	13.597

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Exhibit R-2A, RDT&E Project Justification: PB 2022 Air Force		Date: May 2021		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 625329 / <i>Sensory Evaluation and Decision Science</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2020	FY 2021	FY 2022
acoustic environments for use in training and interface research and development; address requests for direct support from operational community. FY 2021 to FY 2022 Increase/Decrease Statement: FY 2022 decreased compared to FY 2021 by \$0.670 million. Funding decrease due to reduced emphasis described in plans above.				
Title: System Analytics 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 2021 Plans: Leverage ongoing research investments to: develop analytics that bring structure, meaning, and context to mission data in order to build representations to support warfighter mission systems; assess the benefits and costs of integrated data analytics by quantifying how analytics alter thinking and reasoning in order to promote effective decision making. Key research lines include assessment of analytics for full motion video, data visualization for dynamic wide area monitoring, and development of analytics to improve analytic insight and reasoning during exploitation of multiple data sources. 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 ISR, and human language technology. Efforts will include increased investment in evaluation of conversational artificial intelligence, exploitation of publically available information, and explain-ability and ISR applications of topological data analytics. FY 2021 to FY 2022 Increase/Decrease Statement: FY 2022 decreased compared to FY 2021 by \$0.617 million. Funding decrease due to an added emphasis described in plans above.		0.000	13.141	12.525
Accomplishments/Planned Programs Subtotals		27.622	37.547	35.783
		FY 2020	FY 2021	
Congressional Add: Program increase - Advanced technology development		2.923	0.000	

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	FY 2020	FY 2021
FY 2020 Accomplishments: Conduct Congressionally directed efforts		
FY 2021 Plans: Not applicable		
Congressional Adds Subtotals	2.923	0.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not applicable

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

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / Human Effectiveness Applied Research	Project (Number/Name) 627757 / Bioeffects
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COST (\$ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
627757: Bioeffects	0.000	27.125	27.128	18.084	0.000	18.084	-	-	-	-	-	-

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 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 RF exposure allow for the exploitation of directed energy systems for offensive capabilities while protecting the warfighter from adversarial use of RF technologies. The novel directed energy bioeffects mechanisms research examines the physical, physiological, and neural interactions of EM 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 2020	FY 2021	FY 2022
<p>Title: Optical Radiation Bioeffects</p> <p>Description: Conduct laboratory experiments and field research on laser bioeffects, enabling military exploitation of laser technology while providing countermeasures for optical hazards/threats.</p> <p>FY 2021 Plans: Not applicable</p> <p>FY 2022 Plans: Not applicable</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: Not applicable</p>	15.317	0.000	0.000
<p>Title: Radio Frequency Bioeffects</p> <p>Description: Conduct laboratory experiments and field research to enable safe exploitation of directed energy technologies for communication, target identification, and weapons development.</p> <p>FY 2021 Plans:</p>	11.808	0.000	0.000

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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 627757 / <i>Bioeffects</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2020	FY 2021	FY 2022
Not applicable				
FY 2022 Plans: Not applicable				
FY 2021 to FY 2022 Increase/Decrease Statement: Not applicable				
Title: Novel Directed Energy Bioeffects and Mechanisms		0.000	9.495	6.329
Description: Conduct laboratory experiments to provide fundamental knowledge of mechanisms of interaction of directed energy (DE) with molecules, cells, tissues, organs, and whole organisms in support of military DE 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 2021 Plans: Complete bioeffects studies of potential future use laser wavelengths for use in high-energy lasers and the assessment of relative hazards. Develop metrics for the influence of optical distortion in evaluating developing eye protection technology. Conduct studies to understand use of laser eye protection on Airman performance. 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 radio frequency (RF) thermal elastic expansion. Determine acute and chronic bioeffects from emerging sources. Expand in vivo molecular signature of RF exposure to assess acute and chronic bioeffects of RF to inform exposure scenarios.				
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 DE 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 RF and optical radiation. Participate in activities that further development of directed energy bioeffects policy and standards to maximize safe use of the technology.				
FY 2021 to FY 2022 Increase/Decrease Statement:				

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B. Accomplishments/Planned Programs (\$ in Millions)		FY 2020	FY 2021	FY 2022
FY 2022 decreased compared to FY 2021 by \$3.165 million. Funding decrease due to reduced emphasis in novel and experimental directed energy efforts to better understand dynamic tissue characteristics.				
<p>Title: Directed Energy Bioeffects Modeling, Simulation and Analysis</p> <p>Description: Conduct physics-level modeling and simulations to represent and optimize directed energy bioeffects to include direct, scalable, and collateral effects.</p> <p>FY 2021 Plans: Initiate validation and verification experiments for 3-dimensional tissue models of laser exposures. Transition model for probabilistic evaluation of risks from laser exposures on Air Force and Department of Defense laser ranges. Advance dose-response models to include severe retinal and skin optical radiation and radio frequency exposures. Mature models for combining separate images of same retinal or skin area into one image with higher fidelity of injury.</p> <p>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.</p> <p>FY 2021 to FY 2022 Increase/Decrease Statement: FY 2022 decreased compared to FY 2021 by \$5.879 million. Funding decrease due to reduced emphasis in directed energy bioeffects modeling, simulation and analysis efforts, and efforts such as supporting severity of outcome in system risk assessments.</p>		0.000	17.633	11.755
Accomplishments/Planned Programs Subtotals		27.125	27.128	18.084
C. Other Program Funding Summary (\$ in Millions)				
N/A				
Remarks				
D. Acquisition Strategy				
Not applicable				