Science & Technology Directorate

Awareness and Localization of Explosives-Related Threats (ALERT)

COE S&T Review

March 21, 2014

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ALERT Overview

**COE Description**
- Conduct Cutting Edge Research to Counter Explosives Threats
- Identify Technology Gaps
- Transition Innovative Technology to the Field
- Collaborate with End Users
- Prepare Students and Practitioners for the DHS workforce

**Lead**
- Northeastern University
  - Research Activities:
    - Video Analytics
    - Modeling for Improved Imaging
    - Sensor Development (AIT, MMW radar) for Explosives Detection
  - Technology Transition
  - Industrial Partnerships
  - Innovative Hands On Education Modules

**History and Funding**
- Established in 2008
- ALERT has received the following funds through OUP vehicles:
  - $21M in base financial assistance funding from OUP
  - $23.8M in financial assistance funding from other sources
  - $5.65M in contract funding under the Basic Ordering Agreement
ALERT Research Overview

Research Theme Areas

- **Characterization & Elimination of Illicit Explosives**
  - Physical Properties of Explosives
  - Explosive Polymer Interactions
- **Trace and Vapor Sensors**
  - Improved Swab Design for Contact Sensing
  - Orthogonal Sensors for Trace Detection
- **Bulk Sensors & Sensor Systems**
  - Mm-wave Whole Body Scan Hardware for AIT
  - Stand-Off & On-The-Move Detection for Security Threats
- **Video Analytics & Signature Analysis**
  - Dynamics-Based Video Analytics
  - Improved MBIR Reconstruction

Expected Uses

- Characterization & Elimination of Illicit Explosives
- Actionable Remote Trace and Vapor Chemical Detection
- Ultra-Reliable Screening
- Effective > 50 meter Stand-Off Discovery and Assessment
- Seamless Transition of Research to the Field

Customers

- DHS S&T Explosives Division (EXD)
- DHS Transportation Security Administration (TSA)
- U.S. Secret Service (USSS)
- Office of Bomb Prevention (OBP)
- State Homeland Security Agencies
- Joint Improvised Explosive Device Defeat Organization Responders
- Vendors of Detection Instrumentation
- Vendors of Building Materials
- Military
ALERT End-To-End (E2E) – Video Analytics Sensing and Tracking Project

**Description**

The Video Anomaly Sensing and Tracking (VAST) E2E project develops a video anomaly detection system. The first deliverable was to identify “in-the-exit” events (people entering a secure area through the exit). The second deliverable is to monitor the path of a suspicious person in real-time, “tag-and-track.”

- VAST E2E is designed to transition these tools to enable current TSA video monitoring camera systems to function in a real-time (as opposed to forensic) mode
- VAST E2E leverages research at partner institutions NEU, BU and RPI

**Impact & Relevance**

In-the-exit events occur frequently and are extremely disruptive to airport operations, requiring evacuation and re-entry of passengers.

Cost per event has been estimated at $5M; high return on investment to reducing occurrence by identifying and tracking counter-flow individuals.

VAST has demonstrated success in identifying in-the-exit events, in real–time, using airport video data. Results to date can detect in real-time and cope with:

- Multiple people moving in different directions
- Partial Occlusion
- Camera noise

**End Users/Partners**

**Deployed**

- In-The-Exit Testbed Deployed with Cleveland International Airport (CLE) and TSA-FSD

**In Development**

- Proof-of-Concept Tag-And-Track Testbed in development with CLE and TSA-FSD
- Partners: TSA Regional Directors at Cleveland and New England (builds on previous work at Camp Edwards) and Siemens Corporate Research
- End-users throughout TSA and other public spaces requiring video security (e.g. government buildings, stadiums)
- Discussions with Cleveland Light/Heavy Rail Greater Cleveland Regional Transit Authority
ALERT Education Overview

Collaborations/Partners
- Adjunct faculty from government or industry working with students and other mentorship arrangements:
  - Community College Outreach
  - First Responders
  - Bomb Squads
  - K-12 Outreach Programs
  - National Labs - LANL, LLNL
- Other experiential student education:
  - Outreach to general public, community colleges, K-12
  - Research Experience for Undergraduates
  - Co-op program for undergraduate & graduate students

Workforce Development
- Certificates or degree programs offered:
  - 63 graduate students at 12 partner institutions in Chemistry and Electrical, Chemical, & Mechanical Engineering
  - Gordon Engineering Leadership Program
  - ALERT DHS HS-STEM Career Development Program
- Courses developed:
  - High Tech Tools & Toys Lab and Modules
  - Explosives Professional Development Courses at URI
- Research areas of COE-supported students:
  - Characterization & Elimination of Illicit Explosives: 21
  - Trace and Vapor Sensors: 22
  - Bulk Sensors and Sensor Systems: 17
  - Video Analytics and Signature Analysis: 24
- Student fellowships offered: 40+
- Type of COE-supported students: BS, MS, & Ph.D.

Professional Development
- Professionals attending continuing education or graduate education programs:
  - Gordon Engineering Leadership Program had students from 26 industry participants
  - 20 First Responder and Professional Training courses
- Professional development events and training programs delivered:
  - Bi-Annual Algorithm Development for Security Applications Workshops
  - Annual Student Pipeline to Industry Roundtable Event
  - Annual Research to Reality Conference
**Description**

- The High Tech Tools and Toys laboratories (HTT&TL) and modules engage freshmen and community college students in hands-on learning activities using state-of-the-art technology products.

**Goals**

- Modules emphasize homeland security technologies
- Spectroscopic discrimination of oils (corn, motor, olive)
- Use of ultrasound transmitter to image objects concealed behind cloth
- Expansion of modules to be considered for URI and Purdue Chemistry curriculum

**Impact & Relevance**

- The HTT&TL sparks the imagination and interest of entry level engineering students such that they will consider pursing careers in HSE
- Impactful to the Maker Space movement

**Educational Capabilities & Opportunities**

**Capabilities:**

- Professional development courses for First Responders
- Modules emphasize homeland security technologies
- Gordon Engineering Leadership Program for professionals and graduate students
- ADSA workshops for continuing professionals
- HTT&TL modules can be developed in existing engineering curricula at the undergraduate & community college level
- Research Experience for Undergraduates

**Opportunities:**

- HTT&TL modules can be adopted or revised to be included in different settings (community college, high school, workshops, etc.). We are open to working with other groups to expand the use of these modules
- ADSA10 Workshop, May 6-7, 2014
- August 2014 Quantitative Methods to Measure Sampling Efficiency for Trace Chemical Detection Workshop
- Fundamentals of Explosives Course at URI, April 29 – May 1, 2014
### ALERT Research and Education Successes

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<thead>
<tr>
<th>Accomplishment</th>
<th>Impact/End Users</th>
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<tr>
<td><strong>Applied Model-Based Iterative Reconstruction (MBIR) Algorithms to CT Luggage Scanning Systems</strong>&lt;br&gt;<img src="image1.png" alt="CT Luggage Scanning System" /></td>
<td>- Significant potential for artifact reduction and improved resolution in X-ray CT images of luggage&lt;br&gt;- Improved quality of reconstructions leads to better image segmentation, and subsequent reduction in false alarms&lt;br&gt;- Promotes MBIR as a viable alternative to conventional security-based reconstruction methods&lt;br&gt;- Validation ongoing in collaboration with Morpho Detection Inc.</td>
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<td><strong>Multimodal AIT Imaging Testbed partners with L-3 and PNNL to Transition Technology for Portal Based Passenger Screening</strong>&lt;br&gt;<img src="image2.png" alt="Multimodal AIT Imaging Testbed" /></td>
<td>- Unbiased academic testbed for multi-modal sensors and algorithms for Advanced Imaging Technologies (AIT)&lt;br&gt;- Next generation of advanced mm-wave imaging in conjunction with other modalities will produce higher quality error-free imaging of threats faster and at lower cost&lt;br&gt;- Full depth information presented with advanced visualization&lt;br&gt;- Joint efforts applied to a data set containing a threat scenario of interest to TSA and Security Vendors</td>
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<td><strong>Database of explosive properties and tested canine training aids for TATP &amp; HMTD (patent applied)</strong>&lt;br&gt;<img src="image3.png" alt="Database of Explosives" /></td>
<td>- Created protocol for gently destroying TATP&lt;br&gt;- Inactivated hydrogen peroxide preventing concentration (patent applied)&lt;br&gt;- Hundreds for researchers and LEOs using database with multiple sensor (IR, Raman; mass spectroscopy) data on military &amp; HME explosives&lt;br&gt;- Dog training aids in use at numerous canine units throughout U.S.&lt;br&gt;- TSA-ES training throughout U.S.</td>
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<td><strong>Engineering Leaders within DHS Stakeholder Organizations</strong>&lt;br&gt;<img src="image4.png" alt="Engineering Leaders" /></td>
<td>- Gordon Engineering Leadership Program&lt;br&gt;- Engineering MS degree and a Graduate Certificate in Engineering Leadership&lt;br&gt;- Gordon Fellow Candidates complete a year-long “Challenge Project” that must demonstrate development and deployment of an engineering system or commercialization of an innovative product&lt;br&gt;- More than 50 DHS–related Gordon Fellow Graduate students enrolled</td>
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Supplemental Material
### ALERT Partners

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<tr>
<th>Principal Partners</th>
<th>Areas of Expertise/Core Capabilities</th>
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<tr>
<td>Northeastern University</td>
<td>Video Analytics, Modeling for Improved Imaging, Sensor Development (AIT, MMW radar) for Explosives Detection, Technology Transition.</td>
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<tr>
<td>Boston University</td>
<td>Image Processing Algorithms (Segmentation/Reconstruction), Multi-modal Imaging, Sensor Management and Networks, Video Analytics, Anomaly Detection</td>
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<tr>
<td>Purdue University</td>
<td>Image Processing Algorithms (Segmentation/Reconstruction), Trace and Vapor Sensors</td>
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<tr>
<td>University of Rhode Island</td>
<td>Detection: Fundamental Principles of Ion Mobility Spectrometry (IMS) Explosives Characterization: Non-ideal Explosives, Trace and Vapor Sensors</td>
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<td>Hebrew University of Jerusalem &amp; Weizmann Institute of Science</td>
<td>Modeling of Fundamental Properties using Electronic Structure Calculations Together with Molecular Dynamics Simulations</td>
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<td>New Mexico State University*</td>
<td>Detection: Fundamental Principles of IMS</td>
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<tr>
<td>Rensselaer Polytechnic Institute</td>
<td>Video Analytics, Image Processing Algorithms (Segmentation/Reconstruction)</td>
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<tr>
<td>Texas Tech University</td>
<td>Explosives Characterization, Nanomaterials for Detection and Mitigation, Design of Potential New Explosives</td>
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<tr>
<td>Tufts University</td>
<td>Image Processing Algorithms (Segmentation/Reconstruction), Multi-modal Imaging</td>
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<tr>
<td>University of Notre Dame</td>
<td>Image Processing Algorithms (Segmentation/Reconstruction), Trace Explosives Detection</td>
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<tr>
<td>University of Puerto Rico at Mayagüez*</td>
<td>Sensor Development (Chemical, Raman, Hyperspectral) for Explosives Detection</td>
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<td>Washington State University</td>
<td>Explosives Characterization, Mitigative Materials Design</td>
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*Indicates MSIs
## Extended Partner Network

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<th>Non-University Partners:</th>
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<tr>
<td>Analogic Corporation, EMITech Inc., Eos Photonics, HXI LLC, John Adams Innovation Institute, Lawrence Livermore National Laboratory, Lockheed Martin Corporation, Massachusetts General Hospital (MGH), Pacific Northwest National Laboratory, Rapiscan Systems, Raytheon Company, Siemens Corporation</td>
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### ALERT Student Placements

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<tr>
<th>Placements</th>
<th>Internships</th>
<th>Jobs</th>
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<tr>
<td><strong>Federal Government</strong></td>
<td>LLNL, SNL</td>
<td>ORNL, US Army, Department of Commerce-NAVY, PNNL, SNL, BNL, JIEDDO</td>
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<tr>
<td><strong>Industry</strong></td>
<td>Intel, HP, Lockheed-Martin, JEOL, Analogic, AS&amp;E, Lincoln Laboratory</td>
<td>Analogic Corporation, Microsoft Corporation, Scientific Systems, Inc., General Dynamics AIS, Intel, Cisco, Raytheon, Bloomberg, Orica</td>
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<tr>
<td>Research Area</td>
<td>Approaches</td>
<td>Expected Uses</td>
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<tr>
<td>1. Characterization &amp; Elimination of Illicit Explosives</td>
<td>Better understand explosives properties, Rendering precursors ineffective</td>
<td>Refine materials standards, Improve probability of detection and false alarm, Modify products to ensure greater safety during handling, Reduce access to viable precursors.</td>
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<tr>
<td>2. Trace and Vapor Sensors</td>
<td>Novel sensors, Better modeling, Multimodal sensor design</td>
<td>Identify new sensors and enhancements that can be made to existing deployed sensors, to improve probability of detection and false alarm</td>
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<tr>
<td>3. Bulk Sensors &amp; Sensor Systems</td>
<td>Novel sensor configurations, Problem-specific modeling and reconstruction algorithms, Joint multi-modality fusion</td>
<td>Reconfigure COTs and custom sensors and exploit custom algorithms with deployed sensors systems to improve imaging resolution, detection and material characterization</td>
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## ALERT Highlights

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<th>Accomplishment</th>
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| ALERT’s Transition Task comparison of Filter Back Projection and Model-based Iterative Reconstruction (MBIR) provides enhanced imagery | ▪ Experts believe will result in significant improvement in the detection/false alarm tradeoff security CT security screening systems  
▪ We have begun a collaboration and statement of work with Charlie Bouman, Ken Sauer, and Morpho to transfer the MBIR algorithms to the installed base of security CT instruments |
| Advancements in Dielectric Characterization                                   | ▪ Research by ALERT’s Carey Rappaport in collaboration with L3 Communications will augment existing software in the installed base of AIT instruments in the field.  
▪ The SOW, technical objectives and deliverables have been created and a white paper has been circulated to find a sponsor |
| ALERT has initiated a multi-COE collaboration with VACCINE COE                | ▪ The collaborative is to focus on promising Light Rail video analytics in Cleveland.  
▪ We have begun discussions about getting data from the Light Rail stations and are beginning our work to find a sponsor at DHS |
| Annual Student Pipeline Industry Roundtable Event (ASPIRE) was instituted in Spring 2013 | ▪ ASPIRE is an optimum setting for dialog among members of the ALERT academic, industrial, and government communities, and is an opportunity for networking for ALERT students looking for internships, co-op opportunities, and full-time jobs  
▪ The spring 2013 ASPIRE event was so well-received by industry that we held a second ASPIRE event in November with a focus on “Graduating STEM Students or the Lack Thereof” which generated round-table discussion on how to increase the number of U.S. students pursuing science and engineering degrees to fill the growing need as baby boomers retire  
▪ Industry, Students and Faculty all participated in engaging panel discussions and working groups |
| ALERT AND LOS ALAMOS NATIONAL LABORATORY (LANL) received a $750,000 DARPA AWARD for work focusing on Nuclear Magnetic Quadrupole Resonance. | ▪ This research proposal is titled “Multi-Modality Electromagnetic Detection and Localization of Implanted Explosives Using Ultra Low Field MRI and Nuclear Quadrupole Resonance”  
▪ Effort will be led by Prof. Carey Rappaport, the Principal Investigator from Northeastern University, and partner lead, Michelle Espy, from LANL |