Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Office of the Secretary Of Defense	Date: May 2017
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603662D8Z / *Networked Communications Capability*

COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	0.000	5.452	9.331	12.661	-	12.661	7.779	2.882	2.941	3.002	Continuing	Continuing
P663: *Network Communications Analysis*	-	5.452	9.331	12.661	-	12.661	7.779	2.882	2.941	3.002	Continuing	Continuing

A. Mission Description and Budget Item Justification

Currently fielded satellite communications (SATCOM), terrestrial, and Tactical Data Links (TDLs) will be adversely affected during operations in contested Anti-Access/ Area-Denial (A2/AD) environments. The primary threat is from sophisticated electronic warfare capable of advanced jamming and signal collection techniques that are rapidly evolving to be more capable and agile. Department of Defense (DoD) advances in smart sensors and smart weapons have an urgent need for more resilient networks than tactical data links of today. In FY 2016, the Network Communications Capability Program (NCCP) returned with a new focus on developing enabling technologies for Joint assured communications networks. The goals of this program are: to mitigate degradation across battlespace tiers (strategic, operational, and tactical) and domains (nuclear, intelligence surveillance and reconnaissance [ISR], command and control [C2], etc.) and to provide agility that will support the mission needs of Joint Functional Component Commanders (JFCCs), Joint Force Commanders (JFCs), and deployed forces.

The DoD's current TDLs platforms and capabilities are not sufficiently protected from emerging adversary threats and contain insufficient capacity for future needs. In order to enable the promise of net-centric operations for the warfighter, the next generation of airborne and ground tactical networks must provide greater affordability, higher network capacity, greater durability against electronic attack, better network connectivity, and faster response times to the changing demands from airborne, maritime, and ground users. Many line-of-sight (LOS), beyond LOS (BLOS), and SATCOM waveforms have been integrated onto platforms for various missions. These waveforms necessarily exhibit tradeoffs in target performance attributes including capacity, latency, protection, and complexity. As a result, no single waveform capability will be able to satisfy all emerging mission needs emphasizing the need for interoperability and software defined waveforms. The challenge is to understand the essential needs of the users, avoid needless redundancy, develop affordable capabilities, and integrate separate capabilities into a cohesive network. This research will develop transformative technologies to ensure performance in contested A2/AD environments by focusing on future communications networks that are a "leap ahead" of today's capabilities.

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B. Program Change Summary ($ in Millions)	**FY 2016**	**FY 2017**	**FY 2018 Base**	**FY 2018 OCO**	**FY 2018 Total**
Previous President's Budget	5.967	9.331	12.718	-	12.718
Current President's Budget	5.452	9.331	12.661	-	12.661
Total Adjustments	-0.515	0.000	-0.057	-	-0.057
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-0.387	-			
• SBIR/STTR Transfer	-0.128	-			
• Other Adjustments	-	-	-0.057	-	-0.057

Exhibit R-2A, RDT&E Project Justification: FY 2018 Office of the Secretary Of Defense											Date: May 2017	
Appropriation/Budget Activity 0400 / 3					R-1 Program Element (Number/Name) PE 0603662D8Z / *Networked Communications Capability*				Project (Number/Name) P663 / *Network Communications Analysis*			
COST ($ in Millions)	**Prior Years**	**FY 2016**	**FY 2017**	**FY 2018 Base**	**FY 2018 OCO**	**FY 2018 Total**	**FY 2019**	**FY 2020**	**FY 2021**	**FY 2022**	**Cost To Complete**	**Total Cost**
P663: *Network Communications Analysis*	-	5.452	9.331	12.661	-	12.661	7.779	2.882	2.941	3.002	Continuing	Continuing

A. Mission Description and Budget Item Justification

In a contested environment, especially when conducting forward operations, platforms face a significant electronic warfare threat. The primary threat is from advanced jamming, signal collection, and geolocation techniques that are rapidly evolving to be more capable and agile. Concurrently, DoD advances in smart sensors and weapons demand robust tactical waveforms and networks with greater capacity but lower cost than communications links of today.

Beginning in FY 2016, the NCCP's Future Autonomous Battlespace RF with Integrated Communications (FABRIC) (formerly referred to as Robust Tactical Data Links Modernization (RTDLM)) project will develop next generation communications layer architecture for tactical networks for operations in anti-access and area denial (A2/AD) threat environments. This architecture will also deliver capacity and affordability to enable future smart sensors and smart weapons. The network architecture will be flexible enough to support Commander's Intent in any mission, environment, operating tactical platform, and weapon system under various threat conditions. FABRIC's efforts will focus on developing the advanced component technologies, such as Anti-Jam(AJ)/Low Probability of Interference (LPI)/Low Probability of Detection (LPD)/ Low Probability of Exploitation (LPE) waveforms, adaptive processing algorithms, adaptive antenna technologies (transmit/receive/nulling), adaptive power control, Dynamic Spectrum Access (DSA)/Dynamic Spectrum Management (DSM) techniques, self-healing mechanisms and cyber hardening, and advanced routing ensuring Quality of Service. The guiding tenets for creating this new Command, Control, Communications, Computers, & Intelligence (C4I) capability encompass enabling new missions, i.e. providing resilient TDLs, communications and networking "service level" capabilities, interoperation, cost (affordable), and improved performance in terms of military value.

Based on the developed thresholds and objectives for the required network architecture, the specific advanced component technologies were prioritized and form the foundation of the FABRIC design. Through simulation and field experimentation, FABRIC will verify the technology in operationally relevant environments against representative threats, and facilitate the migration and transition of these technologies to service platforms, radios, and other combat mission systems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Future Autonomous Battlespace RF with Integrated Communications (FABRIC) (formerly referred to as Robust Tactical Data Links Modernization (RTDLM))	5.452	9.331	12.661
Description: The FABRIC project researches and develops hardware, software, and algorithms to advance network technologies to create a robust tactical network to operate in contested A2/AD environments. This project will investigate and develop flexible, high performance, and affordable technologies for the tactical network, supporting capability changes as a mission progresses from phase to phase. The project will develop and mature technologies to support direct transition of the algorithms, prototype implementations, waveform improvements, and system design improvements to radio, waveform, and weapon systems programs managed by each military department.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
FY 2016 Accomplishments: FY 2016 focused on developing the required network architecture attributes through the exploration of case studies and scenarios. - Completed Pathfinder analysis to set nine critical technical metrics with threshold and objective measures. - Completed “Arsenal Plane” scenario to establish required capabilities and network attributes. - Developed an extensive classified write-up about anti-access, area denial (A2/AD) scenarios, tactics, techniques and procedures, resulting in 4 scenarios that can be used as reference examples for system performance analysis. - Implemented a high-fidelity emulation model of multi-beam directional network and did extensive performance testing to characterize benefits of multi-beam networking in tactically relevant scenarios. - Performed cross-validation of scenario analysis through independent implementation of models in MATLAB at Ka band and X band frequencies. - Validated link budget calculation and atmospheric attenuation model. Cross-validated the performance metrics including connectivity, average hops, number of active beam cumulative distribution function (CDF) distribution, and antenna beam pointing statistics. - Modeled simultaneous beams and nulls on advanced electronically scanned array (AESA) showing independent beams and nulls. - Created simulations for jamming resistant routing and multi-beam antenna medium access control (MAC) protocols. - Developed a MATLAB model to adjust the data rate and link range to find the maximum link range vs data rate and plot data rates per link range curves. - Developed simulation architecture to study multi-beam directional networking approaches. Assessed physics-based and theoretic performance limits of multi-beam directional networking. - Demonstrated flexible and affordable software defined implementation of a common data link (CDL) waveform. - Completed high level specification of Cyber Hardened Embedded and Exascale Trusted Architecture (CHEETAH) to meet computing needs.			
FY 2017 Plans: FY 2017 focus areas include: Modeling and Simulation Frameworks: Provide high performance computing modeling and simulation capability to support hardware, software, and scenario development. - Define means for models developed in VHSIC (Very High Speed Integrated Circuit) Hardware Description Language (VHDL), MATLAB, C, Network Simulator-3 (NS-3) or CREATE to share the modeled performance to other models as required. - Establish NS-3 baseline simulations for sparse and dense scenarios with performance visualization - Augment NS-3 models for platform orientation (roll-pitch-yaw)			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Assess performance and scalability of network simulation capabilities (as a function of the number of nodes, traffic loads, and the platforms executing) - Develop a VHDL simulation environment to model and simulate FABRIC's CHEETAH processor - Develop and assess VHDL and Instruction Set Architecture (ISA) simulator performance. Hardware and Software Development: Perform detailed design and performance assessment of critical expected software and hardware functions. - Select a suitable software development environment of common tools including C, C++, and MATLAB to enable the development, exchange and validation of models of FABRIC processors, waveforms, networking functionality in order to establish interoperability for all relevant activities of the FABRIC development participants. - Analyze selection and optimization of the operating systems including real time extensions. - Study the selection of cyber defense and information assurance and information management functions suitable for the processor. - Port the Orthogonal Frequency Division Multiplexing (OFDM) Waveform baseline and assess its performance on the CHEETAH processor. - Complete detailed behavioral VHDL design of the processor. Functionality Design and Development: Design and prototype beamforming, modem, and network hardware and software functions. - Perform the mechanical and electrical design of the Electronically Steerable Aperture (ESA) - Develop and evaluate a baseline of directional networking protocols to meet the FABRIC design performance metrics. - Establish and assess OFDM waveform modem baseline and/or alternatives - Model and simulate OFDM waveform acquisition, beam quality, and nulls with platform dynamics Scenario Assessment: Assess system and mission performance in a variety of realistic operational scenarios by integrating the performance models from each hardware, software, and functional domain. - Model multiple scenario environments, concept of operations and network traffic flows through the use/experimentation of static and dynamic engagement models - Define design features of various platform nodes regarding the mission execution that are able to be adapted via software control interactions with or through FABRIC as part of mission functionality in response to threat detection and re-plans. - Characterize performance metrics of all levels of communications (physical, media access control, link, network, etc.) ***FY 2018 Plans:*** FY 2018 focus areas include:			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Hardware and Software Development: Complete detailed design of CHEETAH processor and fabricate through 14 nanometer trusted foundry. Prototyping and experimentation: Code and refine FABRIC directional networking functionality to enable measurements of performance in realistic mission environments. - Complete lab-bench prototyping of the directional networking functionality (radio frequency (RF) front-end and the ESA). Transition Planning - Refine demonstration plans. - Continue to modify and mature variations of the A2/AD related scenarios to identify performance and potential transition opportunities.			
Accomplishments/Planned Programs Subtotals	5.452	9.331	12.661

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

The FABRIC project will address capability gaps for Joint TDL networks by developing the technologies that the Military Departments can incorporate in future platform and radio acquisitions. The proposed experimentation, with field demonstrations and modeling, will increase the Technology Readiness Level (TRL) of critical technology components, suitable for transition to acquisition programs. This will also help provide DoD leadership with the supporting technical and cost details to identify candidate "building blocks" for timely incremental improvements.

E. Performance Metrics

The Research, Development, Test, and Evaluation (RDT&E) goal for FABRIC is capability improvements that achieve greater than 70 percent “Buy-Back” of the tactical data link operational range and 80 percent of the area of operation lost in the A2/AD environment.

- Enhanced Link Capacity: 10X-100X Faster
- Enhanced Connectivity: 4X-10X Network Neighbor Connections
- Enhanced Spatial/Time Filtering: 4-7 Adaptive Nulls (Scenario Dependent)
- Receiver Based Mitigation: 20-30dB per Jammer Type (Scenario Dependent)
- Enhanced LPI/LPD: 4X-10X Closer Range to Target with Same Percent LPI/LPD

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- Enhanced Network Scalability: 300-1000 nodes
- Low cost AESA systems: <$25K each

Achieve significant DoD savings for radio modifications or integration into new terminals or platforms (economies of scale) as services share non-recurring development costs for common and successful TDL enhancements.