Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Office of the Secretary Of Defense	**Date:** February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602234D8Z / *Lincoln Laboratory*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	49.409	50.925	48.269	-	48.269	49.793	56.091	56.911	57.930	Continuing	Continuing
P534: *Lincoln Laboratory*	-	40.135	41.994	39.576	-	39.576	44.340	49.382	50.104	51.006	Continuing	Continuing
P535: *Technical Intelligence*	-	9.274	8.931	8.693	-	8.693	5.453	6.709	6.807	6.924	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Lincoln Laboratory (LL) research line program is an advanced technology research and development effort conducted through a cost reimbursable contract with the Massachusetts Institute of Technology (MIT). The LL Program funds innovations that directly lead to the development of new system concepts, technologies, components and materials in support of Lincoln Laboratory's missions in Advanced Technology; Communications Systems; Cyber Security and Information Sciences; Intelligence, Surveillance and Reconnaissance Systems and Technology; Tactical Systems; Space Systems and Technology; Air, Missile and Maritime Defense; Engineering; and Homeland Protection. The Lincoln Laboratory Program supports these missions by conducting research and development in nine science and engineering disciplines: - Advanced Devices, with emphasis on development of devices and subsystems utilizing microelectronic, photonic, biological, and chemical technologies to enable new approaches to Department of Defense (DoD) systems. - Optical Systems and Technologies, including the development of focal plane arrays, integrated imagers, laser communications, imaging and spectroscopic detection systems. - Radio Frequency (RF) Systems and Technologies, including the development of novel active and passive radio frequency (RF) sensors, development of electronic protection and electronic attack technologies, and system concepts and communication systems. - Information, Computation, and Exploitation, which includes the development of novel architectures, tools, and techniques for the processing, fusion, interpretation, computation, and exploitation of multi-sensor, multi-intelligence data. - Cyber Security, which includes the development of technologies and new techniques for the protection of systems against cyber attack and exploitation. - Biomedical Sciences and Technology, which supports the development of technologies to aid the warfighter, to investigate relevant research in brain and cognitive sciences, to develop engineered biological systems, and to assess physical performance and injury recovery. - Autonomous Systems, which includes the development of technologies with the objective of developing mobile, autonomous, robotic platforms, as well as sensors and algorithms that support key capabilities needed for a wide range of defense applications. - Quantum System Sciences, which develops basic technologies that support sensing, communication and computation using quantum information, focusing on the demonstration of scalable computation platforms, demonstration of quantum protected communications and magnetic field sensing using highly-compact, atomic-like defects in diamond. - Novel and Engineered Materials, with emphasis on new materials for additive manufacturing and emerging nanoscale materials.

Supporting these and other priority technology and capability areas are work efforts entitled Technical Intelligence:
- The Technical Intelligence Program provides global science and technology (S&T) awareness and context in order to assist Defense decision-makers plan for an uncertain future. The program uses intelligence-based and open-source information to characterize today's global S&T environment, exploiting novel technology watch and horizon scanning (TW/HS) tools to identify nascent and disruptive technologies that will shape tomorrow's future. The program complements this with tailored technical assessments that identify the military relevance, research opportunities, and policy recommendations for emerging and disruptive technologies.

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B. Program Change Summary ($ in Millions)	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	47.807	51.026	51.369	-	51.369
Current President's Budget	49.409	50.925	48.269	-	48.269
Total Adjustments	1.602	-0.101	-3.100	-	-3.100
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-	-			
• SBIR/STTR Transfer	-1.580	-			
• Realignment for Higher Priority Programs	0.000	-	-2.727	-	-2.727
• FY15 Reprog. for Cancelled Account	-0.018	-	-	-	-
• Other Reprogrammings	3.200	-	-	-	-
• FFRDC Reduction	-	-0.101	-	-	-
• Economic Assumptions	-	-	-0.373	-	-0.373

Change Summary Explanation

The FY 2015 and FY 2017 adjustment and internal realignments involve funding for higher Department priorities that support the Advanced Capabilities Deterrence Panel / Third Offset strategy.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		**Date:** February 2016
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COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
P534: *Lincoln Laboratory*	-	40.135	41.994	39.576	-	39.576	44.340	49.382	50.104	51.006	Continuing	Continuing

A. Mission Description and Budget Item Justification

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Advanced Devices ***Description:*** This project develops materials, devices, and subsystems utilizing microelectronic, nanostructure, photonic, biological, and chemical technologies that enable new system approaches to Department of Defense (DoD) systems. ***FY 2015 Accomplishments:*** The continuing Quantum Cascade Laser program produced devices that resulted in an infrared power output of greater than 500 mW at a wavelength near 9 micron, making it effective for infrared countermeasures. New digital charge-coupled devices (CCDs) imagers with on-chip digitization and processing at each pixel enabled near-zero-noise images. The project built and tested six 512x512 CCD imagers addressing the growing demand for improved large-format imagers for intelligence, surveillance, and reconnaissance. LL continued developing integrated optics for a novel optical- communications architecture as well as for chemical sensing in the mid-infrared spectral region. For optical communications, the Lab prototyped an 8-channel functional	6.100	5.884	5.578

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
wavelength-division multiplexed (WDM) laser communications transceivers that will provide a new class of flexible, efficient communication devices. Development began on germanium charge-coupled devices (CCDs) that can offer broadband visible and short-wave infrared imaging, as well as sensitivity for higher-energy x-rays relative to silicon-based detectors. Microhydraulic actuators demonstrated a strength approaching that of human muscle. Lincoln Laboratory also designed, fabricated, and tested a soft microrobotic arm. ***FY 2016 Plans:*** Development of advanced CCD technology will remain a focus in FY 2016. The next steps will be taken in ongoing work on germanium-based CCDs as well as digital CCD technology. Work on integrated optics for flexible laser communication transceivers will continue. A new effort will be added to explore the potential for integrated optics to decrease the size and weight of positioning, navigation, and timing (PNT) solutions such as navigation-grade gyroscopes. Work will continue on efforts to develop transistors in diamond for high power, high frequency radar, electronic warfare and communication applications; and new micro-fluidic actuators based on super-capacitor technology for robotics and biomedical applications. ***FY 2017 Plans:*** Prototype Germanium-based CCDs and all-digital-pixel CCDs will be fabricated and developed for specific applications. Anticipated progress toward high-power diamond transistors should see the incorporation of such transistors in prototype circuits. Work will continue on integrated photonic designs for low SWaP applications.			
Title: Optical Systems and Technologies ***Description:*** This project develops focal planes, integrated imagers, laser communication systems, imaging and spectroscopic systems applicable to DoD missions. ***FY 2015 Accomplishments:*** Activities related to multi-aperture interferometry showed significant progress. Development of interferometric imaging algorithms for a deployable space telescope on a CubeSat led to sponsored funding for specific parts of the deployable technology portfolio. A novel concept for coded-aperture imaging may enhance resolution by an order of magnitude over comparably sized unmasked imagers. A separate effort demonstrated all-electronic adaptive optical coherent communications with distributed apertures. Surrogates for chemical and biological agents have been remotely detected with a new technique called photothermal speckle interferometry. Studies of undersea optical communication suggest that high data rates can be achieved over much larger distances than previously demonstrated. Last, but not least, 3D ladar systems were miniaturized to allow their integration on much smaller platforms. ***FY 2016 Plans:*** A demonstration of deployable telescope technology will provide proof-of-concept for high-resolution imaging from a CubeSat in low-earth orbit. Imaging algorithms will be developed for laboratory demonstrations of interferometric and coded-aperture imaging. The undersea communication hardware will be assembled and demonstrated in a variety of environments from turbid	6.100	6.706	6.356

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
harbors to relatively clear open oceans. New technologies for all-electronic wide-angle beam steering in communication and ladar applications would apply to many DoD systems. ***FY 2017 Plans:*** Continuing improvements in stabilization will allow coherent combining of signals at frequencies up to 1015 Hz. Plans are to develop and field prototypes in FY 2017 and find new applications in the years to follow. An additional major thrust will increase computation at the individual pixel scale of large imagers. This, combined with the current work on improved imaging algorithms, will enable imagers that will recognize objects and movements without processing the entire image. Other algorithms under development may be implemented, which will result in revolutionary new capabilities of both visible and infrared sensors.			
Title: Radio Frequency (RF) Systems and Technologies ***Description:*** This project develops novel active and passive RF sensors, new RF communication techniques, technologies for electronic protection and electronic attack, and new system concepts. ***FY 2015 Accomplishments:*** Researchers successfully completed a novel RF compression algorithm for efficient information extraction. A second project, using a different compressed-sensing algorithm, demonstrated capability to effectively monitor millimeter-wave frequencies using minimal hardware. The Microwave Photonic Low Noise Amplifier (LNA) shows promise to reduce harmonic distortion. A Simultaneously Transmit and Receive (STAR) phased-array project built a digital noise canceller. The use of advanced Complementary Metal-Oxide Semiconductor (CMOS) devices for RF applications for Systems on Chip, ultralow power electronics, and Gallium Nitride (GaN) on Silicon push the state-of-the-art in those domains. ***FY 2016 Plans:*** Gallium nitride on silicon technology research will continue to advance and enable large, high-power, low-cost/scalable RF arrays for radar, communication and electronic warfare applications. A new effort using microjets to enhance the cooling capability of Silicon aims to provide orders of magnitude improvement for output power of high-power amplifiers and other electronics. Two space-systems efforts focused on CubeSat – scale satellites will enable the ability to deploy millimeter wave and microwave capabilities in very small form factors. Technology to simultaneously transmit and receive in a phased array will continue with the goal of 100 dB of isolation. Finally, several RF communication efforts aim to enable networking in contested environments, provide higher-security RF waveforms and use compressed sensing techniques to create more advanced, low-cost receiver capabilities. ***FY 2017 Plans:*** GaN programs will enter their final year and produce fieldable prototypes. Depending on the outcome of the FY 2016 exploratory efforts in microjet cooling of Silicon, devices will be fabricated and tested. Further expansion in the realm of small satellites and	4.100	5.120	4.623

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
additional antenna designs will be made. Developers will seek to lower size, weight, and power for the simultaneous transmit and receive program.			
Title: Information, Computation, and Exploitation Sciences	4.600	4.706	4.461
Description: This project develops novel architectures, tools, and techniques for the processing, fusion, interpretation, computation, and exploitation of multi-sensor, multi-intelligence data. ***FY 2015 Accomplishments:*** Grid and cloud computing researchers continued to develop techniques for secure computing on masked data, added new security tools, integrated social media analysis tools with denser data sets, and expanded capabilities to process large sensor-derived data sets. Furthermore, the graph processing team moved from the design and simulation stage to the prototyping and demonstration stage by developing an efficient sparse memory system, sparse arithmetic logic unit, and communication engine. Sparse matrix multiplication was demonstrated using multiple commercial-off-the-shelf field-programmable gate array boards. Research into the joint audio/visual mining of uncooperatively collected video data produced improvements in the accuracy of information retrieval and expanded the ability to incorporate user feedback. The work in benchmarking military mobile ad-hoc networks created tools that enabled comparison of theoretically achievable performance of different communication techniques and protocols and has identified the throughput gains achievable through improving scheduling algorithms. Work in the covert and anomalous network discovery and detection effort expanded into the key area of network and graph control. Researchers also collected and analyzed operationally significant datasets to explore limits of detectability, and used this insight to develop and produce graph fusion and detection techniques that offer improved accuracy. ***FY 2016 Plans:*** Cloud computing researchers will prototype data storage and processing technologies for handling massive data for a new secure internet-of-things (IoT) initiative for military and intelligence community (IC) applications. The graph-processing program will continue and produce an initial hardware unit that will demonstrate the capability of this innovative approach. The joint audio/visual mining program will enter its last year and will culminate in a rigorous development and evaluation of cross-media search and classification techniques. The covert and anomalous network discovery and detection effort will likewise enter its last year and concentrate on utility within the DoD. A new effort will be launched in dynamic deep learning. This work will perform learning of multiple increasingly sophisticated network layers to do semantic interpretation of unstructured video / LADAR data and also demonstrate near-human-level performance on key unsolved signature detection problems. Another new multi-year effort will begin in creating an autonomous processing, exploitation and dissemination (PED) system that will operate collaboratively with human operators to significantly increase PED efficiency and effectiveness for both DoD and IC missions. In this first year, researchers will focus on developing the system architecture and will integrate key processing technologies and will reduce the burden on human operators that will set the framework in place for future autonomous operation. ***FY 2017 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
Cloud computing researchers will continue to advance the military and IC Internet-of-Things (IoT) initiative. The work will focus on (1) enhancements to secure cloud computing techniques to protect integrated IoT systems, and (2) advances in computing infrastructure to provide low latency measurement, analysis and control of IoT multi-tasking and data processing. The final year of the graph processor program will focus on integrating the processor with Lincoln's grid computing system (LLGrid), to provide users with the ability to do big-data graph analytics at an unprecedented scale and throughput. The autonomous PED program will integrate new techniques that were previously developed as part of individual analysis tool development programs, including work done under (1) the joint audio visual mining program, (2) the covert and anomalous network and discovery effort, and (3) the dynamic deep learning program. With this capability intact, the autonomous PED program will use embedded instrumentation and measurement tools to determine operational effectiveness of collaborative machine-human operations on mission scenarios that exploit autonomous advance indications and warnings. The deep dynamic learning program will also continue, with the goal of demonstrating unprecedented high-throughput detection performance on video and LADAR imagery.			
Title: Cyber Security ***Description:*** This project develops technologies and new techniques for the protection of systems against cyber attack and exploitation. ***FY 2015 Accomplishments:*** Cyber Security development focused on better approaches to protect systems and better tools to understand vulnerabilities and exploitation strategies in both small and large-scale systems. Techniques were developed for protecting information storage, processing and communications in the cloud. Innovative techniques including multiparty computation, data provenance analysis and intra-cloud secure networking showed great promise for securing the cloud. With an enhanced private cloud testbed at Lincoln Laboratory, the applicability of these techniques for future DoD and US government cloud systems was tested. In more advanced research, a secure processor prototype demonstrated more secure computing by decrypting data and operating instructions only during a small window of time and in limited regions of the processor. Software to produce large numbers of exploitable software vulnerabilities generated data sets for assessing the performance of static and dynamic software analysis tools. Many computer and network components manufactured abroad make cyber vulnerabilities in hardware an important consideration. In FY 2015, hardware exploits were inserted into a processor and triggered externally to demonstrate multiple vulnerabilities. Vulnerabilities in software-defined radio are also being studied. ***FY 2016 Plans:*** Most of the cyber protection and evaluation efforts will continue to be advanced with the addition of a few new efforts. Efforts to protect cloud computing systems will focus on creating and demonstrating a full stack of cloud provenance services and tools. Both the software and hardware vulnerability generation efforts will continue, better spanning the space of potential	4.100	5.313	5.037

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
vulnerabilities that can occur in real systems. A cyber/EW software-defined radio will be demonstrated and new efforts in cyber secure architectures for small satellites, functional encryption, and cyber security metrics will be initiated. ***FY 2017 Plans:*** Rapid response to the evolving cyber threats along with Lincoln's particular DoD cyber expertise will guide future R&D plans. The need for understanding vulnerabilities in both the hardware and software domains is expected to continue. In the hardware domain, efforts to reduce vulnerability to foreign built computer and network components will continue. In addition, the ability of near-peers to emulate and devise EW/cyber strategies that limit U.S. capabilities will result in new mitigation strategy research. In the software domain, the increased government/DoD cloud usage will put a premium on defensive network strategies.			
Title: Biomedical Sciences and Technology ***Description:*** The Biomedical Sciences and Technology effort aids the warfighter, especially within the brain and cognitive sciences domain, with engineered biological systems and physiological monitoring for performance enhancement and injury recovery. ***FY 2015 Accomplishments:*** A 3D multi-material Bioprinter effort addressed gaps in current 3D printing technology to combine organic and inorganic materials, enabling the creation of unique structures. The design team built and tested a printer that included two high-end gantries, several print heads for printing plastic, metal and biological materials, and a motion controller system with user interface. In the Synthetic Biology domain, the Artificial Gut (ArtGut) project team designed, 3D-printed, and tested multiple prototypes to simulate what complex communities of engineered microbes would experience in the digestive tract. This effort has included creating subsystems capable of peristaltic motion, testing a wide range of 3D-printable polymer materials, and embedding oxygen sensors. The Brain-Computer Interface (BCI) effort is directed toward the ultimate goal of allowing humans to consciously control computers with thoughts. This project developed a noninvasive cognitive assessment platform and a series of tests that permits understanding of subject's cognitive state based on purely mental tasks such as simply envisioning the manipulation of object rather than physically moving an object. A new effort was also launched to develop a non-contact ultrasound system for volumetric imaging. This effort employs laser excitation and sensing arrays for high-resolution volumetric imagery, which has the potential to monitor bone health, assess traumatic brain injury, and diagnose internal bleeding. In the pursuit of identifying neural correlates of learning, the Functional Brain Network Analysis effort characterized neural connectivity by collecting longitudinal EEG data during task learning. This data will be utilized to create a brain map and uncover fundamental properties governing changes in neural connectivity while learning. Two projects are developing software modules for tracking and analyzing multimodal markers of individual health and performance to assess and understand DoD-relevant driving biomedical problems, including cognitive disorders such as traumatic brain injury and depression. ***FY 2016 Plans:***	3.335	3.320	3.147

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
The 3D multi-material Bioprinter effort will conclude by developing the capability to print materials that will assist in cartilage repair. The ArtGut program will also conclude and develop a new microfluidic system to isolate microbial strains and attempt to improve on current microbial culture methods. The Non-contact Ultrasound program is expected to have preliminary results. The Function Brain Network Analysis study will evaluate functional neural connectivity and extend methods to characterize temporal dynamics of connectivity patterns. Four new efforts are anticipated, covering a wide range of topics. One project aims to more effectively restore muscle loss after injury by re-programing the fibroblasts and fibrotic scar cells by re-awakening muscle-forming genes using proteins and drugs. A second project will use brain-based behavioral measures and neural-model parameters that predict severity of a disorder and stress, as well as predict the effect on cognitive performance. A cellular-resolution brain-mapping project will utilize data gathered from a novel microscale brain mapping method to build a big-data management framework for brain imagery and develop automated neuron-tracing algorithms. This program has the long-term goal of creating large scale mapping for human brains to diagnose and treat conditions such as Alzheimer's and PTSD. ***FY 2017 Plans:*** The volumetric-muscle-loss project will conclude this year with an in vitro demonstration. The Cellular-Resolution Brain Mapping program is expected to produce preliminary capabilities to map the brain network topology. The project portfolio will see increasing emphasis on cognitive-science-related projects and diminished focus on physiological monitoring, in keeping with emergent science trends and anticipated DoD needs.			
Title: Autonomous Systems ***Description:*** Autonomous systems technologies with the objective of developing mobile, autonomous, robotic platforms, sensors and algorithms that support key capabilities needed for a wide range of defense applications. ***FY 2015 Accomplishments:*** Autonomous systems efforts progressed in four key areas. In the first area, the fabrication and testing of the digital-vision-sensor readout electronics and detector-tier for real-time autonomous low-altitude optical navigation was completed and sensor hybridization and camera firmware development was initiated. After demonstrating sidecar control of the small-UAS autopilot, the team collected imagery from a small-UAV using off-the-shelf imagers as a baseline. In the second area, oceanographic flow and ship wake models were integrated into a dynamic path planner to enable safe and energy-optimized UUV operations in the complex environments in the vicinity of ships. At-sea demonstrations were executed to validate the oceanographic forecasting and energy-optimized path plans in a realistic environment. In the third area, the team developed a target tracking framework that can provide the sustained visual cue needed for a UAV to follow a ground target and a dynamic platform-and-sensor planning framework to improve observation distance and view diversity of the UAV's target to support identification. In the final area, which is developing algorithms for data-driven autonomy, involved applying the Coreset video-ranking software library to video data	2.100	3.377	3.201

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
recorded from a tactical UAV. The team utilized offline data processing to generate 3D maps from the 2D video streams of both the entire frameset and evaluated the reduced-size Coreset and geo-registration accuracy. ***FY 2016 Plans:*** The autonomous system hardware efforts will continue and will enter a demonstration phase of development. Developers will complete the integration of the digital vision sensor for fast autonomous airborne navigation and demonstrate the capability in a flight test. Additionally, the UUV effort will continue with testing in an autonomy simulator and real-time processor and result in a demonstration at sea. For the data-driven autonomy effort, the team will adapt the Lab Coreset video software library to static-object change detection and moving-vehicle tracking, enabling a demonstration exercise that is relevant to the DoD. The Lab will also be launching a new effort to develop a novel silent UAV propulsion system that will offer significant efficiency advantages over traditional propulsion methods. A new effort to develop coordination of multi agent UAVs will enable decentralized planning under real-world communication constraints. Furthermore, development of a new biomimetic sonar system that mimics dolphin sonar will enable improved autonomous object detection, localization and classification. ***FY 2017 Plans:*** Research will continue to improve current autonomous system capabilities for air, land, and sea. These improvements will encompass both hardware advancements, such as the on-going silent propulsion system, as well as algorithm improvements for swarm and multi-agent coordination. The Lab expects continued exploration of underwater and cross-domain problem sets.			
Title: Quantum System Sciences ***Description:*** Quantum System Science develops technologies that support sensing, communication and computation using quantum information. ***FY 2015 Accomplishments:*** Quantum computing, which has the potential of exponentially faster computation for some important problems (e.g., in cryptography), includes efforts on superconducting qubits, theory of qubits, and computing with trapped ion qubits. Trapped-ion work focused on a more scalable approach using microchips. Quantum coherent operations were demonstrated in individual Sr+ ions using 674-nm-wavelength light routed in and emitted from silicon nitride waveguides and couplers lithographically integrated within a linear surface-electrode ion trap chip. Planar superconducting qubits showed broad frequency tunability, strong anharmonicity, high reproducibility, and coherence times in excess of 40 µs. A quantum communication effort developed technology to support a new protocol for high-rate, quantum-protected communication that avoids the need for a separate, slow, key exchange step. These technologies included a high-gain optical-parametric-amplifier-based two-mode quantum receiver and a multi-channel, high-rate single photon counting receiver architecture with photon number resolution. Finally, a quantum sensing effort advanced technology based on nitrogen vacancies in diamond for sensing magnetic fields. Initial record-sensitivity experiments in FY 2014 were further advanced in FY 2015 by demonstrating approaches to align the field measurements to a single crystal axis, to remove temperature effects from the measurements and to further improve the sensitivity. All of these	4.300	4.772	4.523

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
quantum sciences efforts are closely connected to work on MIT campus through collaborations that involve the MIT faculty, who are world-experts in these fields, their graduate students, who work collaboratively in both locations, and a dedicated 40-km fiber link for quantum communication experiments. ***FY 2016 Plans:*** Plans include improved scalability and the implementation of quantum error correction techniques. The superconducting qubit work will continue to advance the state-of-the-art for the superconducting qubits themselves, particularly for long-term, gatebased quantum computing architectures. Initial qubit computing using trapped ions on a microchip will be demonstrated. Development of modulators suitable for the wide range of wavelengths necessary to address the ions (and many other applications) will continue. The ultra-sensitive magnetometer using diamond will produce full vector measurements. A new protocol for high-rate, quantum-protected communication that avoids the need for a separate, slow key-exchange step will be demonstrated. ***FY 2017 Plans:*** The quantum communication protocols will be tested in the field over a fiber link between Lincoln Laboratory and MIT campus. In addition to continued advances in superconducting qubits, trapped ions, quantum-protected communication and quantum magnetometry, additional efforts will be made to advance quantum algorithms. As the basic technology components and the path to scalable quantum systems are demonstrated, additional work on algorithms for quantum computation and quantum communication will become increasingly important to define future system architectures.			
Title: Novel and Engineered Materials ***Description:*** Invent, de-risk, and establish materials and processes that can make transformative impact on the nation's national security needs. ***FY 2015 Accomplishments:*** An important frontier in new materials is the ability to make heterogeneous materials on very small size scales (e.g., nanomaterials) with properties that are more than just a mixture of the component materials. A collaboration with Harvard University developed low-RF-loss 3D-printable polymers with high feature resolution. A printable A-B-A triblock copolymer, which has nanoscale spherical occlusions, rivals the best-in-class dielectric in initial tests of a printed 29-34 GHz band pass filter. Important milestones of building structures with 8 μm resolution and 0.1 μm RMS surface roughness were demonstrated. A second effort investigated the applicability of transition metal dichalcogenide (TMD) materials for flash memory and room-temperature solid-state qubits (logical units of quantum calculation). Academic collaborators at MIT and Carnegie Mellon University helped grow and characterize TMD films with 300 nm spatial resolution using photoluminescence (PL) to provide detailed maps of alloy composition, heterostructure overlap, and defects. The team compared and evaluated different growth techniques of other materials (MoS_2, WS_2, WSe_2) using Raman, PL spectroscopy, and atomic force microscopy (AFM). ***FY 2016 Plans:***	1.700	2.796	2.650

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
The low-RF-loss 3D printing project will continue with the development of polymer/inorganic composite ink for increased dielectric constant. In addition, the program will fabricate RF devices by 3D printing both conductor and dielectric materials concurrently, demonstrating dielectric tuning and multiple permittivity in a single device. Studies of TMD materials and work toward prototyping of valleytronic flash memory and room-temperature solid-state qubits will continue. Three new programs will be launched. The 3D Printing of Metal-Ceramic Microlattices project will create transformative structural materials using architected designs that provide extreme stiffness-to-density ratios. A key goal is to create a ductile material with 1/10th the weight of aluminum and the stiffness of fiberglass. A second new project seeks to improve on semiconductor device architecture by creating a light-weight, flexible fiber with the functionality of wafer-based devices. Fibers containing multiple materials have demonstrated applicability in many areas; a major new capability would combine optical and electronic properties in the fiber to develop fibers with designed photonic bandgaps. ***FY 2017 Plans:*** A continuing area of focus will be in additive manufacturing envisions materials with properties that are designed to exhibit desired mechanical, thermal, electro-optical performance in a number of devices of interest to the DoD, including in the RF domain. As the resolution improves, high-performance devices for mm-wave applications (up to 100 GHz) will be printed. Lightweight structural materials will be deployed in low-SWaP systems, such as in a UAV or Cubesat payload. Advances in designing and drawing of composite fibers will result in scintillators for gamma and neutron detection, for example.			
Title: Missile Defeat-X Lab ***Description:*** X-LAB in support of Missile Defeat will conduct an experiment with the goal of demonstrating a multi-INT threat defeat framework using a rapid insertion of new data sources, new analytics and pluggable libraries of analytics and visualization tools from developer community (Universities, Industry, Government Labs, FFRDCs). The project will work towards fusion across unclassified and classified data for the Joint Staff organization. ***FY 2015 Accomplishments:*** Initial planning and technical interchange meetings were conducted, initial demonstration use cases identified. Initial work identified which tools under development by AFRL, ARL, LLNL, Radiant Blue, and MIT LL could be used. Performance characterization of architecture elements was conducted. The initial emphasis on commercial and open source data. ***FY 2016 Plans:*** In FY 2016 leveraging prior year funds, X-Lab will deploy the updated infrastructure, create a knowledge base, ingest data from selected data sets / target events, finalize interface protocols and formats among participants, develop analytic algorithms and perform a capability assessment.	3.700	0.000	-
Accomplishments/Planned Programs Subtotals	40.135	41.994	39.576

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602234D8Z / *Lincoln Laboratory*	**Project (Number/Name)** P534 / *Lincoln Laboratory*

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		**Date:** February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602234D8Z / *Lincoln Laboratory*	**Project (Number/Name)** P535 / *Technical Intelligence*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
P535: *Technical Intelligence*	-	9.274	8.931	8.693	-	8.693	5.453	6.709	6.807	6.924	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Technical Intelligence Program provides global science and technology (S&T) awareness and context in order to assist Defense decision-makers plan for an uncertain future. The program uses intelligence-based and open-source information to characterize today's global S&T environment, exploiting novel technology watch and horizon scanning (TW/HS) tools to identify nascent and disruptive technologies that will shape tomorrow's future. The program complements this with tailored technical assessments that identify the military relevance, research opportunities, and policy recommendations for emerging and disruptive technologies.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Technical Intelligence	9.274	8.931	8.693

Description: The Technical Intelligence Program provides global science and technology (S&T) awareness and context in order to assist Defense decision-makers plan for an uncertain future. The program uses intelligence-based and open-source information to characterize today's global S&T environment, exploiting novel technology watch and horizon scanning (TW/HS) tools to identify nascent and disruptive technologies that will shape tomorrow's future. The program complements this with tailored technical assessments that identify the military relevance, research opportunities, and policy recommendations for emerging and disruptive technologies.

FY 2015 Accomplishments:
In FY 2015, the Technical Intelligence program supported efforts characterizing today's global S&T environment, exploited novel TW/HS tools to identify nascent and disruptive technologies that could shape tomorrow's future, and developed tailored technical assessments that identify the military relevance, research opportunities, and policy recommendations of emerging and disruptive technologies. Specifically:
• JASON Program: Supported focused technical assessments on defense relevant problems. The topic areas included: Defense against Hypersonics, Missile Defense, Science-Based Explosive Design, and Impacts of Emerging Biological Capabilities.
• Technology Watch and Horizon Scanning (TW/HS) Tool Exploitation: Sponsored efforts on exploiting data analysis and TW/HS tools to identify existing and unrecognized patterns, to provide non-obvious relationships using open source information, and to develop a better understanding of how to incorporate private-sector data analysis regarding technology development, trends, and potentially disruptive developments.
• Technical Assessment Program: Sponsored multiple technical assessment activities that included integrated photonics, autonomy, and technology forecasting.

FY 2016 Plans:
In FY 2016, the Technical Intelligence program is funding efforts characterizing today's global S&T environment, exploiting novel TW/HS tools to identify nascent and disruptive technologies that will shape tomorrow's future, and developing tailored technical

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
assessments that identify the military relevance, research opportunities, and policy recommendations of emerging and disruptive technologies. Specifically: • JASON Program: Supporting focused technical assessments on defense relevant problems. The potential topic areas include: Artificial Intelligence, defending against cooperating UAVs, and micro-satellite. • Technology Watch and Horizon Scanning (TW/HS) Tool Exploitation: Funding efforts on exploiting data analysis and TW/HS tools, to identify existing and unrecognized patterns, and to provide non-obvious relationships using open source information. The program is investigating improvements in query generation, and metrics and validation of TW/HS algorithms. • Technical Assessment Program: Working on multiple technical assessment activities supporting the community of interest topic areas, including Artificial Intelligence and Internet of Things, and may include additional topics such as cognitive neuroscience, and optics and directed energy. ***FY 2017 Plans:*** In FY 2017, the Technical Intelligence program will continue to support efforts characterizing today's global S&T environment, exploiting novel TW/HS tools to identify nascent and disruptive technologies that will shape tomorrow's future, and developing tailored technical assessments that identify the military relevance, research opportunities, and policy recommendations of emerging and disruptive technologies. Specifically: • JASON Program: Will support focused technical assessments on defense relevant problems. The potential topic areas include: advanced electronics, autonomy, electronic warfare and protection, energy and power technologies, engineered resilient systems, space, sensor and processing systems, and human systems. • Technology Watch and Horizon Scanning (TW/HS) Tool Exploitation: Will continue to sponsor efforts on exploiting data analysis and TW/HS tools with the goal of having an operational TW/HS toolkit available to DoD researchers and scientists. The program will identify outreach opportunities to inform and train DoD S&T organizations in the usage of analytical tools and methodologies to support "in-house" decision making and expand organizational knowledge into emerging technology areas of strategic interest. • Technical Assessment Program: Will sponsor multiple technical assessment activities that support the community of interest topic areas, which may include advanced computing, cognitive decision-support tools, and non-traditional sensing.			
Accomplishments/Planned Programs Subtotals	9.274	8.931	8.693

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2017 Office of the Secretary Of Defense		**Date:** February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602234D8Z / *Lincoln Laboratory*	**Project (Number/Name)** P535 / *Technical Intelligence*

E. Performance Metrics

N/A