Exhibit R-2a, RDT&E Project Justification							Date: February 2003	
Appropriation/Budget Activity RDT&E, DW BA2				Project Name and Number Lincoln Laboratory 0602234D8Z				
Cost ($ in millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Project Name or Future Naval Capability /No./Subtotal Cost	21.969	26.769	27.231	26.514	26.938	27.415	27.763	28.315

A. Mission Description and Budget Item Justification:

(U) The Lincoln Laboratory (LL) Line program is an advanced technology research and development effort conducted through a cost reimbursable contract with the Massachusetts Institute of Technology (MIT). LL is operated as an FFRDC administered by the DoD, and is unique among DoD FFRDC's: the laboratory is operated (under A-21) by MIT with no fee. Thus, the Research Line is the laboratory's only dedicated source of funding for innovative research and development efforts.

(U) The LL Line funds advanced research activities that directly lead to the development of new system concepts, new technologies, and new components and materials. These activities enable the DoD to address latent technology needs that affect a broad spectrum of missions, services, and transformational operational capabilities. The Lincoln Laboratory Research Line contributed foundation technologies to two systems which received the 2002 Packard Excellence in Acquisition Award: (1) the Bio-aerosol sensing and micro-laser technologies were transferred to industry and are in production for the Joint Biological Defense Sensor (JBPDS), and (2) the Free-space optical communications technologies were used in the GeoLite optical communications satellite demonstration system. The GeoLite demonstration provides the underpinnings of the Transformation Communications Architecture. Other recent successes include a compact 3D imaging laser radar that uses unique photon-counting avalanche photodiode arrays and has demonstrated, in the DARPA Jigsaw program, high quality imagery of targets obscured by dense foliage or camouflage, and a biosensor that uses genetically engineered immune cells and has demonstrated the ability to identify major biowarfare agents in under two minutes with high sensitivity and low false alarm rate.

(U) The LL Line program currently has impact in five core research areas:

(U) *Target Surveillance and Recognition*, with emphasis on (1) revolutionary sensing techniques and algorithms for detecting and recognizing battlefield targets both in the clear and in difficult deployments, (2) demonstrating the technologies associated with multi-sensor fusion for target ID, and (3) advanced signal processing techniques to improve the ability of present systems to detect ground moving targets.

(U) *Military Communications*, with emphasis on high bandwidth, low probability of intercept, jam resistant links and machine-to-machine applications. Includes advanced antenna designs, RF technology, high-rate fiber and free-space optical communications systems, network protocols (including for mobile users with lightweight transceivers) for "socketing" sensors into the network and the interconnection of these very disparate modalities into a global defense network that can truly realize the vision of a "from sensor to decider to shooter" communications infrastructure. Developing unique intrusion detection/response techniques to protect computer networks.

(U) *Combat Support Technology,* including active hyper spectral sensing systems, compact biological agent detection systems, advanced 3D laser radars (LADARs), and High-Energy Laser (HEL) technology. The primary objective for the active hyper spectral sensing system development is to demonstrate the feasibility and utility of combining active illumination with hyper spectral imaging for a range of military applications including Combat IDentification (CID). The focus in biological agent detection is in developing technology for compact, lightweight, real-time biological-agent sensors with extremely high sensitivity and low false alarm rate. The high-energy laser technology program is focused on improving beam control for stressing atmospheric conditions (e.g., tactical HELs in near-surface engagements) and developing novel, more efficient lasers to reduce the size and weight of HEL systems.

(U) *Advanced Electronics Technology*, including revolutionary, advanced electronic/optical devices, with specific emphasis on low power and high sample rate Anolog to Digital (A/D) conversion for digital receivers for radar and electronic intercept, 3-D imaging and photon-counting focal-plane arrays for ISR and advanced missile seekers, mid-infrared semiconductor lasers to counter advanced heat-seeking missiles, new sensors for rapidly detecting and identifying low concentrations of bio-warfare agents, solid state low-light imagers for surveillance and targeting, and high-speed, radiation hard, ultra-low power analog and digital circuits tailored for DoD applications.

(U) *Counter Terrorism Technology*, including defense against bio-warfare, identification and tracking of individuals, surveillance and reconnaissance over wide areas, covert communications and electronic tagging, as well as exploitation of all-source data for identifying illicit behavior and facilities.

B. Accomplishments/Planned Program

Target Surveillance and Recognition	FY 2002	FY 2003	FY 2004	FY 2005
Accomplishment/ Effort/Subtotal Cost	0	5.773	5.873	5.719

FY 2003 Accomplishments:

(U) *Surface Surveillance*: Developed an integrated multi-intelligence (multi-INT) surface target detection system by integrating Signal Intelligence (SIGINT) cues with high-resolution SAR imagery. This work was the first step towards integrating the synoptic and narrow field-of-view sensors of the reconnaissance/strike lattice. Developed system was evaluated using Image Analysts and performance was quantified. System is being developed for eventual integration into the Paul Revere Airborne Command and Control Test Aircraft (MC2A-X).

(U) *Advanced Phased-Array Technologies*: Developed advanced Very Large Scale Integration (VLSI) technology for implementation of a wideband, Electronic Counter Measures (ECM)-resistant receiver for Space-Based Radar and other radar system applications. Developed advanced phased-array architectures and signal processing concepts directed towards achieving full time-energy utilization in airborne and space-based Ground Surveillance radars through the use of mode interleaving and multiple simultaneous beams. Such designs could

improve the performance of Ground Surveillance radar systems by an order of magnitude, but will require advanced digital signal processing and packaging technologies for implementation.

FY 2004 Plans:

(U) *Surface Surveillance*: Extend multi-INT system to include ID sensors and use experimental system to form a substrate for the time-critical strike lattice. Develop cueing strategies and use of contextual information in behavior databases.

(U) *Advanced Phased-Array Technologies*: Integrate wideband Very Large Scale Integrated (VLSI) channelized receiver with electronically-scanned phased array antenna to demonstrate Space-Based Radar Electronic Counter-Countermeasures (ECCM) and signal processing functionality. Build several channels of an advanced conformal phased-array architecture for airborne and space-based Ground Surveillance radars, and demonstrate improvements in time-energy utilization using mode interleaving and multiple simultaneous beam formation.

FY 2005 Plans:

(U) *Surface Surveillance:* Extend system to include multiple synoptic, narrow field-of-view, and ID sensors such that the system provides the mechanism of linking sensors in the reconnaissance/strike lattice. Transfer technology to BMC2 contractor for use in Command Air Operations Center (CAOC), Distributed Common Ground Station (DCGS) and Multi-mission Command and Control Aircraft (MC2A).

(U) *Advanced Phased-Array Technologies*: Demonstrate adaptive conformal array antenna technologies needed to achieve high performance jamming resistance and improved radar resource efficiency.

Military Communications	FY 2002	FY 2003	FY 2004	FY 2005
Accomplishment/ Effort/Subtotal Cost	0	3.306	3.363	3.274

FY 2003 Accomplishments:

(U) *Global Networks*: Continue to focus on evolving architecture and technology for global high-rate military communications and networking, including optical communications in space and fiber, future Milsatcom, and tactical theater communications, particularly to forces on the move and to support time-critical strike. Continue laboratory demonstrations of technology for DoD-specific applications, refine networking architecture and protocols, and aid DoD in defining its development and procurement strategy for the future global defense network that will provide C3 and ISR with product transport within tactical timelines. Application is to the emerging integration of DoD command elements, information centers, and execution forces into a unified Global Information Grid. Specific technologies include

free-space optical systems for multi-Gbps readout of Airborne Intelligence, Surveillance and Reconnaissance (AISR) platforms and connectivity to airborne C2 platforms through space communications as envisioned by the DoD Transformational Communications Architecture, multi-frequency RF systems and antenna designs for ground mobile"comm-on-the-move" satcom systems, and protocols for high-speed wireless networks.

(U) Development of robust collaboration applications for network-centric operations involving wireless airborne and ground operations, which are subject to both varying link problems and information attacks.. Near term focus on robust, secure chat to support airborne C4ISR in the Multi-mission C2 Constellation environment

(U) *Airborne C^2 Node*: Use the Air Force Airborne Command and Control Test Aircraft (MC2A-X) to test new communication, command, and control concepts for ISR and weapon targeting.

FY 2004 Plans:

(U) *Global Networks:* Refine the architecture and technology for global high-rate military communications to permit seamless line-of-sight and over-the-horizon connectivity for peer-to-peer computer-based tactical applications to include distributed operations centers, distributed sensor ground processing, and integrated C2 of reconnaissance and strike assets. Technologies that will receive priority include moving to a "packet-based" network design, redesigning crypto and transec to retain hardness in a packet topology, revising network control to provide both tactical "dial-up" services and transient provisioning of large data pipes.

(U) *Defensive Information Warfare*: Research and development will focus on the problems of robustness and security of collaborative applications, including chat, against information attacks and varying link availability in an airborne C4ISR environment.

(U) *Airborne C2 Node:* Use the Air Force MC2A-X to test new communications, command, and control concepts for ISR and for interface to strike, including the electronic threat environment as influenced by Electronic Countermeasures (ECM) and jamming.

FY 2005 Plans:

(U) *Global Networks*: Continue to develop, demonstrate, and transfer technologies for high speed optical and RF networked communications into funded DoD programs that put global connectivity into the hands of the warfighter.

(U) *Defensive Information Warfare*: Continue focus on tactical ISR used to support joint air-sea and air-land networks, working the wired and wireless robustness and security issues facing net-centric warfare, with attention to robustness for collaborative applications.

(U) *Airborne C2 Node:* Use the Air Force MC2A-X to exploit Global Airspace Traffic Management data to enhance the air picture; provide computer-to-computer network interfaces to the Navy Cooperative Engagement assets; and to provide firepower support to transformational army elements.

Combat Support Technology	FY 2002	FY 2003	FY 2004	FY 2005
Accomplishment/ Effort Subtotal Cost	6.170	7.676	7.808	7.602

FY 2002 Accomplishments:

(U) *Active Hyperspectral Sensing System*: Development of a measurement system consisting of passive hyperspectral and multi-spectral imaging sensors along with selected discrete-frequency laser illuminators was completed. The system is adaptable. Both the sensing wavebands and target-recognition algorithms are tailored to fit specific applications. In the past year, measurements were made in the laboratory and at Redstone Arsenal. In addition to combat ID, these systems are being investigated for detecting bio-agents remotely (~100m to 1km) using spectral and polarization characteristics of the biological aerosols. System calculations show that multi-aspect sensing is effective with these features.

(U) *Biological Agent Detection Systems*: An Urban Testbed for evaluating approaches to sensing biological threats in an urban environment was made operational. The Lincoln bio-agent identification sensor (CANARY) was used in test trials and achieved identification of an unknown biological agent in a shorter time than any other existing bio-agent identifier. In addition to speed, the sensitivity of the CANARY detector is comparable to a PCR analysis, and the false positives are less than 0.4%. The Lincoln Interim Nucleic-acid Kit (LINK) cartridge allows rapid acquisition of purified DNA from field samples using our Simple Nucleic Acid Protocol (SNAP). USAMRIID evaluated LINK and requested prototype cartridges for use in analyzing biological samples.

(U) *3D Laser Radar*: Development of laser radar technologies for applications to advanced ballistic and tactical seekers, and combat identification progressed. The first integrated 32x32 detector arrays were used to collect 3-D imagery of military targets at Eglin AFB and Redstone arsenal. The arrays have Geiger-mode avalanche photodiode arrays bonded to a silicon timing integrated circuit. A 3-D ladar simulation was developed to model the detection of targets surrounded by foliage. Multi-function laser radar system designs have been analyzed.

(U) *High Energy Laser Technology:* For many tactical scenarios, conventional adaptive optics is expected to perform poorly because of strong atmospheric turbulence along the entire propagation path. Simulations indicate that multi-conjugate systems may perform better than conventional adaptive optics systems. Candidate multi-conjugate optical designs were developed and an optical configuration was selected. A wavefront sensor and deformable mirrors were specified and procured. The wave optics simulation code has been upgraded to run on a multi-processor computer.

FY 2003 Accomplishments:

(U) *Biological Agent Detection Systems*: There are two primary foci: the continuation of the Urban Testbed initiative and the development of a prototype sensor that combines the rapid trigger feature of the Bio-Aerosol Warning System (BAWS) sensor and the rapid identification capability of CANARY. In the Urban Testbed, a second subway platform will be outfitted with sensors, as will a large-area forum, for the continued testing and evaluation of biosensors. In the BAWS/CANARY effort, the focus will be on fabricating a multichannel prototype instrument that demonstrates real-time bio-detection/identification capability, with applications in military force and facility protection. Other efforts include development of novel anti-viral techniques, a high-discrimination compact biosensor, non-Polymerase Chain Reaction (PCR)-based detection of DNA, and bioinformatics techniques applied to interpretation of micro array data.

(U) *3D Laser Radar*: Develop laser radar technologies for applications to advanced ballistic and tactical seekers and combat identification. Demonstrate fully-functional 32 x 32 arrays of InGaAs Geiger-mode avalanche photodiodes at the 1.0-micron wavelength. Focus on integrating these systems into lightweight, low power packages consistent with advanced seeker applications, which will provide single-photon-sensitivity and high-precision range resolution for generating detailed 3-D imagery of targets. Collect 3-D image data that demonstrates the utility of these sensors for force protection, such as increased situational awareness, and counter-terrorism, such as imaging into buildings. Investigate high-efficiency alternative transmit lasers for 3-D imaging systems that enable further miniaturization. Continue the development of multi-function laser-radar systems, for applications to Ballistic Missile Defense (BMD) interceptors, combat identification and foliage penetration. This development will involve the integration of a multi-function laser radar testbed, which will enable the collection of 3-D and range-Doppler image data on a variety of relevant targets. Integration and testing of laser radar concepts on test ranges and air platforms.

(U) *High Energy Laser Technology:* A laboratory test bed is being assembled to explore Multi-Conjugate Adaptive-Optics (MCAO) compensation for atmospheric distortions. MCAO should provide enhanced performance in certain stressing scenarios. The lab should be assembled and initial results obtained by the end of the year. A new multi-node cluster has been installed to run the wave-optics propagation code, and the code has been upgraded to model MCAO. A high-brightness beam-combined slab-coupled optical waveguide laser (SCOWL) is being developed; it will be the highest power diffraction-limited diode laser by more than an order of magnitude.

FY 2004 Plans:

(U) *Biological Agent Detection Systems*: We will continue the Urban Testbed initiative and conduct a series of comparative technology evaluations of both individual and networked sensors. The BAWS/CANARY prototype will be evaluated in field measurements, and compared to the best available detect-to-warn systems in current use. Work will continue on development of screening probes for the rapid (non-PCR-based) detection of pathogens with the goal of obtaining rapid pathogen diagnostic techniques. The anti-viral work will continue, and we will expand the bioinformatics initiative to include development of pathogen signatures via a diverse set of techniques.

(U) *3D Laser Radar*: Development of laser-radar technologies for applications of advanced ballistic and tactical seekers, surface surveillance, and combat identification. This includes the development of visible and near-infrared-sensitive, eye safe, Geiger-mode avalanche photodiode arrays with bonded timing circuitry for 3-D laser radars. Integrate these systems into small (~150cm^3) lightweight (~1kg), low power, packages consistent with advanced seeker applications, which will provide single-photon-sensitivity and high-precision range resolution for generating detailed 3-D imagery of targets. Continue the development of multi-function laser-radar systems, which combine 3-D imaging and range-Doppler sensing for applications to BMD interceptors, combat identification and foliage penetration. These systems will use the same laser transmitter for incoherent 3-D laser radar, utilizing the avalanche photodiode arrays, and coherent laser radar for range-Doppler imaging. Collect simultaneous Range-Doppler and 3-D images of various targets in order to demonstrate the target-recognition and discrimination capability of the combined measurement modalities using ground and airborne platforms.

(U) Combine laser radar with hyper spectral techniques to achieve 4D systems. Test these systems on ground and air platforms.

(U) *High Energy Laser Technology:* Multi-conjugate adaptive-optics (MCAO) experiments will be conducted in the lab. These experiments will be extended to include non-linear phase conjugation. The wave-optics propagation code will be merged with lethality codes and laser codes to begin to create a "photon birth-to-death" model. The Slab-Coupled Optical Waveguide Laser (SCOWL) laser developed in FY03 will be used to pump a fiber laser in a building-block demonstration for scaling to high power. Exploration of novel Miniature Electro Mechanical Structures (MEMS) chip-based chemical laser that may have significant benefits in reduced weight (e.g., for ABL) will begin.

FY 2005 Plans:

(U) *Biological Agent Detection Systems*: The focus will be on the continued development of advanced sensing constructs that satisfy the criteria for rapid, broad-spectrum detection and identification. A system architecture that, for example, combines the early warning capability of the BAWS/CANARY with the rapid confirmation enabled by direct-DNA detection will have applications in both force protection and facility defense. The informatics initiative will expand to include fusion of data from disparate sources, including sensors, environmental data, weather, people movement, and terrain.

(U) *3D Laser Radar*: Development of laser-radar systems for applications in advanced ballistic and tactical seekers, surface surveillance, and combat identification to demonstrate operational form, fit, and function. This includes efforts at electronics miniaturization using Application Specific Integrated Circuits (ASIC) components to generate systems that show a direct development path to fit on a seeker, hand carried sensor, or small UAV.

(U) *High Energy Laser Technology*: Test new compensation algorithms in the lab. Complete "photon birth-to-death" model. Demonstrate combined spectral and coherent beam combining for high-power fiber lasers. Continue to explore Miniature Electro Mechanical Structures (MEMS) chip-based chemical laser.

Advanced Electronics Technology	FY 2002	FY 2003	FY 2004	FY 2005
Accomplishment/ Effort Subtotal Cost	6.293	7.592	7.723	7.520

FY 2002 Accomplishments:

(U) 4Mb SRAMs, finite-impulse-response filters, and other test chips were fabricated in a 180-nm fully depleted SOI CMOS process developed in-house for use in DoD applications, such as, 3-D stacked focal planes, cryogenic readouts, and space electronics. These SRAMs provide a test vehicle to evaluate and enhance process yield and to study the performance limitations of deeply scaled SOI CMOS in DoD applications, such as, space radiation environments. CCD focal plane technologies were developed in support of next generation space surveillance systems and high-speed imaging of explosions. Mask design was completed for a CCD/CMOS imager with on-chip A/D and control. A low power 250 Msps charge domain A/D converter was fabricated and tested, and the technology has been transferred to industry. Avalanche photodiodes and readout circuits to support ladar-imaging systems were further developed, and used in prototype systems to evaluate capabilities for foliage and camouflage penetration. Dense vertical interconnect processes were developed for the next generation of multi-layer focal planes. Approaches for realizing molecular electronic switches were explored, to address future needs for nanoscale electronic devices. Photon counting detector technologies were extended into the near infrared part of the spectrum. The reliability of a microelectromechanical RF switch invented at Lincoln Laboratory was studied, and operation exceeding 40 billion cycles was demonstrated. An optically sampled A/D converter testbed was fielded at the HAX imaging radar and used to directly downsample the radar IF; combined with other recent improvements in photodetectors and calibration algorithms, the key technologies needed for using optical sampling for wideband radars have now been demonstrated. The design was completed and fabrication is underway for the first tests of a new high brightness semiconductor laser being investigated for IRCM and other laser illuminator applications.

FY 2003 Accomplishments

(U) Developed materials and component technologies that provide transformational opportunities for DoD. Initiated design of ultra low power active-pixel imagers capable of day/night imaging for use in unattended ground sensors. Began fabrication of a CCD/CMOS imager with integrated control electronics and readout. Completed testing of first fabrication lot of 4Mb fully depleted SOI/CMOS SRAM yield test structures, and identified process changes to further improve yield of process; applied the SOI process technology to advanced 3-D stacked focal planes, LADAR focal planes, and space electronics. Extended photon-counting detector array technology to 1.0-1.5 μm, and developed materials for further extension to the 2-4 μm wavelength range, and improved detection efficiency, dark count rate, fill factor, and pixel pitch of visible and near-IR detector arrays. Continued development of nanoscale device and process technologies to enable logic and memory at nanometer feature sizes, with emphasis on molecular approaches. Continued development of advanced integration technologies for microwave and millimeter-wave RF systems, with emphasis on techniques for integration of passives and frequency control elements. Fabricated and tested SCOWL high-brightness diode lasers and demonstrated applicability to high power arrays. Continued work on biologically based sensors. Continued our technology transfer efforts.

FY 2004 Plans:

(U) Focus on component technologies that apply 3-D integration to build smart focal planes and high-clock-rate low-power digital processing functions, and fabricate 3-D circuit prototypes as a research foundry for the DoD design community. Demonstrate highly integrated imager with digital output in an optimized low-power-consumption configuration suitable for micro-sensor use. Continue development of UV, visible, IR and hyper spectral imaging devices with on focal plane processing for "smart" multimode sensors. Demonstrate optimized super-wideband Electromagnetic Intelligence (ELINT) compressive receiver in airborne field test. Continue development of optically sampled A/D and wideband photonic waveform generator technologies for radar and electronic intelligence use. Develop component integration technologies including integrated passives and frequency control elements, silicon active RF components, and MEMs switches, enabling low-cost, miniaturized receiver-on-a-chip and receiver-in-a-package solutions tailored to DoD applications. Explore low-voltage CMOS/SOI analog and digital circuits for cryo-cooled focal-plane and special-purpose processing applications, including combinations with superconductive and optical devices. Continue work to extend the scaling of integrated circuits to nanometer dimensions, including emerging techniques such as molecular electronics. Demonstrate key building blocks for high-power lasers using spectrally and coherently combined fiber or diode lasers. Continue work on biologically based sensors. Continue our technology transfer efforts to industry.

FY 2005 Plans:

(U) Develop technologies for focal planes which enable new approaches to DoD electro-optical sensors, with emphasis on improved photon-counting arrays and related readout circuits, three-dimensionally integrated detectors and mixed-signal readout circuits, and unique designs and processes for ultra-low power operation, high data collection rates, or operation in stressing environments. Develop technologies for highly integrated RF front ends, including silicon-based transceivers for use in low cost and reconfigurable RF systems. Continue development of advanced electro-optical and cell-based bio-defense sensors. Continue development of solid state and semiconductor laser illuminators for active sensing, countermeasures, and high power laser applications. Develop new approaches to electronic devices to allow continued scaling and performance improvements for defense and commercial electronics. Continue our efforts to transition technology to a wide range of DoD system demonstrations, and to industry for volume manufacturing.

Counter Terrorism Technology	FY 2002	FY 2003	FY 2004	FY 2005
Accomplishment/ Effort Subtotal Cost	0	2.422	2.464	2.399

FY 2003 Accomplishments:

(U) *Bio-Aerosol Sensing System*: Develop a system concept for stand-off imaging of bio-aerosols. The efficacy of sensing bio-aerosols using multi-spectral and hyperspectral sensing is evaluated in a test chamber. The chamber contains aerosol generators and optical sensors for quantitative measurements.

(U) *Urban Bio Testbed*: The objective of this effort is the testing of sensing technology for biodefense in realistic urban areas, the analysis of the background aerosol composition, and the generation of discrimination algorithms to alert the response community. FY03 will continue the long-term measurements of aerosols, airflows, and trains in a subway station. An initial algorithm for detecting unusual aerosols will be improved and assessed. Additional measurements of aerosol conditions in a sporting arena and in airport terminals will be analyzed. An additional subway station will be instrumented in FY03. Measurements of potentially interferent background conditions in a municipal water system will be made, along with an assessment of the performance of water sensors in those conditions.

FY 2004 Plans:

(U) Focus on developing solutions to finding and tracking terrorists, their associates, and their assets. Technologies to be pursued in this area are (1) cognitive sciences: multi-source information processing, needle-in-a-haystack data sorting, person ID/recognition, and evidence accrual; (2) optical and electronic devices; (3) sensors and sensor systems: bistatics; stand-off detection of firearms, explosives, chem/bio, nuclear material and personnel; (4) covert communications: LPI/LPD, low power consumption; and (5) dismounted soldier electronic technologies: integration of communications, navigation and surveillance capabilities; lightweight power sources. The work ranges from individual devices to full-up systems.

FY 2005 Plans:

(U) Continue focus on solutions to finding and tracking terrorists, their associates, and their assets.

(U) New biometric approaches will be investigated, to include identification and tracking of individuals by their unique markers, including effluents, DNA, RNA and physical features.