Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency											Date: February 2015	
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*					R-1 Program Element (Number/Name) PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*							
COST ($ in Millions)	**Prior Years**	**FY 2014**	**FY 2015**	**FY 2016 Base**	**FY 2016 OCO**	**FY 2016 Total**	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**	**Cost To Complete**	**Total Cost**
Total Program Element	-	229.510	239.265	201.335	-	201.335	122.646	147.512	132.324	133.683	-	-
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	141.023	135.561	115.265	-	115.265	110.646	135.512	124.324	133.683	-	-
CCC-04: *SECURE INFORMATION AND NETWORK SYSTEMS*	-	11.740	1.706	-	-	-	-	-	-	-	-	-
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	76.747	101.998	86.070	-	86.070	12.000	12.000	8.000	-	-	-

A. Mission Description and Budget Item Justification

The Command, Control and Communications Systems program element is budgeted in the Advanced Technology Development Budget Activity because its purpose is to demonstrate and evaluate advanced information systems research and development concepts.

The goal of the Information Integration Systems project is to develop and demonstrate technologies that will provide effective communications to U.S. forces. The success of military operations depends on timely, reliable, secure, and synchronized dissemination of command and control and relevant situational awareness information to every military echelon. While wired communications and networks are fairly well developed, providing assured high-bandwidth mobile wireless capabilities that match or exceed commercial wired infrastructure is needed to meet the demands of military users. Approaches to this goal include developing technologies in these areas:

- High-Capacity Links technologies - enables greater back-haul capability.
- Advanced Networking technologies - supports resilience, adaptability, and scalability.
- Low Probability of Detection and Anti-Jam (LPD/AJ) technologies - provides assured communications in a very high-threat environments.
- Novel Radio Frequency and Spectral Sensing (RF/SS) - supports efficient spectrum management in congested environments and detection of electromagnetic threats.

The Secure Information and Network Systems project will develop and demonstrate computer and network technologies and systems suitable for use in military networks, U.S. government enterprise networks, critical infrastructure, and embedded computing systems. The project will develop, integrate, and test technologies for re-using software components.

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603760E *I COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*

B. Program Change Summary ($ in Millions)	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	239.078	243.265	227.402	-	227.402
Current President's Budget	229.510	239.265	201.335	-	201.335
Total Adjustments	-9.568	-4.000	-26.067	-	-26.067
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-4.000			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-2.500	-			
• SBIR/STTR Transfer	-7.068	-			
• TotalOtherAdjustments	-	-	-26.067	-	-26.067

Change Summary Explanation

FY 2014: Decrease reflects reprogrammings and the SBIR/STTR transfer.

FY 2015: Decrease reflects congressional reduction.

FY 2016: Decrease reflects completion of the Computational Leverage Against Surveillance Systems (CLASS), Fixed Wireless at a Distance, and Mobile Hotspots programs.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency			Date: February 2015
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	Project (Number/Name) CCC-02 / *INFORMATION INTEGRATION SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	141.023	135.561	115.265	-	115.265	110.646	135.512	124.324	133.683	-	-

A. Mission Description and Budget Item Justification

The success of military operations depends on timely, reliable, secure, and synchronized dissemination of command and control and relevant situational awareness information to every military echelon. While wired communications and networks are fairly well developed, providing assured high-bandwidth mobile wireless capabilities that match or exceed commercial wired infrastructure is needed to meet the demands of military users. The goal of the Information Integration Systems project is to develop and demonstrate technologies that will provide effective communications to U.S. forces. Approaches to this goal include developing technologies in these areas:

- High-Capacity Links technologies - enables greater back-haul capability.
- Advanced Networking technologies - supports resilience, adaptability, and scalability.
- Low Probability of Detection and Anti-Jam (LPD/AJ) technologies - provides assured communications in a very high-threat environments.
- Novel Radio Frequency and Spectral Sensing (RF/SS) - supports efficient spectrum management in congested environments and detection of electromagnetic threats.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: 100 Gb/s RF Backbone	10.000	13.770	21.750
Description: The proliferation of video, voice, chat, and other important data-streams on the battlefield is driving a need for higher capacity, reliable, assured, and all-weather communications that are deployable on a wide range of air, ground, and maritime platforms. The goal of this High-Capacity Links technologies program is to demonstrate a 100 Gigabit-per-second (Gb/s) radio frequency (RF) backbone that will meet the anticipated mid-term (within 3-10 years) wireless networking requirements of deployed military forces. DARPA's hybrid Free Space Optical RF Communications Adjunct (ORCA) system has broken the 10 Gb/s wireless network boundary using free-space optical links, but all-weather Ku band components are currently limited to much less than 1Gb/s capacity. Furthermore, the hybrid optical/RF system exhibits size, weight, and power (SWaP) consumption characteristics that preclude deployment on many SWaP-limited platforms. Moving to a millimeter-wave (mmW) solution will provide high capacity and all-weather resiliency, but presents technical challenges that include the generation of higher-order waveforms (beyond common data link), efficient power transmission, high-speed routing, and low-noise receivers. This program seeks to develop the constituent subsystems (waveform generation, efficient power amplifiers, and receivers) and spatial multiplexing architectures to construct an all-weather mmW 100 Gb/s backbone at half the SWaP consumption of the current ORCA system. The 100 Gb/s RF Backbone program is intended for transition to multiple Services. ***FY 2014 Accomplishments:*** - Developed millimeter-wave waveforms with higher modulation constellation to achieve high spectral efficiencies. - Began developing approaches to achieving power transmission efficiency improvements at mmW frequencies.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Began developing low noise-figure receiver technologies for mmW frequencies. - Began developing and testing candidate architectures, hardware, and algorithms for spatial multiplexing to achieve high spectral efficiencies. ***FY 2015 Plans:*** - Build and evaluate modulators capable of generating high-order waveforms and demodulators capable of digitizing the high-order waveforms. - Evaluate high-order modulation approaches at mmW frequencies in field demonstrations to tactically relevant distances. - Evaluate the hardware and software capable of spatially multiplexing and de-multiplexing multiple mmW signals. - Evaluate mmW spatial multiplexing approaches to distances at or beyond the Rayleigh Range. ***FY 2016 Plans:*** - Begin design and development of integrated prototype system that includes higher-order modulation and spatial multiplexing. - Continue to reduce the size, weight, and power of the system components to metrics consistent with high altitude, long endurance aerial platforms. - Initiate prototype performance evaluation planning for mountain-to-ground tests at a Government test range. - Conduct initial prototype testing using multiple system configurations to characterize initial system performance.			
Title: Wireless Network Defense ***Description:*** A highly networked and enabled force increases efficiency, effectiveness, and safety by making relevant information available when it is needed and at the appropriate location (person/platform/system). Accomplishing this depends on providing reliable wireless communications to all U.S. forces, platforms, and devices in all phases of conflict. Based on initial work under this effort, the Spectrum Efficiency and Access program in this PE/Project was created to enable reliable operation of military and commercial communications and radar systems when occupying the same spectrum bands. As part of the Advanced Networks technologies effort, the Wireless Network Defense program increases wireless network capacity and reliability for tactical users, with the ultimate vision of making high quality data services pervasive throughout the DoD. The primary focus is mitigation of advanced threats particular to the security of wireless networks. The program intends to leverage the capabilities of the dynamic network to identify sources of misinformation, whether malicious or due to poor configuration, across the functional components of the complex system, and mitigate the corresponding effects. Technologies developed under this program will transition to the Services. ***FY 2014 Accomplishments:*** - Developed techniques to characterize reliability of information in networks with misbehaving devices and evaluate performance through simulation.	12.000	18.880	16.550

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Developed approaches using the control functions of wireless networks using reliability values to create innately resilient control systems. - Determined system-level performance goals for subsequent phase of the program. - Began integration of most promising technology components for reliability estimation and robust network control into laboratory prototypes of robust wireless networks. ***FY 2015 Plans:*** - Complete integration of candidate algorithms and protocols for protecting networks from, and detecting and reacting to, misinformation attacks in laboratory-based prototype systems. - Test resilience of prototype capabilities in a laboratory environment. - Refine protection mechanisms based on test findings and begin development of systems for field demonstrations. - Quantify the performance impact of network misconfiguration in simulations of networks in contested environments. ***FY 2016 Plans:*** - Complete integration of candidate algorithms and protocols to prepare for field experiments. - Test resilience of prototype capabilities against advanced attacks in a field environment. - Refine protection mechanisms based on test findings and begin development of systems for transition. - Integrate with military tactical radios and quantify the performance impact through experiments.			
Title: Spectrum Efficiency and Access	8.400	23.899	18.840
Description: Current Presidential Initiatives, FCC Broadband Task Force, and Congressional legislation are working to transition large swaths of spectrum (up to 500 MHz) from Federal (DoD is the primary contributor) to civilian use for broadband telecommunications. The DoD will need more highly integrated and networked data/sensor capacity over the next decades and will therefore need new technology that requires less spectrum to operate. The objective of the Spectrum Efficiency and Access program is to investigate improvements in spectral reuse, such as spectrum sharing of sensor/radar bands. The program will leverage technical trends in cooperative sharing to exploit radar anti-jam and interference mitigation technologies that could enable spectrum sharing by allowing overlay of communications within the same spectral footprint. The approach will include exploring real-time control data links between radars and communications systems, and developing the advanced waveforms and components to enable radars and communication networks to operate in close proximity. The ultimate goal is to turn the DoD spectrum loss into a net gain of up to hundreds of MHz in capacity. Technology from this program will be made available to the DoD. ***FY 2014 Accomplishments:*** - Developed concepts and management policies for enabling radars and communications networks to share spectrum spatially and temporally.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Developed models and simulation capability for research on spectrum sharing between radar and communications systems. - Assessed the limits on achievable spectral reuse between radar and communications in order to evaluate sharing concepts and implementations. - Assessed threats to military systems created by sharing spectrum information with non-military users. ***FY 2015 Plans:*** - Model and assess multiple mechanisms for spatial and temporal spectrum sharing between radars and communications networks. - Develop and assess a baseline set of strategies to defend military systems against threats created by sharing spectrum information between military radars and commercial communications systems. - Develop concepts for a control system to manage mechanisms for spectrum sharing between radars and communication systems. - Demonstrate technologies for signal separation between radar and communications systems operating at the same time, place, and frequency. - Develop concepts and approaches for a joint system design between military radar and military communications systems operating in a shared spectrum allocation that improves overall performance in electronic countermeasure operating environments. ***FY 2016 Plans:*** - Model and assess methods for automatically mitigating interfering transmissions caused by malfunctioning or misconfigured communications devices. - Develop and assess updated strategies to defend military systems against threats created by sharing spectrum information between military radars and commercial communications systems. - Develop baseline version of control system to manage spectrum sharing mechanisms. - Demonstrate spectrum sharing among conforming radar and communications systems that incorporates multiple sharing mechanisms. - Model and assess performance of jointly designed military radar and military communications systems operating in a shared spectrum allocation in electronic countermeasure operating environments.			
Title: Advanced RF Mapping	15.577	17.762	17.125
Description: One of the key advantages on the battlefield is the ability to actively sense and manipulate the radio frequency (RF) environment, enabling reliable and assured communications, as well as effectively mapping and manipulating the adversary's communications in ways that defy their situational awareness, understanding, or response. Current approaches are emitter-based, with the signal processing techniques focused on array and time-based processing for each emitter. As the RF environment becomes more complex and cluttered, the number of collection assets and the required level of signal processing			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
inhibits our capability to pervasively sense and manipulate at the precision (time, frequency, and space) required for effective action. To address these Radio Frequency and Spectral Sensing (RF/SS) challenges, the Advanced RF Mapping program will develop and demonstrate new concepts for sensing and manipulating the RF environment based on distributed rather than centralized collection. This approach will take advantage of the proliferation of RF devices, such as radios and cell phones, on the battlefield. To leverage these existing devices effectively, the program will develop new algorithms that can map the RF environment with minimal communication load between devices. It will also develop approaches to exploit our precise knowledge of the RF environment and the distributed proximity of RF devices to provide reliable and assured communications for our warfighter as well as to infiltrate or negate our adversaries' communications networks. Building upon technologies investigated within other programs within this project, the Advanced RF Mapping program will enable both offensive and defensive operations in complex RF environments. Advanced RF Mapping technology is planned to transition to the Services.			
FY 2014 Accomplishments: - Developed and deployed prototype networks employing multiple types of RF devices of different types for experimentation with the RF mapping technology. - Demonstrated RF mapping capability to characterize RF signals in tactically relevant VHF and UHF frequency bands, using a limited number of distributed devices while minimizing communications requirements between devices. - Determined the performance improvement for signal detection and identification of RF mapping systems over tactically relevant collection times. - Improved RF collection capabilities to cover low-rate tactical networks and limited device availability in tactical environments. - Established baseline capability for defending against hostile use of the RF spectrum.			
FY 2015 Plans: - Carry out field experiments that demonstrate use of currently deployed tactical radios as sensors within a heterogeneous RF mapping network. - Develop a software layer that simplifies addition of new capabilities to the heterogeneous RF mapping network after it has been fielded. - Demonstrate improved battlefield spectrum planning and spectrum management operations through feedback of spectrum utilization information from RF sensors. - Develop a command and control system for optimizing use of devices as RF sensors in a changing operational environment. - Develop and demonstrate geo-location capability of RF emitters using the heterogeneous RF mapping network.			
FY 2016 Plans: - Conduct RF Mapping experiments with Services during field exercises. - Develop a management console enabling mission planners to configure the RF mapping system. - Develop a baseline user interface for presenting RF mapping information to tactical unit leaders.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Develop software for interconnecting the RF mapping capability with other tactical EW systems enabling cueing and results sharing. - Develop software for storing RF maps and querying the stored data.			
Title: Computational Leverage Against Surveillance Systems (CLASS)	28.325	24.600	-
Description: Commercial Test and Measurement equipment has advanced greatly with the emergence of sophisticated cellular and wireless local area network technology and can be used to intercept, analyze, and exploit our military communications signals. The Computational Leverage Against Surveillance Systems (CLASS) program, working to expand Low Probability of Detection/Anti-Jam (LPD)/(AJ) technologies, seeks new ways to protect our signals from exploitation by increasingly sophisticated adversaries, in ways that can be maintained as commercial technology advances. Three different techniques are in development: 1) Waveform Complexity uses advanced communications waveforms that are difficult to recover without knowledge and understanding of the signals itself; 2) Spatial Diversity uses distributed communications devices and the communication environment to disguise and dynamically vary the apparent location of the signal; and 3) Interference Exploitation makes use of the clutter in the signal environment to make it difficult for an adversary to isolate a particular signal. The program's objective is to make modular communications technology that is inexpensive to incorporate in existing and emerging radio systems (<$100 incremental cost) but pushes adversaries to need more than 1,000x our processing power - supercomputer-level processing power. Another track of the program will extend the CLASS technology to provide LPD communications. These techniques will drastically reduce the detectability of communications signals beyond current capabilities. Scalable performance will allow LPD techniques to better trade information rate for communications capacity. Technologies from this program are planned to transition to the Services. ***FY 2014 Accomplishments:*** - Developed operational concepts for distributed airborne operations. - Conducted RF transceiver studies for airborne operations. - Finalized design of CLASS RF and modem integrated circuits; released to foundry for fabrication. - Integrated application driver software for CLASS technology in preparation for Application Specific Integrated Circuits (ASIC) testing. - Produced modular CLASS products and developed board for ASIC testing and a radio product module. - Leveraged advancements towards an alternative development environment for communications systems that takes advantage of commercial smartphone development environment methodology. - Developed an alternative generalized reference architecture that supports communications system integration specifically, and that supports future revisions for other electronic systems anticipated in airborne force projection systems. - Investigated candidate satellite constellation configurations to quantify the trade-off between space segment cost and system coverage and capacity.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Investigated techniques to collaborate among distributed transmitters and receivers for the geometries of beyond line-of-sight solutions (such as airborne and/or space layers), and quantify expected performance relative to predicted system threats. - Investigated applying CLASS receiver beamforming techniques for blind interference cancellation to the Link 16 waveform. - Conducted multi-kilometer demonstration of coherent distributed communications. ***FY 2015 Plans:*** - Develop concepts for integrating CLASS technologies with aircraft antennas and communications equipment. - Measure CLASS modem performance processing power, power consumption, and radio waveform interoperability. - Integrate CLASS modular technology with host processor. - Demonstrate CLASS communication capability with and without interference against Army threat intercept surrogates. - Measure CLASS modem transmit power reduction as number of cooperative transmitters is increased from 1 to 8. - Conduct field tests of integrated CLASS system. - Analyze field test data and compare achieved performance to program metrics.			
Title: Communication in Contested Environments	4.033	18.000	18.000
Description: Building upon the technologies explored and developed under the Computational Leverage Against Surveillance Systems (CLASS) program budgeted in this PE/Project, the Communication in Contested Environments program will seek to address communications problems anticipated in networked airborne systems in the mid-21st century. Expected growth in sensor systems, unmanned systems, and internetworked weapons systems will strain the size of networks that our current communications technology can support in the contested environment. As adversary capabilities advance, the DoD will need new techniques to quickly and efficiently accommodate better networking and improved communications capabilities, specifically communications systems with higher capacity, lower latency, greater jamming resistance, and reduced detectability. As part of Advanced Networks technologies efforts, the Communication in Contested Environments (C2E) program addresses these needs with a three-pronged approach: first, to develop heterogeneous networking capabilities and advanced communication technology for airborne systems. Low Probability of Detection (LPD), Anti-Jam (AJ), low latency, and high capacity communication protocols will be developed. Second, to create a government controlled and maintained reference architecture for communications systems that draws from commercial communication architectures. The defense contractor community can build specific communications systems based upon this reference architecture. Finally, C2E will create a government controlled development environment to allow rapid refresh of communications technology and allow third party native application and waveform developers to contribute their own communications technologies. Technologies from this program are planned to transition to the Services. ***FY 2014 Accomplishments:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Created initial version of a development environment for military communications applications and waveforms similar to the development environments used in the commercial smartphone market. - Developed an initial reference architecture to support interoperable communications and heterogeneous networking. ***FY 2015 Plans:*** - Build a communications reference hardware system to support L-band and microwave communications. - Breakdown waveform implementations into re-usable processing elements and compile representative waveforms for the reference hardware. - Build infrastructure networking automation layer for link establishment, maintenance, and service prioritization. - Test infrastructure networking code on the reference system and evaluate pervasive networking performance. ***FY 2016 Plans:*** - Complete development of advanced network patterns. - Finalize and integrate LPD/AJ capabilities. - Release updated version of the combined software architecture, development environment and tool set, verification environment, and repository. - Demonstrate Heterogeneous Networking LPD/AJ features, and implement a C2E reference design on a small form factor UAV. - Finalize development of the C2E waveforms and demonstrate performance through laboratory testing.			
Title: Scalable Optical Nodes for Networked Edge Traversal (SONNET)	-	-	8.000
Description: Graph analytics on large data sets is currently performed on leadership-class supercomputers that are designed for other purposes. These machines are required because they have the memory capacity required for large graph problems, but the demand on the processors is low, resulting in extremely low compute efficiency. Computationally, graph analysis is characterized by many short, random accesses to memory which is inefficient on current systems, which are optimized for regular predictable access. The SONNET program will build a silicon photonics-based graph processor that will perform graph analysis on terabytes (TBs) of data with performance comparable to peta-scale supercomputers in a significantly smaller size, weight and power (SWaP) envelope. SONNET will optimize the design of the graph processor by co-designing processor and photonic hardware, and the computer and network architectures to exploit the high bandwidth provided by silicon photonics. SONNET will demonstrate a scalable, power efficient prototype of such a graph processor and quantify performance for DoD-relevant applications. The performance, efficiency, and size will be transformational for big data analytics and enable real-time analysis on dynamic graphs in the fields of cyber security, threat detection, and numerous others. This program will explore the efficient processing of local information using stacked memory and integrated circuits specially made for specific tasks, as well as the efficient transfer of data between local information processors.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
The SONNET program will optimize silicon photonic links and improve their power efficiency while also developing packaging techniques for high bandwidth silicon photonic transceivers. SONNET will integrate high capacity memory cards with photonic transceivers to enable high bandwidth access to high capacity memory. The program will build a four node prototype system with a silicon photonic switch connecting the nodes. The program will demonstrate the scalability of the prototype to petascale computational capability. This will also explore the use of processing very close to a stacked memory to investigate the benefits of local processing within the islands connected by the photonic links. This program has applied research efforts funded in PE 0602303E, Project IT-02. Technologies developed under this program will transition to the Services. ***FY 2016 Plans:*** - Demonstrate fully integrated, high efficiency, multi-channel photonic link in a silicon platform, scalable to the bandwidth requirements of the prototype. - Identify gaps in optical packaging technology and design solutions to enable a fully packaged prototype.			
Title: Communications Module - Millimeter-wave (COMMO-MMW) ***Description:*** The Communications Module - Millimeter-wave (COMMO-MMW) program will develop a compact, scalable, millimeter wave (mm-wave) active electronically scanned array (AESA) module to enable high-performance communications links. The module will focus on low cost connectivity of weapons platforms and systems. The cost will be reduced through exploitation of mass manufacturing techniques at the chip scale and a reduction in size of the system which will aid in retrofitting into existing platforms. The COMMO-MMW module will operate in the high frequency portion of the electromagnetic spectrum to take advantage of reduced competition for bandwidth compared to the increasingly congested bands at lower frequencies. By leveraging mass manufacturing processes to reduce module cost, and new advances in compound semiconductors to enhance system performance, the COMMO-MMW program will realize affordable mm-wave communications that can be made ubiquitous across the domains of modern warfare. Additionally, mm-wave operation offers the potential for extremely high data rate communications links that are intrinsically jam resistant and low probability of detection due to narrow beamwidths and atmospheric propagation characteristics at these frequencies. The lack of commercial component technology in the mm-wave band will further increase the military advantage gained by this capability. This program will develop the critical compound semiconductor devices and circuits for high performance, high power efficiency mm-wave front end electronics, and will apply 3-D and/or heterogeneous integration approaches to build a compact, scalable, mm-wave AESA module. COMMO-MMW not only will revolutionize Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) capability but also make it possible and affordable to retrofit existing military systems and extend high performance communications link capability to smaller platforms. Technologies developed under this program will transition to the Services. ***FY 2016 Plans:***	-	-	7.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Analyze and design a compact, scalable, mm-wave AESA module supporting a communication demonstration system for long-range power-constrained missions. - Define specifications for the critical components of a 4 x 4 element AESA. - Develop and demonstrate integration approaches for a compact, scalable, mm-wave AESA module with high output power and high power-added efficiency. - Develop and demonstrate the mm-wave devices and circuits to be integrated for transmitter and receiver array demonstration. - Develop a system integration and test plan for the 4x4 element AESA.			
Title: Self-Optimizing Networks ***Description:*** Wireless networks have evolved into complex systems having many configurable parameters/features, including link data rates, power settings, inter-network gateways, and security associations. The optimal settings for these features vary greatly depending on the mission for which the network is deployed and the environment in which it is operating. Currently, the majority of these features are optimized off-line for specific scenarios and assumptions and are pre-set before use in a mission. There is no capability for the settings to adapt if the actual mission or environment differs from the original assumptions used to configure the network. The problem is exacerbated in scenarios in which intelligent adversaries can affect the topology and operation of the network unpredictably and on short timescales. Furthermore, future operations will include multiple, different radios interconnected on the same platform, which requires adaptation of the interaction between different networks. Building upon concepts explored under the Wireless Network Defense program, which is budgeted in this PE/Project, the Self-Optimizing Networks program will develop new approaches to configuring and controlling networks and networks of networks for operation in dynamic and contested environments. The program will address optimization within military networks, interactions between networks, and availability of necessary network services to support mission success. Technologies developed under this program will transition to the Services. ***FY 2016 Plans:*** - Develop candidate near-real-time optimization algorithms to improve network reliability and efficiency when affected by advanced threats. - Propose and analyze candidate inter-network coordination and decentralized network services for operation in the presence of a peer adversary. - Develop mission-based network architecture control and information delivery mechanisms.	-	-	8.000
Title: Fixed Wireless at a Distance ***Description:*** Unlike commercial wireless communications, the military cannot count on a set of secure, fixed cell towers to establish wireless networks capable of receiving and distributing large amounts of data from distributed sources. Rather, such communication must rely on approaches such as balloons and temporary communication towers that have a high logistical burden	5.500	4.000	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
and are extremely vulnerable. Building upon technologies investigated under other High-Capacity Links technologies programs within this project, the Fixed Wireless at a Distance program is overcoming these limitations by developing a re-locatable, long-range (10-100s of km) communication infrastructure that provides high-capacity (10s of megabits per second) data links from within a protected space. The key innovation in this program is the use of a large number of rapidly deployable, distributed, ground-based antenna arrays that can form a coherent aperture for directional transmission and reception of information to/from tactical wireless networks. Program challenges include the fundamental limits (power and extent) of transmitter gain as well as the rapid and practical deployment of the ground-based arrays. When completed, the Fixed Wireless at a Distance program will significantly extend the reach of tactical communication systems without the need for vulnerable and costly infrastructure. ***FY 2014 Accomplishments:*** - Field tested collaborative beam focusing radios to measure power as a function of speed. - Built prototype infrastructure module supporting 4 channels divided between a select legacy military waveform and a Computational Leverage Against Surveillance Systems (CLASS) extended range waveform. - Measured network performance improvement, throughput and pervasiveness, comparing Mobile Ad Hoc Network with Gateway and Fixed Wireless network protocol. ***FY 2015 Plans:*** - Developed self-organizing communications software to automatically configure distributed communication systems without operator configuration.			
Title: Mobile Hotspots ***Description:*** Communications requirements are growing exponentially due to the proliferation of high-data rate sensors (full motion video), Unmanned Aerial Vehicles (UAVs), and the emergence of the Soldier/Marine as both an operator and a sensor within military networks. However, limited spectrum availability results in a large disparity between capacity requirement and availability. Supporting the development of Advanced Networks technologies, Mobile Hotspots will develop an airborne high capacity data distribution network to interconnect groups of tactical users in a manner that is conceptually similar to the commercial tiered approach of interconnecting cell towers and wireless hotspots. Mobile Hotspots will exploit advances in millimeter-wave technology and airborne networking to develop a self-organizing, 1 Gb/s mobility tactical airborne network formed from highly-directional communications links to interconnect mounted and dismounted warfighters, dispersed tactical operations centers, and intelligence, surveillance, and reconnaissance (ISR) assets. Low size, weight, and power (SWaP) designs will be integrated with commercial and military communications equipment and mounted on tactical UAVs and ground vehicles to provide network access to mobile users via infrastructureless hotspots that are compatible with existing radios. The Mobile Hotspots program is targeted to transition to the Army and Marine Corps Expeditionary Forces. ***FY 2014 Accomplishments:***	17.678	14.650	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Manufactured antenna, amplifier, modem, and networking hardware needed to implement a self-organizing network comprising at least five hotspot nodes interconnected by 1 gigabit per second point-to-point millimeter-wave links to form a tactical airborne network. - Completed the design and began development of Mobile Hotspots prototype into pods for mounting on UAVs and tactical ground vehicles. - Began test planning for the Mobile Hotspot initial ground-based field experiment. ***FY 2015 Plans:*** - Evaluate initial capabilities of the Mobile Hotspot prototype network and millimeter-wave tactical airborne network in an initial ground-based field experiment. - Identify and implement system and subsystem improvements in preparation for final field experimentation and flight test. - Conduct ground testing of integrated air and ground vehicle systems to validate system operation and performance. - Conduct flight tests to evaluate system performance in various air-to-air, air-to-ground, and multi-node networking configurations.			
Title: Scalable Millimeter-wave (MMW) Architectures for Reconfigurable Transceivers (SMART)	6.000	-	-
Description: The Scalable Millimeter-wave (MMW) Architectures for Reconfigurable Transceivers (SMART) program developed a new technology for producing very thin millimeter-wave array apertures and transceivers. The technology development culminated in the demonstration of a large-sized coherent, active electronically scanned array (AESA) with an output power density of 5W per square centimeter and a total layer thickness of less than one centimeter. As part of the High-Capacity Links efforts in this Project, the SMART technology approach resulted in a breakthrough in performance over conventional millimeter-wave approaches. The 3-D multi-layer assemblies developed will greatly reduce AESA packaging complexity and enable very compact, low-cost, millimeter-wave, and radio frequency circuit "building blocks" to combine to form arbitrarily large arrays. New capabilities, such as the ability to construct reconfigurable and/or multi-band AESAs and other MMW circuits, will be enabled by this architectural approach. The SMART program transitioned to industrial producers of MMW radar and communication system components for DoD applications. ***FY 2014 Accomplishments:*** - Developed high-yield processes for planarization and through-via fabrication. - Increased manufacturability and affordability of SMART baseline sub-array modules using cost-effective silicon and indium phosphide foundries for front-end device fabrication and back-end interconnect processes, leveraged high-speed pick and place bonding tools to improve accuracy and speed of module integration.			

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Fabricated more than 10,000 indium phosphide power amplifiers and silicon beamformers for integration into SMART baseline sub-array modules for prototype demonstration.			
Title: Content-Based Mobile Edge Networking (CBMEN) ***Description:*** The CBMEN program's goal was to provide tactical warfighters operating at the edge with interactive, on-demand access to relevant information and a greater ability for real-time sharing of new operational content. This content can include images, video, maps, situational awareness, and command and control information. Advances in communications technologies are enabling high-capacity communications in remote environments. However, the current centralized or regional storage and dissemination of information presents reliability and capacity challenges with distributing relevant information to users at the edge. Commercial industry has developed approaches to the autonomous dissemination of high demand information by using distributed servers and advanced networking and information database technologies, combined with highly reliable fixed networking infrastructure that have embedded complex information exploitation tools. Unfortunately, the commercial system is enabled by infrastructure that is not available to the warfighter. This Advanced Networks technologies program leveraged commercial technologies to develop, prototype, and demonstrate the networking technologies and information dissemination techniques needed to enable efficient and robust content distribution using dynamic, mobile, and ad hoc military networks. CBMEN was installed and demonstrated on existing radios. Capabilities from this effort transitioned to the DoD. ***FY 2014 Accomplishments:*** - Developed objective metrics for advanced scenarios and simulation development for program evaluation and analysis. - Developed representative military small unit scenarios for simulations, over-the-air testing, demonstration, and transition. - Implemented CBMEN technologies for content naming, distribution, management, and security on handheld devices. - Demonstrated capabilities to transition partners in successive field experiments with increasing mobility, network size, content-rich applications, and content segregation based on access permissions using militarily relevant content in operationally relevant scenarios.	13.510	-	-
Title: Wireless Network after Next (WNaN) and Advanced Wireless Networks for the Soldier (AWNS) ***Description:*** The Wireless Network after Next (WNaN) and Advanced Wireless Networks for the Soldier (AWNS) program goals were to develop and demonstrate Advanced Networks technologies and system concepts that enable densely deployed radio networks to compensate for limitations of the physical layer of a low-cost wireless node. WNaN/AWNS networks managed node configurations and the topology of the network to reduce the demands on the physical and link layers of the network. The technology created by the WNaN/AWNS effort provided reliable and available battlefield communications at low system cost. AWNS also investigated the integration of Multi-User Detection (MUD) and Multiple-Input Multiple Output (MIMO) technology into the WNaN radio platform to position these technologies for transition into the WNaN radio node, as well as the Soldier Radio waveform (SRW) Anti-Jam (AJ) mode waveform. In addition, this effort investigated Wireless Distributive Computing	7.500	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
(WDC), Content Based Access (CBA), and smart antenna technologies to enhance the network and node ability to understand the operating environment, mission concept of operations, and node responsibilities to assist in data processing, information dissemination, and accomplishment of military mission objectives. Further, this program developed a low-cost handheld/body wearable wireless node that can be used to form high-density ad hoc networks and gateways to the Global Information Grid. This program also developed robust networking architecture(s) and network technologies/processes that exploit high-density node configurations. ***FY 2014 Accomplishments:*** - Completed demonstration of network scaling to support company-level utility and scalability to large numbers of nodes. - Completed network integration evaluations and field experiments with Marine Corps, Army, and Air Force to establish feasibility and utility for transition.			
Title: Communications Under Extreme RF Spectrum Conditions (CommEx) ***Description:*** The Communications Under Extreme RF Spectrum Conditions (CommEx) program developed signal detection and reasoning technology that allows radios to recognize interference and jamming attacks and then adapt to maintain communications, even in the presence of cognitive jammer attacks and dynamic interference of multiple cognitive network interactions. As part of Low Probability of Detection/Anti-Jam (LPD/AJ) technologies efforts in the Project, the program developed models of adversary, commercial, and friendly cognitive radios and implemented those models to assess, in real time, the current and future dynamics of the communications network. Core technologies for operation in highly dynamic and/or high jamming to signal environments were developed to include: automated jamming waveform forensics; local environment assessment (time, space, frequency, polarization); technologies for addressing known attack strategies and interference properties; and antenna, signal processing, modulation, and network optimization technologies. Based on predictions of the level of communication success compared to mission communication requirements, the cognitive radio chooses waveform selections/configurations that best achieve mission objectives. The cognitive radio includes the capability to analyze and select optimum frequency, waveform, and network configurations during all aspects of a mission. The design effort led to new radio communication architectures, more robust radio communication networking, and better understanding of optimization amongst interference avoidance and interference suppression strategies. This program also sought to enable communication between dispersed and distributed emitters and receivers to provide a multiplier in capacity for both locating emitters and assessing effectiveness of an electronic attack. Technologies developed in this program transitioned to the Navy and Air Force. ***FY 2014 Accomplishments:*** - Performed subsystem demonstrations in the laboratory that validated the performance and network overhead of systems that implement the principles developed in this program.	12.500	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Implemented technology and algorithms on specific radio hardware to confirm that implementation specifics can be transitioned and integrated into communication systems. - Developed architecture to allow CommEx technology to be inserted into radio platforms that will enable assessment of military utility. - Evaluated the application of CommEx principles on existing military systems. - Conducted laboratory evaluations and demonstrations using Link 16 communications systems to determine military utility.			
Accomplishments/Planned Programs Subtotals	141.023	135.561	115.265

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency			Date: February 2015
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	Project (Number/Name) CCC-04 / *SECURE INFORMATION AND NETWORK SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
CCC-04: *SECURE INFORMATION AND NETWORK SYSTEMS*	-	11.740	1.706	-	-	-	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

Computer and networking technologies have rapidly matured in the last decade with profound effect on the DoD and the nation. The Secure Information and Network Systems project will develop and demonstrate computer and network technologies and systems suitable for use in military networks, U.S. government enterprise networks, critical infrastructure, and embedded computing systems. The project will develop, integrate, and test technologies for re-using software components.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Rapid Software Development using Binary Components (RAPID)	11.740	1.706	-
Description: The Rapid Software Development using Binary Components (RAPID) program will develop a system to identify and extract software components for reuse in new applications. The DoD has critical applications that must be ported to future operating systems. In many cases, the application source code is no longer available requiring these applications to continue to run on insecure and out-dated operating systems, impacting operations. A companion applied research effort is budgeted in PE 0602303E, Project IT-03. RAPID capabilities will transition to the Services. ***FY 2014 Accomplishments:*** - Demonstrated the system to military users and conducted initial transition planning. - Participated in technology evaluation exercises with military stakeholders. - Supported transition partners in developing an initial software reuse concept of operations. ***FY 2015 Plans:*** - Transition system outputs based on results from technology evaluation exercises. - Deploy prototype systems at transition partner sites and support initial operations.			
Accomplishments/Planned Programs Subtotals	11.740	1.706	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-04 / *SECURE INFORMATION AND NETWORK SYSTEMS*

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency			Date: February 2015
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	Project (Number/Name) CCC-06 / *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	76.747	101.998	86.070	-	86.070	12.000	12.000	8.000	-	-	-

A. Mission Description and Budget Item Justification

This project funds classified DARPA programs that are reported in accordance with Title 10, United States Code, Section 119(a)(1) in the Special Access Program Annual Report to Congress.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Classified DARPA Program	76.747	101.998	86.070
Description: This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2014 Accomplishments:*** Details will be provided under separate cover. ***FY 2015 Plans:*** Details will be provided under separate cover. ***FY 2016 Plans:*** Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	76.747	101.998	86.070

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Details will be provided under separate cover.