SuperUROP Projects

“Wireless Anomalies Have No Place to Hide”

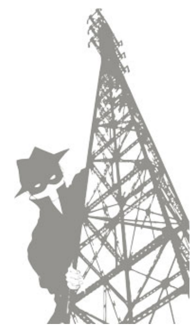
Faculty Advisor:

Mentor(s): W. Mark Smith, PhD

Contact e-mail: wireless-student@ll.mit.edu

Research Area(s): Cyber Systems and Operations

UROP researchers will investigate incorporating transactions in wireless protocols into anomaly detection and response systems. Research topics will include monitoring at the RF layer to complement existing anomaly detectors at the network layer, monitoring and computing resources needed to identify and track anomalous behavior, and responses at the RF layer when anomalies are identified. Given an understanding of anomalous wireless activity, the researcher will develop realistic wireless mobile user application models and incorporate them into an existing emulation infrastructure exercising all layers of the protocol stack.



“HLT-Based Advanced Analytics”

Faculty Advisor:

Mentor(s): William Campbell, PhD

Contact e-mail: wcampbell@ll.mit.edu

Research Area(s): Human Language Technology

UROP researchers work with teams in the Human Language Technology Group to research and develop algorithms for analyzing large collections of speech and text. The effort may include the extraction and analysis of semantic content (names, topics, etc.), social networks, and geo-spatial information. Processing may also include multi-lingual data requiring machine translation. Possible UROP projects include social network analysis, data visualization, and information retrieval based on semantic knowledge. This role involves programming, using machine learning methods, applying text and speech processing algorithms, and presenting results to a technical audience. The work is expected to be challenging, interesting, and involve real data.

“Finding Needles in Needlestacks”

Faculty Advisor:

Mentor(s): Steve Smith, Frederick Waugh

Contact e-mail: stsmith@ll.mit.edu, fwaugh@ll.mit.edu

Research Area(s): Computing and Analytics

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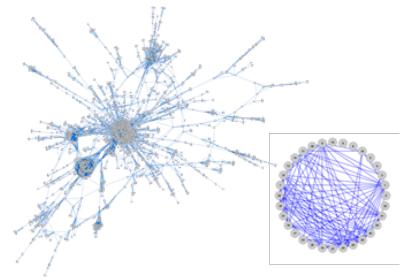
UROP researchers will take part in state-of-the-art research in the rapidly evolving field of data analytics. This research involves devising novel approaches for ingestion and enrichment of high-velocity, high-volume data, developing new information-theoretic analytic approaches, and applying recent innovations in machine learning and visual analytics to human-machine integration. Tools developed during the course of this research will be applied to a variety of data sources, including social media and geo-tagged event data.



"Securing Our Cyber Future"

Faculty Advisor:

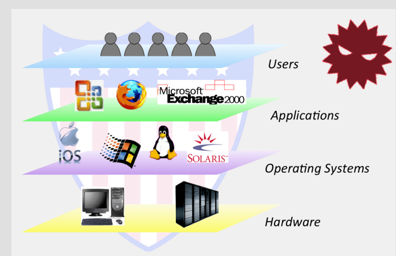
Mentor(s): Hamed Okhravi, Roger Khazan, Kyle Ingols

Contact e-mail: hamed.okhravi@ll.mit.edu, rkh@ll.mit.edu, kwi@ll.mit.edu

Research Area(s): Secure Resilient Systems and Technology

UROP researchers in the Cyber Systems and Technology Group will work on assessing and improving the security of U.S. government systems. Researchers will be mentored by world-class cyber security experts and have the opportunity to study, develop, and prototype innovative cyber security technologies.

Researchers join R&D teams in cyber science and analysis, resilient cyber architectures, or secure embedded platforms. Past projects include cyber sensors and analytics, secure clouds, applied cryptography and key management solutions, cyber decision support tools, and secure embedded processors. UROP researchers are encouraged to participate fully in the group's activities and attend a variety of seminars.



"Assessing the cyber-vulnerabilities of wireless power"

Faculty Advisor:

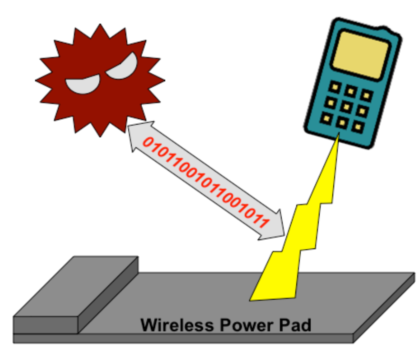
Mentor(s): Kevin B. Bush

Contact e-mail: kevin.bush@ll.mit.edu

Research Area(s): Cyber Systems and Operations

Technology for short-range wireless power transmission is poised to revolutionize the way we charge consumer electronics and defense systems. However, it remains unknown what cyber-risks this technology presents to the host systems it powers. *Is wireless power fundamentally more susceptible to denial of service (DoS) than traditional means? Can wireless power signals be remotely and maliciously altered to cause permanent physical damage? What novel cyber attack-vectors do wireless power systems present to the systems they charge?* This project seeks to answer those questions and more by identifying cyber weakness and profiling wireless power standards, characterizing the fundamental cyber-security vulnerabilities of wireless power transmission, and demonstrating a cyber-attack against a real wireless power platform.

Engaged in a wide range of cyber security-related activities, the Cyber



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System Assessments Group is focused on analyzing, understanding, and assessing cyber systems, including red teaming, system exploitation, building cyber range infrastructure, and conducting tests and evaluations of cyber capabilities.

UROP researchers will work with a team to support one of four project areas: 1) the test and evaluation (T&E) of national cyber capabilities and systems, including the development of new test methodologies and metrics for evaluation; 2) the development of new technologies and infrastructure for "cyber ranges," which are large, isolated network and physical environments in which potentially disruptive cyber capabilities can be safely explored; 3) the reverse engineering and exploitation of software and embedded systems; and 4) the red teaming and vulnerability assessment of cyber systems.

"Low-Frequency Antenna Design for Small UAV Foliage Penetrating Radar"

Faculty Advisor: TBD

Lincoln Mentor(s): Jason Franz, Pamela Evans

Contact e-mail: franz@ll.mit.edu, evans@ll.mit.edu

Research Area: Electromagnetics / Antennas

UROP researchers will develop and evaluate designs for low-frequency antennas suitable for a small foliage-penetrating synthetic aperture radar (SAR) system. The entire radar system, including four antennas to support adaptive beamforming, needs to fit within two pods mounted to a small Unmanned Air Vehicle (UAV) platform. Each pod provides only 2-3 ft of length to accommodate the antennas, transmit and receive hardware, and on-board processor. The antennas need to operate in the UHF radar band from 250-450 MHz, where the electromagnetic signals can penetrate foliated areas to image objects below. A key design challenge will be to impedance match the antennas over this bandwidth and maintain pattern and gain while fitting the antennas into a small form factor, within close proximity of the other radar hardware. The UROP researchers may evaluate the ability to support dual linear polarization versus a single linear polarization, and may investigate designs that utilize active tuning across the UHF band to support a stepped-frequency waveform. The project will require antenna design and modeling, antenna fabrication and tuning, and pattern/gain measurements in an anechoic chamber. Facilities at MIT Lincoln Laboratory may be utilized to support the fabrication and measurement work.

"Analysis and Design of Object Tagging Systems"

Faculty Advisor:

Lincoln Mentor(s): Janet Hallett

Contact e-mail: jhallett@ll.mit.edu

Research Area: Small Sensor Technologies

UROP researchers will perform an assessment of small form-factor tags that can be used to detect, locate and track moving ground objects of interest from long physical ranges. Different sensor modalities should be considered in the assessment. Strawman designs

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will be developed to include both the tag and the read-out system, and potential performance will be predicted through physics-based modeling. Key performance metrics will include tag detection range, tag form factor, tag signal persistence, and overall tag lifetime. The UROP researcher may also build hardware for one or more promising tag concepts, and perform proof-of-concept measurements to validate modeled results.	
"Soft-core Microprocessor Infrastructure for a Graph Processing Cluster" Faculty Advisor: TBD Lincoln Mentor(s): Vitaliy Gleyzer, William Song Contact e-mail: vgleyzer@ll.mit.edu, song@ll.mit.edu Research Area: Advanced Graph Processor Architecture	
The project involves developing components of the novel high-performance graph processor that will be able to perform state-of-the-art graph analytics on large databases. The student would implement and design a soft-core microprocessor subsystem to enable the control infrastructure for an FPGA-based graph processing cluster. It would consist of evaluation and selection of real-time operating systems, design and integration of busses and peripherals for various graph computing modules, as well as implementation of an RTOS software framework for the Graph processor instruction set. Pre-requisites: Advanced Digital Design, Operating Systems, VHDL, C/C++	
"Embedded, Real-time 3D Perception for Robot Autonomy and Augmented Reality Display" Faculty Advisor: TBD Lincoln Mentor(s): Nicholas Armstrong-Crews Contact e-mail: nickarmstrongcrews@ll.mit.edu Research Area: Embedded Processing Architectures for Perception	
Emerging 3D sensors provide a wealth of information that simplifies common perception tasks (a pre-requisite for robot autonomy and natural human-robot interaction); however, standard computing methods cannot keep up with this big data stream to react in real-time, especially on platforms with constrained size, weight, and power. This project intends to explore tightly-integrated, embedded sense/compute architectures that exploit data parallelism, including FPGAs, GPUs, and digital focal plane arrays used in conjunction with LIDAR, stereo, and structured light sensors.	
"Modeling Open Architecture Standards" Faculty Advisor: TBD Lincoln Mentor(s): Eddie Rutledge, Stacy Doyle Contact e-mail: rutledge@ll.mit.edu, sad@ll.mit.edu Research Area: Model-Aided Software Architecture, Simulation, and Verification	

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Software open architecture (OA) standards define standard architectural elements, interfaces, and rules for composition in building software systems. Software architecture modeling can help predict and validate aspects of a software system such as performance, reliability, availability, and correctness. This research will focus on modeling OA standards and the systems that conform to them. Research topics could include characteristics of an OA standard that enable or simplify modeling of conformant systems, capabilities and limitations of existing modeling tools and techniques in modeling OA conformant systems, the modeling and analysis of an OA standard itself to determine general properties of all conformant systems, and the specification of OA standards and conformant systems as formal models.	
“Multi-Input Multi-Output Processing for Feature Extraction and Detection” Faculty Advisor: Lincoln Mentor(s): Huy Nguyen Contact e-mail: hnguyen@ll.mit.edu Research Area: Multiple Aperture Sensing	
This project explores a generalized MIMO framework and distributed computation techniques for feature extraction, detection, and tracking from multi-channel “sensors”. A diverse set of application areas will be considered including: millimeter-wave imaging, focal-plane array imaging, and cyber activity monitoring.	
“3D SAR Image Formation using a Unmanned Air Vehicle” Faculty Advisor: TBD Lincoln Mentor(s): Dan Rabinkin Contact e-mail: rabinkin@ll.mit.edu Research Area: Small Form Factor Radar and SAR Processing	
Traditional SAR imagery is formed from flying platforms that sweep out linear aperture and produce 2-D images. A hovering UAV can be used to sweep out a 2-D aperture and produce 3-D imagery. Three-dimensional SAR imagery, combined with proper display tools, can provide details of structures and obstructions to soldiers and rescue workers, and provide an enhanced mapping capability to render terrain in hyper-real detail. Advances in UAV platform design, miniaturized RF receivers, and miniaturized and high precision differential navigation systems can be combined to integrate a system capable of producing focused 3-D SAR images. This research will focus on component system architecture and COTS component integration leading to a platform prototype.	
“Theoretical and Practical MIMO Radio Communication Techniques in Congested Spectrum” Faculty Advisor: Lincoln Mentor(s): Adam Margetts	

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Contact email: margetts@ll.mit.edu Research Area: Wireless Communications	
Multiple-input multiple-output (MIMO) radio systems are beginning to dominate the commercial wireless communication world with their promise to increase data rates and extend range. The application of this technology to applications to situations where a large number of strong interference sources are present is still in its infancy. This project would consist of examining with the mentor algorithms relevant to this scenario and building a Matlab simulation with realistic channel models to test the selected algorithms. The student would be immersed in all aspects of modern communication theory from the physical layer to the network layer.	
"Theoretical and Practical MIMO Radio Communication Techniques in Congested Spectrum" Faculty Advisor: Lincoln Mentor(s): Keith Forsythe Contact email: forsythe@ll.mit.edu Research Area: Wireless Communications	
In challenging environments (e.g., underwater acoustic or skywave RF channels) signals suffer from distortions associated with time and Doppler spreads introduced by the propagation medium. These distortions create difficulties for the implementation of spatial filtering as employed by multi-sensor receiving arrays. With only delay spread, signal energy can be localized in separate frequency cells; each cell can use conventional array processing for spatial filtering. The dual problem with only Doppler spread also reduces to a known solution. The inability to localize in both time and frequency makes signal processing much more difficult when both distortions are present. The level of performance becomes highly dependent on the signal processing architecture and is affected by the ability to train the spatial filters in a dynamic environment. This project will explore the design and performance of various architectures for spatial filtering of signals with large delay-Doppler spreads.	
"MU-MIMO-MUD Systems" Faculty Advisor: Lincoln Mentor(s): P. D. Fiore Contact e-mail: pfiore@ll.mit.edu Research Area: Signal Processing and Communications	
Usage of wireless communications devices will continue to increase, and optimization of spectrum usage will become paramount. Advanced signal processing techniques, such as multi-user-detection (MUD), can allow much higher effective use of RF channels, especially when coupled with multi-input, multi-output (MIMO) transmission schemes. However, the efficacy of these techniques, as well as the cost of implementation, will be a function of the symbol constellations chosen for the communications. In this project, we will investigate multiuser MIMO symbol constellations for commercial and personal	

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wireless communications. Explore combinations of scale-recursive constellation designs, OFDM, and STBC to achieve higher throughput than current QAM approaches.	
“Reinforcement Learning for Multi-Agent Markov Games” Faculty Advisor: Lincoln Mentor(s): David Browne Contact email: dbrowne@ll.mit.edu Research Area: Communications, Robotics, Machine Learning	
Reinforcement Learning is a class of learning algorithm that allows an agent to autonomously learn how to achieve some goal state through repeated interaction with its environment. These algorithms have demonstrated applicability in sequential decision making problems for robotic navigation and radio communications among others. The project will explore and extend the theory of reinforcement learning in Markov games comprised of two or more agents interacting in either cooperative or competitive games. Open source simulation software will be used as the sandbox for development and experimentation with agents. Options for implementing agent algorithms in software-defined radio networks will be explored.	
“Sharpening of Time-Frequency Representations” Faculty Advisor: Lincoln Mentor(s): Paul Calamia Contact e-mail: pcalamia@ll.mit.edu Research Area: Signal Processing	
The reassigned spectrogram (or time-corrected instantaneous-frequency spectrogram) is a spectral analysis tool often used to determine the precise instantaneous frequencies and associated times of occurrence of spectral components in an acquired signal of interest. It has been described in the literature as an effective method of analysis for, among other things, human speech, animal communications, and music. In this project, we would like to explore various aspects of the reassigned spectrogram including efficient implementations, display methods (specifically artifact removal / de-noising), and extensions to the analysis of other non-stationary signals.	
“Crowd-sourced Exploitation of NGO Data” Potential Faculty Advisors: Rob Miller (CSAIL) Lincoln Mentor(s): Olga Simek Contact e-mail: osimek@ll.mit.edu Research Area: Crowdsourcing	
This project will create a process and tools for extracting and analyzing relevant information from Non-Governmental Organization (NGO) resource collections using crowdsourcing. NGOs produce detailed reports about the situation on the ground in places of interest	

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to the government. However, information in these collections can be difficult or impossible to find using standard search tools, because it is generally unstructured and/or embedded in images. Our goal is to develop effective workflows, task designs and result aggregation algorithms for fast, cheap and accurate crowd-sourced data exploitation. Our basic objective is to develop a prototype system which will utilize workers on an open crowdsourcing platform like Amazon Mechanical Turk to quickly and cost-effectively create intelligence from NGO documents. Crowdsourcing can be used all along the data collection and exploitation pipeline, including: • Identifying potential sources of NGO data • Collecting data from NGO sources • Transforming unstructured data (e.g. images, text) into structured data (e.g. annotated maps, spreadsheets) • Identifying anomalies in charts Analysts today are overwhelmed by an ever-increasing volume of open source data, and methods and algorithms are needed to effectively extract useful data from this valuable information. It has been amply demonstrated that crowds of non-experts can solve complex problems if problems are presented in an accessible way. The first part of an effective strategy for producing fast, cheap and accurate results consists of breaking the problem into small tasks, and using work redundancy and iterative workflows to ensure data accuracy. The second part is to utilize problem-specific worker quality algorithms to correctly aggregate the results. Both parts are active research areas.	
"Quantifying Decision Performance for Early Warning" Faculty Advisors: Sertac Karaman (MIT Department of Aeronautics and Astronautics) Lincoln Mentor(s): Frederick Waugh Contact e-mail: fwaugh@ll.mit.edu Research Area: Decision Support, Resource Optimization, Games	
This research program will explore strategies to improve the utilization of data collection assets using a representative early-warning game. We will quantify the human performance in such scenarios with respect to varying degrees of uncertainty and complexity as follows: 1. We will design a simple (but realistic) structured early warning game that is amenable to mathematical analysis. 2. We will employ mathematical and algorithmic analysis to quantify the best possible performance in the game. More precisely, we will prove (in a mathematically-rigorous way) tight upper bounds on performance. This analysis will employ applied probability theory, stochastic geometry, network science, and percolation theory, which have been employed to analyze similar planning problems [1]. We will also design and implement effective algorithms that perform close to such upper bounds, similar to those developed in [2]. These will help	

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us quantify the optimal performance as a function of both system noise and complexity. 3. Time permitting, we will design and conduct experiments to understand how human performance, simulating current tasking procedures, compares with computed bounds. [1] S. Karaman and E. Frazzoli, "High-speed Flight in an Ergodic Forest," presented at the IEEE International Conference on Robotics and Automation, 2011. [2] S. Karaman and D. Rus, "Persistent Monitoring of Events with Stochastic Arrivals at Multiple Stations," submitted to the IEEE International Conference on Robotics and Automation, 2014.	
"Dynamic Saliency Map Generation for Resource Allocation, Situation Awareness, and Decision-Making" Potential Faculty Advisors: Patrick Jaillet, Alan Willsky, John Fischer Lincoln Mentor(s): Bea Yu, Danelle Shah Contact e-mail: bea.yu@ll.mit.edu; danelle.shah@ll.mit.edu Research Area: Resource Optimization, Data Fusion	
As sensors become more capable, more autonomous, and more ubiquitous in humanitarian, military and scientific discovery missions, it becomes increasingly important for such sensors to self-assess their effectiveness against mission objectives and react to changing needs in real-time. A self-assessment scheme would ideally fuse multiple data sources and consider multiple simultaneous objectives. The output may be used for automatic resource re-allocation, provided to a human operator to maintain Situation Awareness (SA), or shared with collaborating agents to form a Common Operating Picture (COP). For this project, the concept of a "saliency map" will be used to quantify, visualize, and exploit sensor effectiveness. Key research questions to be answered are: how to fuse multiple different data sources into a single "saliency" value, how to quantify "sensor effectiveness" for different mission objectives, and how different saliency maps effect operator situation awareness	
"Nonparametric Multivariate Change Point Detection Using Probabilistic Graphical Models" Potential Faculty Advisors: Alan Willsky, John Fischer Lincoln Mentor(s): Peter Mastromarino Contact e-mail: peterm@ll.mit.edu Research Area: Change and Anomaly Detection, Probabilistic Graphical Models	
Multivariate change point detection is a common statistical analysis task with applicability to a variety of problems in different fields in which data correlations and inter-dependencies are important considerations [1]. Traditional methods of detection typically rely on an analysis of the means and covariance matrix of the variables involved in order to detect changes [2]. Being thus sensitive to only the first and second moments of the data, however, such methods are	

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extremely limited in the types of changes they are able to detect. These limitations can be partially addressed by expanding to the third moments and beyond, but such a strategy is statistically inefficient, since many of the moments share statistical support and are therefore coupled. Nonparametric approaches offer a way out of such statistical inefficiency by attempting to model and detect changes in the underlying structure of the full joint probability distribution function (pdf) governing the random variables [3]. As the number of random variables grows, however, it quickly becomes intractable to model the full joint pdf, or even its compact representation (such as Bayesian network graphical models). This project will leverage recent advances in efficient sampling techniques for estimating the distribution of possible pdf representations [4] in order to build a system capable of detecting change points in multivariate time series and of providing estimates of their uncertainty. Elements of the project will include a development of the mathematical theory underlying the techniques as well as prototype development of the user interface. The tools will be tested using a combination of synthetic and real-world, publicly available data sets, such as Congressional voting records (to automatically detect from voting patterns alone events such as elections) and financial market data (to detect significant market events). [1] J. Reeves et al., "A review and comparison of changepoint detection techniques for climate data," J. Applied Meteorology and Climatology, Vol. 46, pp. 900 – 915 (2007). [2] M. Lavielle, G. Teyssière, "Detection of multiple change points in multivariate time series," Lithuanian Mathematical Journal, Vol. 46, No. 3, pp. 287 – 306 (2006). [3] B. Brodsky, B. Darkhovsky, Nonparametric Methods in Change-Point Problems, Kluwer Academic Publishers, Norwell, MA (1993). [4] N. Friedman, D. Koller, "Being Bayesian about network structure," Machine Learning, Vol. 50, pp. 95 – 125 (2003).	
"Adaptive Multi-vehicle Sensing" Potential Faculty Advisors: Nick Roy, Emilio Frazzoli, Brian Williams, Julie Shah, Jon How, Asu Ozudaglar Lincoln Mentor(s): Bea Yu, Danelle Shah, Dan Griffith, Frederick Waugh Contact e-mail: dan.griffith@ll.mit.edu, fwaugh@ll.mit.edu Research Area: Autonomous Systems, Resource Optimization	
Sensing systems are important for ecological, humanitarian, military and space exploration applications. The aerial sensing domain is rapidly evolving to include autonomous systems. The deployment and control strategies for these systems have both human centric and computational implications. In this study, we will consider different deployment and control strategies for a futuristic multi-vehicle sensing system. Given a dynamic information map model, which responds predictably but stochastically to new information collections and evolves exogenously when no sensing is performed, and a set of N	

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unmanned aircraft resources for sensing, the objective is to optimize the deployment of resources in order to maximize the information content of the resulting map.	
"MIMO Radar Signal Processing" Faculty advisor: TBD LL Mentor(s): John Kay Contact e-mail: jkay@ll.mit.edu Research Area: Antenna Arrays, Waveforms, Signal Processing	
As small and unmanned platforms proliferate, there is an increased demand for them to perform more and varied missions. The limited space on small platforms inhibits the ability to carry large podded phased-array radar systems which are traditionally needed to achieve the required resolution and sensitivity for airborne surface surveillance radar systems. One potential alternative is a distributed, thinned arrays which have reduced size and weight and, when coupled with MIMO signal processing, can regain much of the benefit of larger filled arrays. This project is to explore potential configurations of arrays on mid-size UAVs as well as waveforms strategies to optimize performance for airborne surface surveillance missions.	
"Oscillator Time/Frequency Transfer" Faculty Advisor: TBD Lincoln Mentor(s): Joshua Kantor Contact e-mail: Joshua.kantor@ll.mit.edu Research Area: Wireless Communications, Embedded Digital Systems	
The project is to demonstrate the ability to precisely synchronize oscillators (on widely separated moving platforms using a bidirectional data link (two way time transfer) and FPGA processing. The goal is to show that with this synchronization, coherent integration time in bistatic SAR and TDOA/FDOA processing can be extended beyond the limits imposed by the oscillators' intrinsic low frequency phase noise characteristics.	
"Feature detection and classification algorithms for 3-dimensional data" Faculty Advisor: Lincoln Mentor(s): Luke Skelly Contact e-mail: skelly@ll.mit.edu Research Area: Computer Systems / Computer vision	
Develop new algorithms for feature detection, classification and scene understanding of 3D point clouds collected from ladar systems. In order to scale performance to enormous data sets, new algorithms must be auto-tuning, and this typically requires a rigorous theoretical underpinning based on the physics of the ladar data collection process as well as statistical description of the scene. The codes must be	

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written efficiently enough to handle large data sets. Familiarity with statistical signal processing, data structures (trees, graphs, etc.), and pattern recognition is preferred.	
“Embedded processing of ladar data” Faculty Advisor: Prof. Vivienne Sze Lincoln Mentor(s): Dale Fried Contact e-mail: dgf@ll.mit.edu Research Area: Circuits / Embedded Processing	
Photon counting laser radar systems are highly capable system that can produce high resolution, 3-dimensional maps over large areas at an impressive rate. Typically these systems are big (>1000lbs) and draw sizeable amount of power (>kWs) There is a concerted effort to significantly reduce their size, weight and power by orders of magnitude by using a combination of aggressive packaging and a novel architecture. Photon counting ladar image formation processing requires noise filtering that differentiates detections from actuals surfaces from those due to noise and/or background. Currently such noise filtering algorithms occurs on multi-core CPUs. The goal of the project is to perform this ladar image formation processing on low-power embedded processors. These processing algorithms must be able to keep up with high data rates, implement data compression in hardware to match the limited off-package communication bandwidth. Familiarity with FPGA, embedded processing and data compression techniques is needed.	
“Video Tracking Sidecar and Control System” Faculty Advisor: Lincoln Mentor(s): Seth Trotz, Emily Fenn, Bob Michniak, and James Truitt. Contact e-mail: seth.trotz@ll.mit.edu Research Area:	
Airborne passive imaging sensors can be employed to provide situation awareness and tracking of aircraft. Tracking of unresolved targets at long range can be limited by sensor performance as well as scene complexity or clutter. UROP researchers will work with Lincoln staff to develop a generalized video tracking and control system. This real-time capable system will take as input a choice of digitized video streams and navigational data, apply appropriate algorithms such as spatio-temporal differencing or optical flow, and track one or more objects within the sensor field of view. The system may operate in a passive "sidecar" mode or in an active closed-loop mode in which sensor pointing is also commanded. Experience or interest in implementing a variety of novel algorithms in flexible high-speed image processing hardware such as GPUs or FPGAs to enable rapid prototyping is expected. The system will initially be developed in a laboratory environment and subsequently run in airborne flight tests.	
“Measurement Assisted Modeling of Electromagnetic Scattering”	

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Faculty Advisor: TBD Lincoln Mentor(s): Hsiu Han, Andrew O'Donnell Contact e-mail: hsiu@ll.mit.edu Research Area: Electromagnetics	
This research focuses on the prediction of microwave far-field scattering cross sections of complex and electrically large objects using computational models validated with near-field measurement data. The initial emphasis is to develop understanding of the impact of non-uniform or partial near-field illumination on the model validation process and the accuracy of the resulted far-field prediction. Both measurement and prediction will be performed under this project.	
“Optical Phased Arrays” Faculty Advisor: R. Ram, M. Watts Lincoln Mentor(s): R. Swint, S. Spector Contact e-mail: swint@ll.mit.edu, spector@ll.mit.edu Research Area: optics, photonics	
The optical beam from an array of lasers or optical amplifiers can be non-mechanically steered or used to generate an arbitrary beam pattern by adjusting the optical phase of each array element. The speed and physical robustness of such a non-mechanical beam steering system is a holy grail for many applications ranging from free-space optical communications, LIDAR, or laser printing. While phased array systems have had a huge impact in real-world microwave radar systems, a similar system in the optical domain has proved elusive due to technical challenges. Integrated photonics is potentially part of the solution to realizing practical optical phased array systems. UROP researchers will assist in developing this capability. The researchers will simulate and design photonic integrated circuits (PICs), support internal or external PIC fabrication, characterize devices and subsystems, and/or develop optical phased array control algorithms and real-time software.	
“Wavelength Filtering in Silicon Photonics” Faculty Advisor: R. Ram, L. Kimerling Lincoln Mentor(s): R. Swint, S. Spector Contact e-mail: swint@ll.mit.edu, spector@ll.mit.edu Research Area: Solid state photonics	
UROP researchers will design and develop high quality optical filters that may be implemented in silicon technology. Silicon photonics is a technology which uses silicon as an optical material, so that the vast investment made in the development of integrated electronics can be applied to integrated optics. A common element in an optical system is a wavelength or frequency-selective filter. High quality filters have been demonstrated using resonant devices in silicon photonics, but challenges remain. Depending on the application, these challenges include controlling the resonant wavelength, achieving extremely high resonant quality factors (Qs), and handling large amounts of optical	

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power. Solutions to one or more of these challenges will be investigated.	
"Microladar" Faculty Advisor: V. Sze and/or M. Watts Lincoln Mentor(s): D. Fried, D. Schuette Contact e-mail: dgf@ll.mit.edu, drschuette@ll.mit.edu Research Area:	
UROP researchers will design and implement a scanning ladar system. Ladar sensors have proven themselves a critical component of autonomous navigation systems because they directly measure the 3D character of a scene rather than inferring it indirectly using less reliable computer vision techniques. The size and weight of these sensors and their power requirements have historically precluded their use in small platforms such as UAVs or in low cost 3-D scanners, but technology under development will produce a ladar sensor element the size of a child's thumb whose capacity surpasses that of much larger systems. Research topics include the scanning transmitters and receivers, and 3D image processing chips.	
"Wideband Imaging Radar" Faculty Advisor: TBD Lincoln Mentor(s): B. Perry, F. Robey Contact e-mail: bperry@ll.mit.edu, robey@ll.mit.edu Research Area: RF Electronics / signal processing	
UROP researchers will design, build and test a low cost wideband imaging radar. Radar imaging has many potential uses in defense, homeland security and local security. Recent opening of the frequency spectrum to unlicensed, part 15 operations provides the potential for deployment in broad applications and new circuit technologies have significantly reduced the cost for radar systems. The result is that many new vehicles have radars built in. For this UROP one of the interests is to investigate radar that could assist law enforcement that currently rely only on camera video to determine physical features. Wideband radar imaging algorithm development at many universities is often starved for data. A short range wideband imaging radar system could fill that gap. Under this UROP a low cost, wideband imaging radar will be developed by leveraging microwave motion sensor, vehicle safety radar, or personal communication services technology.	
"Photonics for Quantum Information Systems" Faculty Advisor: R. Ram, D. Englund Lincoln Mentor(s): R. Swint, S. Yegnanarayanan Contact e-mail: swint@ll.mit.edu, siva.yegnanarayanan@ll.mit.edu Research Area:	
The field of quantum information science (QIS) is exploring new	

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paradigms for computing, sensing, and communications based on quantum-mechanical principles. Laser sources and photonic devices are critical to the development of QIS technologies in areas including atom cooling and state manipulation, entangled-photon generation, frequency translation, optical signal switching and distribution, laser stabilization and control, integrated optical isolation, and optical signal detection. The realization of a practical quantum computer will require the integration of atomic or superconducting qbits, photonics, and electronics. Example research projects include development of low-noise high-efficiency lasers at atomic-specific wavelengths, development of monolithic or hybrid photonic integrated circuits (PICs), investigation of novel photonic materials and material platforms, and electronic-photonic integration.	

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