Exhibit R-2, RDT&E Budget Item Justification: PB 2021 Air Force											Date: February 2020	
Appropriation/Budget Activity 3600: *Research, Development, Test & Evaluation, Air Force* / BA 2: *Applied Research*					R-1 Program Element (Number/Name) PE 0602890F / *High Energy Laser Research*							
COST ($ in Millions)	**Prior Years**	**FY 2019**	**FY 2020**	**FY 2021 Base**	**FY 2021 OCO**	**FY 2021 Total**	**FY 2022**	**FY 2023**	**FY 2024**	**FY 2025**	**Cost To Complete**	**Total Cost**
Total Program Element	-	40.400	48.221	45.088	0.000	45.088	46.019	46.933	47.872	48.845	Continuing	Continuing
625096: *High Energy Laser Research*	-	40.400	48.221	45.088	0.000	45.088	46.019	46.933	47.872	48.845	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program funds Department of Defense Directed Energy applied research through the Joint Directed Energy Transition Office. This program is part of an overall Department of Defense Directed Energy Science and Technology program. Directed Energy weapon systems have many potential advantages including speed of-light delivery, low collateral damage, significant magazine depth, low incremental cost per kill. Directed Energy Weapon Systems have the potential to perform a wide variety of military missions including high value asset and base protection, precision strike and platform self-protection versus a wide variety of missile, rocket, artillery, mortar and air platforms. Efforts under this program are generally chosen for their potential to have an impact on multiple Directed Energy Weapon systems and multiple Service missions while complementing Service/Agency efforts that are directed at specific Service needs. A broad range of technologies are addressed in key areas such as laser sources, microwave sources, laser beam control, antennas, waveguides, modeling and simulation, and lethality mechanisms. This program provides the enabling technology necessary to demonstrate advanced concepts for high power microwave sources, antennas and waveguides for mission areas not considered to date. The high power microwave lethality, hardware and software improvements and modeling and simulation advances provided by this program are essential to expand and build upon current architectures. This program supports the Senior Official as required. Efforts in this program have been coordinated through the Department of Defense Science and Technology 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, 0602202F, 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 2019	FY 2020	FY 2021 Base	FY 2021 OCO	FY 2021 Total
Previous President's Budget	43.192	44.221	45.103	0.000	45.103
Current President's Budget	40.400	48.221	45.088	0.000	45.088
Total Adjustments	-2.792	4.000	-0.015	0.000	-0.015
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	4.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-1.492	0.000			
• Other Adjustments	-1.300	0.000	-0.015	0.000	-0.015

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2019	FY 2020
Project: 625096: *High Energy Laser Research*		
Congressional Add: *Program increase - Directed energy fiber lasers*	0.000	4.000
Congressional Add Subtotals for Project: 625096	0.000	4.000
Congressional Add Totals for all Projects	0.000	4.000

Change Summary Explanation

Decrease in FY 2019 in Other Adjustments of $1.300 million is due to realignment of funds to PE 0602212F 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).

C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Title: Directed Energy Technologies	7.168	7.750	7.900
Description: Mature technologies that will provide system level performance commensurate with fieldable directed energy devices. ***FY 2020 Plans:*** Continue to develop high reliability, lower cost, efficient and high temperature diode pump sources. Scale alternate laser wavelengths to additional militarily relevant uses and power levels. Investigate novel high power fiber technologies. Reduce technical risk in solid state lasers for inclusion in future laser weapon systems. Perform trade space analysis to understand performance, fielding, robustness and integration issues for military platforms. Investigate, analyze trade space, and reduce			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
technical risk for high power microwave devices. Evaluate radiofrequency and microwave capabilities and effects against various threats of interest. Perform analysis and trade studies to determine the most effective microwave parameters and system components needed to defeat classes of selected military targets. ***FY 2021 Plans:*** Continue to develop high reliability, lower cost, efficient and high temperature diode pump sources. Continue to scale alternate laser wavelengths to additional militarily relevant uses and power levels. Continue investigations into next generation high power fiber technologies. Continue to reduce technical risk in solid state lasers for inclusion in future laser weapon systems. Continue trade space analysis to understand performance, fielding, robustness and integration issues for military platforms. Continue to investigate, analyze trade space, and reduce technical risk for high power microwave devices. Continue to study radiofrequency and microwave capabilities and effects against various threats. Continue analysis and trades studies to determine the most effective radiofrequency and microwave parameters and system components needed to defeat classes of selected targets. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** FY 2021 increased compared to FY 2020 by $0.150 million. Justification for the increase is described in the plans above.			
Title: Advanced Directed Energy Technologies ***Description:*** Investigate new technologies that have revolutionary potential for high energy lasers and high power microwaves. ***FY 2020 Plans:*** Explore advanced concepts for high energy laser technologies that will improve efficiency and decrease mass and volume for future weapon systems. Evaluate advanced materials for high energy laser applications. Improve the understanding of laser technologies to include material interaction and propagation. Scale electrically pumped lasers to higher kilowatt class power levels. Characterize and understand the physics of high energy laser atmospheric propagation in adverse environmental conditions such as fog, rain, smoke and dust. Evaluate and test Avoidance and Air Space De-confliction systems on directed energy test ranges. Collaborate with the international directed energy community on progress in the development and application of high energy laser technologies for military missions. Validate predictive models through analysis of atmospheric propagation data and measurements. Study the desired radiofrequency and microwave effects that drive the radiofrequency and microwave component and system design, including power. Improve understanding of required power system components including power generation and storage, high temperature / high power devices, power converters, and power conditioning. Ensure that radiofrequency and microwave effects and power components work is coordinated with and, as appropriate, leveraged by RF microwave and power / energy programs across the Services and Agencies. Characterize and understand the physics of high power microwave propagation in adverse environmental conditions. Collaborate with the international directed energy community	5.826	6.300	6.428

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
on progress in the development and application of high power radiofrequency directed energy weapon (DEW) technologies for military missions. ***FY 2021 Plans:*** Continue to explore advanced concepts for directed energy technologies that will improve efficiency and decrease mass and volume for future weapon systems. Continue to evaluate materials for high energy laser applications. Continue to improve understanding of laser technologies to include material interaction and propagation. Continue to scale electrically pumped lasers to higher kilowatt class power levels. Continue to characterize and understand the physics of high energy laser atmospheric propagation in adverse environmental conditions such as fog, rain, smoke and dust. Continue to evaluate and test Avoidance and Air Space De-confliction systems on directed energy test ranges. Continue to collaborate with the international directed energy community on progress in the development and application of high energy laser technologies for military missions. Validate predictive models through analysis of atmospheric propagation data and measurements. Continue to validate predictive models through analysis of atmospheric propagation data and measurements. Continue to study the desired radiofrequency and microwave effects that drive the radiofrequency and microwave component and system design, including power. Improve understanding of required power system components including power generation and storage, high temperature / high power devices, power converters, and power conditioning. The ongoing radiofrequency and microwave effects and power components work is coordinated with and, as appropriate, leveraged by radiofrequency and microwave and power/energy programs across the Services and Agencies. Continue to characterize and understand the physics of high power microwave propagation in adverse environmental conditions. Continue to collaborate with the international directed energy community on progress in the development and application of high power radiofrequency directed energy weapon (DEW) technologies for military missions. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** FY 2021 increased compared to FY 2020 by $0.128 million. Justification for the increase is described in the plans above.			
Title: Directed Energy Propagation Technologies ***Description:*** Develop technology to support high performance beam control systems and integrated demonstrations. ***FY 2020 Plans:*** Develop beam control technologies for high energy laser weapon use on multiple platforms (aircraft, ground vehicles and shipboard systems) in stressing environments. Advance the development of a predictive avoidance fire control system for use on multiple platforms with the development of associated kill assessment technologies. Develop hardware and technologies to improve throughput efficiency of the beam director, decrease component weight, and improve tracking and compensation through the atmosphere. Select and develop additional concepts for Service-specific applications. Develop theoretical physical models describing the propagation of a high power microwave pulse through the atmosphere to understand the reflection characteristics of the high power microwave propagation. Study and understand the dynamic behavior of the propagation of	19.790	21.936	22.370

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
high power microwave pulses and the effects on the intensity, frequency, and width of the pulse and the physical processes occurring during the interaction of the pulse with the air. Select and develop additional concepts for Service-specific applications and associated kill assessment technologies. Develop hardware and technologies to improve throughput efficiency of the antenna, decrease component weight, and improve tracking and compensation through the atmosphere. ***FY 2021 Plans:*** Continue to develop beam control technologies for high energy laser weapon use on multiple platforms (aircraft, ground vehicles and shipboard systems) in stressing environments. Continue the development of a predictive avoidance fire control system for use on multiple platforms. Continue to develop kill assessment technologies. Continue to develop hardware and technologies to improve throughput efficiency of the beam director, decrease component weight, and improve tracking and compensation through the atmosphere. Continue to select and develop additional concepts for Service-specific applications. Continue to develop theoretical physical models describing the propagation of a high power microwave pulse through the atmosphere to understand the reflection characteristics of the high power microwave propagation. Continue to study and understand the dynamic behavior of the propagation of high power microwave pulses and the effects on the intensity, frequency, and width of the pulse and the physical processes occurring during the interaction of the pulse with the air. Continue to select and develop additional concepts for Service-specific applications. Continue to develop kill assessment technologies. Continue to develop hardware and technologies to improve throughput efficiency of the antenna, decrease component weight, and improve tracking and compensation through the atmosphere. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** FY 2021 increased compared to FY 2020 by $0.434 million. Justification for the increase is described in the plans above.			
Title: Directed Energy Lethality Research ***Description:*** Conduct directed energy vulnerability experiments on materials, components, and targets. Develop a lethality database, and integrate into a systems-level architecture plan and lethality models. ***FY 2020 Plans:*** Integrate target lethality data into campaign-level high energy laser system models. Conduct high energy laser vulnerability experiments on materials, components, and targets. Develop a suite of high energy laser weapon tools to be used in a database from which the warfighter can assess target vulnerabilities and mission utility for given high energy laser weapon platform and engagement. Develop warfighter tools employing Service and Agencies metrics and criteria such as the Joint Munitions Effectiveness Standards. Develop new predictive modeling software tools to assess the effectiveness of high power microwave weapons on electronic systems of interest for blue-on-red or red-on-blue engagements. Understand and evaluate statistical and deterministic cavity coupling algorithms to estimate the temporal and spectral characteristics of the high power microwave energy coupled into complicated enclosures. Leverage advancements in predictive circuit effects, garnered through several Service and	3.856	4.170	4.250

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
Agency-funded programs, to model and predict the response of complicated electronics to the incident high power microwave stimulus. Develop warfighter tools employing Service and Agencies metrics and criteria such as the Joint Munitions Effectiveness Standards. ***FY 2021 Plans:*** Continue to integrate lethality data into campaign-level high energy laser system models. Continue to conduct high energy laser vulnerability experiments on materials, components, and targets. Continue to develop a suite of high energy laser weapon tools to be used in a database from which the warfighter can assess target vulnerabilities and mission utility for given high energy laser weapon platform and engagement. Continue to develop warfighter tools employing Service and Agencies metrics and criteria such as the Joint Munitions Effectiveness Standards. Continue to develop new predictive modeling software tools to assess the effectiveness of high power microwave weapons on electronic systems of interest for blue-on-red or red-on-blue engagements. Continue to understand and evaluate statistical and deterministic cavity coupling algorithms to estimate the temporal and spectral characteristics of the high power microwave energy coupled into complicated enclosures. Continue to leverage advancements in predictive circuit effects, garnered through several Service and Agency-funded programs, to model and predict the response of complicated electronics to the incident high power microwave stimulus. Continue to develop warfighter tools employing Service and Agencies metrics and criteria such as the Joint Munitions Effectiveness Standards. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** FY 2021 increased compared to FY 2020 by $0.080 million. Justification for the increase is described in the plans above.			
Title: Directed Energy Modeling	3.760	4.065	4.140
Description: Maintain and evaluate high-fidelity engineering models for high energy laser and high power microwave system scenario evaluation and incorporation into the directed energy toolkit. Provide atmospheric propagation and directed energy system modeling for mission-level war-gaming activities. ***FY 2020 Plans:*** Provide maintenance, verification, validation, and accreditation for updated system level atmospheric propagation and high energy laser system models. Collaborate with Service-sponsored field-test planning to correlate model predictions with measured data for surface, maritime and aerospace environments. Incorporate atmospheric data into theater models to support performance characterization tables. Conduct verification and validation planning to support advanced beam control objectives, diagnostics and warfighter tools. Collaborate with Service and Agency sponsored High Power microwave survivability/ lethality community's interest in, and use of, high power microwave engagement models. Provide maintenance, verification, validation, and accreditation for updated system level standalone models that can be used to estimate the probability of electronic upset or damage as a function of the high power microwave power density on the target and associated range. Provide the warfighter tools to determine the power density required on a target to produce a functional kill and understand the required parameters of			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2019	FY 2020	FY 2021
the high power microwave, such as power, frequency/wavelength, modulation, and engagement angle for the kill. Incorporate atmospheric data into theater models to support performance characterization tables. Conduct verification and validation planning to support advanced beam propagation objectives, diagnostics and warfighter tools. ***FY 2021 Plans:*** Continue to provide maintenance, verification, validation, and accreditation for updated system level atmospheric propagation and high energy laser system models. Continue to collaborate with Service-sponsored field-test planning to correlate model predictions with measured data for surface, maritime and aerospace environments. Continue to incorporate atmospheric data into theater models to support performance characterization tables. Continue to conduct verification and validation planning to support advanced beam control objectives, diagnostics and warfighter tools. Continue to collaborate with Service and Agency sponsored High Power microwave survivability / lethality community's interest in, and use of, high power microwave engagement models. Continue to provide maintenance, verification, validation, and accreditation for updated system level standalone model that can be used to estimate the probability of electronic upset or damage as a function of the high power microwave power density on the target and associated range. Continue to provide the warfighter tools to determine the power density required on a target to produce a functional kill and understand the required parameters of the high power microwave, such as power, frequency/ wavelength, modulation, and engagement angle for the kill. Continue to incorporate atmospheric data into theater models to support performance characterization tables. Continue to conduct verification and validation planning to support advanced beam propagation objectives, diagnostics and warfighter tools. ***FY 2020 to FY 2021 Increase/Decrease Statement:*** FY 2021 increased compared to FY 2020 by $0.075 million. Justification for the increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	40.400	44.221	45.088

	FY 2019	FY 2020
Congressional Add: Program increase - Directed energy fiber lasers	0.000	4.000
FY 2019 Accomplishments: Not applicable.		
FY 2020 Plans: Conduct Congressional directed efforts.		
Congressional Adds Subtotals	0.000	4.000

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

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E. Acquisition Strategy

N/A