Fiscal Year (FY) 2005 Budget Estimates Exhibit R-2, RDT&E Budget Item Justification							Date: February 2004	
Appropriation/Budget Activity RDT&E., DW BA2				R-1 Item Nomenclature: Lincoln Laboratory 0602234D8Z				
Cost ($ in millions)	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	
Total PE Cost	26.056	26.830	25.441	26.854	27.367	27.752	28.349	

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 technology thrusts:

(U) *Surveillance Systems*, with emphasis on revolutionary sensing techniques, algorithms for detecting and recognizing battlefield targets both in the clear and in difficult deployments, and high performance computing to enable rapid prosecution of suspected targets. The advanced sensing techniques include simultaneous multi-mode operation to improve the ability to monitor multiple ground surveillance sites. These improvements are complemented with innovations in algorithm techniques to efficiently extract information from multi-modalities operation. Develop signal processing computing architectures to respond in real-time on-board the sensor platform. The multi-modality sensing is fused with archived data to improve target ID and classification. These techniques will enable dramatic improvements in ground surveillance targeting, identification and classification.

(U) *Communications and Decision Support*, with emphasis on high bandwidth, low probability of intercept, jam resistant communication links and machine-to-machine applications that operate over a network of these links. Links include advanced antenna designs, RF technology, and high-rate fiber and free-space optical communications systems. Develop 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. Develop unique intrusion detection/response techniques to protect computer networks and applications that fuse information for presentation to decision makers.

(U) *Applied Optics*, including advanced 3D laser radars (ladars), high-energy-laser (HEL) technology, and active and passive hyper spectral imaging (HSI). The ladar efforts develop and test advanced concepts in both 3D direct detection ladar and in coherent ladar. These ladar efforts are providing the enabling technology for a variety of new DoD systems, including target identification systems as part of the Army Future Combat Systems (FCS) and discrimination systems for advanced ballistic-missile-defense (BMD) seekers. The HEL technology efforts focus on improving beam control for stressing atmospheric conditions (e.g., tactical HELs in near-surface engagements) and on developing novel, more efficient lasers to reduce the size and weight of future HEL systems. The HEL efforts will potentially enable future HEL systems, such as Block upgrades to the Airborne Laser (ABL) and an Advanced Tactical Laser with a solid-state laser as the weapon laser. The HSI efforts have been principally focused on active sensing and the combining of HSI sensing with ladar sensing.

(U) *Advanced Electronics Technology*, with emphasis on development of materials, devices, and

subsystems utilizing microelectronic, photonic, biological, and chemical technologies to enable new system approaches to DoD sensors. Specific focus areas include work on low power and high sample rate analog 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) *Bio-Chem Defense*, including technology, analysis and systems aimed at defeating enemy use of biological and chemical weapons, and includes efforts in agent detection, diagnosis and treatment, and informatic systems. Agent detection is aimed at rapid, accurate, and sensitive methods for collecting, analyzing and reporting the presence of a biological or chemical agent, and involves analysis of chemical and physical properties of the agents, such as DNA, RNA, antigens and various other proteins. Both stand-off (remote) detection and point sensors are included. Treatment methodologies include novel anti-viral techniques that open new immune-system pathways for biological-warfare agent-induced diseases that might otherwise be untreatable. Bioinformatics systems are specifically targeted at the analysis of micro array images, applying first to pattern recognition techniques for agent identification, but expanding into large integrated systems.

Program Change Summary:

	FY 2003	FY 2004	FY 2005
Previous President's Budget	26.769	27.231	26.514
Current FY 2005 President's Budget	26.056	26.830	25.441
Total Adjustments	-.713	-.401	-1.073
Congressional program reductions			-1.073
Congressional rescissions			
Congressional decrease	-.713		
Reprogrammings			
SBIR/STTR Transfer			
Other			

	Fiscal Year (FY) 2005 Budget Estimates Exhibit R-2a, RDT&E Project Justification						Date: February 2004	
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Project Name or Future Naval Capability /No./Subtotal Cost	26.056	26.830	25.441	26.854	27.367	27.752	28.349	

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(U) *Surveillance Systems*, with emphasis on revolutionary sensing techniques, algorithms for detecting and recognizing battlefield targets both in the clear and in difficult deployments, and high performance computing to enable rapid prosecution of suspected targets.

(U) *Communications and Decision Support*, with emphasis on high bandwidth, low probability of intercept, jam resistant communication links and machine-to-machine applications that operate over a network of these links

(U) *Applied Optics*, including advanced 3D laser radars (ladars), high-energy-laser (HEL) technology, and active and passive hyper spectral imaging (HSI).

(U) *Advanced Electronics Technology*, with emphasis on development of materials, devices,

and subsystems utilizing microelectronic, photonic, biological, and chemical technologies to enable new system approaches to DoD sensors.

(U) *Bio-Chem Defense,* including technology, analysis and systems aimed at defeating enemy use of biological and chemical weapons, and includes efforts in agent detection, diagnosis and treatment, and informatic systems.

B. Accomplishments/Planned Program

Surveillance Systems	FY 2003	FY 2004	FY 2005	
Accomplishment/ Effort/Subtotal Cost	4.938	5.023	4.891	

FY 2003 Accomplishments:

(U) *Advanced High Performance Computing Technologies*: Developed advanced Very Large Scale Integration (VLSI) technologies for implementation of a wideband, Electronic Counter Measures (ECM)-resistant receiver for Space-Based Radar and other multi-modality sensing applications. Demonstrated integrated small size, weight and power technologies to achieve high computation throughput with very low latencies. Implemented a heterogeneous architecture to permit real-time robustness against ECM.

(U) *Surface Surveillance Phased Array System*: 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.

(U) *Parallel and Distributed Processing*: Develop innovative techniques to distribute processing load across multiple computing nodes based on an easy to use interpretive language. This technology provides several factors of improvement in rapid prototyping and development of advanced signal processing concepts.

FY 2004 Plans:

(U) *Advanced High Performance Computing 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.

(U) *Surface Surveillance Phased Array System*: 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. Characterize and quantify sensor performance to detect targets in the presence of high levels of ground clutter and other signal interferers.

(U) *Array Element Level Digitization*: Develop innovative architectures to enable digitization at the element level. Integrate digital signal processor with radiating antenna manifold. These architectures will eliminate the existing complexity present with more conventional analog hardware architecture.

(U) UAV Video Exploitation: Plans include developing video processing algorithms to process large amounts of video data from Unmanned Air Vehicles (UAVs) presently overloading image analysts and precluding fast turn around responses. Rapid confirmation of suspected targets will be enabled by correlating multiple frames to quickly identify mobile threats within a 3-D scene under surveillance.

(U) *Parallel and Distributed Processing*: Continue development of techniques to implement signal processing algorithms across a number of heterogeneous computing platforms. Demonstrate unique approaches on small cluster of computing nodes.

FY 2005 Plans:

(U) *Surface Surveillance Phased Array System*: Demonstrate prototype system instrumented on-board of a sensor platform. Applied advanced signal processing algorithms to collected data to verify predicted performance.

(U) *Array Element Level Digitization*: Develop hardware design and build concept hardware with key enabling technologies. Begin demonstration on a sub-scale prototype.

(U) UAV Video Exploitation: Demonstrate video processing algorithms based on representative scenario data. Quantify improvements compared to today's conventional approaches. Implement algorithms in real-time on-board an experimental Navy airborne sensor platform.

(U) *Parallel and Distributed Processing*: Exercise highly efficient distributed processing across a larger node cluster. Address challenges in fault tolerance and reallocation of computing resources for close to real-time performance.

Communications & Decision Support	FY 2003	FY 2004	FY 2005	
Accomplishment/ Effort/Subtotal Cost	4.548	4.627	4.505	

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) *Defensive Information Warfare*: Developed robust collaborative applications for network-centric operations involving wireless airborne and ground operations, which are subject to both varying link problems and information attacks. Near term focused on robust, secure chat to support airborne C4ISR in the Multi-mission C2 Constellation environment

(U) *Airborne C2 Node*: Used the Air Force Command and Control Constellation Test bed (Task Force Paul Revere) to test new communication, command, and control concepts for ISR and weapon targeting. Developed an integrated multi-intelligence (multi-INT) surface target detection system by combining Signal Intelligence (SIGINT) cues with high-resolution SAR imagery. This work was the first step towards integrating synoptic and narrow field-of-view sensors of the reconnaissance/strike lattice.

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 Information Assurance in a packet topology, revising network control to provide both tactical on-demand connectivity and transient provisioning of large data pipes for sensor flows.

(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 Paul Revere Test bed 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. 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.

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 war fighter.

(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 Paul Revere Test bed 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. Extend system to include multiple synoptic and narrow field-of-view 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).

Applied Optics	FY 2003	FY 2004	FY 2005	
Accomplishment/ Effort Subtotal Cost	4.264	4.337	4.223	

FY 2003 Accomplishments:

(U) *Laser Radar*: Developed laser radar technologies for applications to advanced ballistic and tactical seekers and combat identification. Demonstrated fully-functional 32 x 32 arrays of InGaAs Geiger-mode avalanche photodiodes at the 1.0-micron wavelength. Focused 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. Investigated high-efficiency alternative transmit lasers for 3-D imaging systems that enable further miniaturization. Continued the development of multi-function laser-radar systems, for

applications to Ballistic Missile Defense (BMD) interceptors, combat identification and foliage penetration.

(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.

(U)*Hyper spectral Imaging*: A system concept for stand-off imaging of bio-aerosols has been developed. The efficacy of sensing bio-aerosols using multi-spectral sensing has been evaluated in a test chamber.

FY 2004 Plans:

(U) *Laser Radar*: Develop 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 (~150 cm^3) lightweight (~1 kg), 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 and the same photon-counting avalanche photodiode array for both direct-detection laser radar for 3D imaging 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) *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 real-time decision aids to help optimize the performance of HELs in varying atmospheric conditions will begin.

(U) *Hyper Spectral Imaging:* HSI measurements will be combined with 3D ladar measurements to explore the utility of 4D systems.

FY 2005 Plans:

(U) *Laser Radar*: Develop 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. Implement a proof-of-principle real-time decision aid.

Advanced Electronics Technology	FY 2003	FY 2004	FY 2005	
Accomplishment/ Effort Subtotal Cost	7.374	7.501	7.303	

Bio-Chem Defense	FY 2003	FY 2004	FY 2005	
Accomplishment/ Effort Subtotal Cost	4.932	5.342	4.512	

FY 2003 Accomplishments:

(U) *Agent Detection Systems*: Developed a prototype sensor that combines the rapid trigger feature of the Bio-Aerosol Warning System (BAWS) sensor and the rapid identification capability of the B-cell based CANARY. A multi-channel breadboard instrument has been fabricated that demonstrates real-time bio-detection/identification capability, with applications in military force and facility protection. The sensor system is ready to be fielded in FY04. Also, continued development of a non-PCR (polymerase chain reaction) based approach to detection of DNA. Thirdly, completed building of lab system for interrogating individual suspect biological aerosol particles.

(U) *Diagnosis and Treatment*: Initiated exploration of chemical signatures of bacteria not normally observed in the breath of healthy individuals, to establish high-confidence early markers of infection. Continued laboratory proof-of-concept development of anti-viral therapies with significant milestone in curing common cold *in vitro* without affecting normal host cells.

(U) *Bioinformatics*: Initiated efforts in applying automated target recognition techniques developed for military target discrimination to the problem of identifying biological agent DNA signatures from micro array data and images.

(U) *Facility defense*: Concluded measurements program addressing a subway, an arena, an airport terminal, and in the process of documenting findings on background and other conditions that affect a variety of potential biological or chemical agent targets.

FY 2004 Plans:

(U) *Agent Detection Systems*: Plans include fielding the combined BAWS-CANARY in refereed trials against simulant agents to determine effectiveness of sensor relative to other fielded and prototype systems. Initiating new efforts in improving logistics of CANARY sensor, particularly addressing cell lifetime in storage and handling. Concluding effort in analyzing individual bio-aerosol particles. Also, initiating efforts aimed at taking advantage of bacterial cell signaling as sensor modality. Toxins and standoff sensing also to be addressed.

(U) *Diagnosis and Treatment*: Continue exploration of chemical signatures of bacteria in the breath, looking for new exudates. Continue work on anti-viral therapies.

(U) *Bioinformatics*: Continue efforts in applying automated target recognition techniques to micro array data and images, working toward building a pathogen signature data base.

(U) *Facility defense*: Initiate efforts aimed at neutralizing agents in ventilation systems, utilizing aerosol chamber and germicidal ultraviolet light.

FY 2005 Plans:

(U) *Agent Detection Systems*: Based on data from field trials, design and begin to prototype compact BAWS-CANARY sensor, combined as practicable with rapid DNA analysis. Continue efforts in improving toxin response and logistics of CANARY sensor, emphasizing dried-cell techniques. Continue efforts aimed at taking advantage of bacterial cell signaling as sensor modality. Advanced standoff sensing designs to be considered.

(U) *Diagnosis and Treatment*: Expect to build prototype breath analysis instrument and conduct limited field testing. New biometric approaches will be investigated, to include identification and tracking of individuals by their unique markers, including effluents, DNA, RNA and physical features. Continue work on anti-viral therapies.

(U) *Bioinformatics*: Expand bioinformatics effort into analyzing signatures from a network of chemical and biological sensor systems, to include fusion of data from disparate sources, environmental data, weather, people movement, and terrain.

(U) *Facility defense*: Based on FY 2004 results, conduct field testing of ultraviolet light neutralization systems and other advanced techniques.
ultraviolet light.