II. PROJECT DESCRIPTION

A. Project Overview

The aim of this project is to develop new methods for those involved in the Homeland Security Enterprise (HSE) to collect, handle and store explosives. Because there are many applications where explosives must interact with other materials, a number of approaches have been developed. To date, the applications of this study have been safe trace explosive sources for canine and instrument calibration and training; explosives sampling devices (swabs), which are effective at pick-up and release of explosives residues; and better methods for analyzing these hazardous materials.

Military explosives are rarely used pure, meaning without plasticizers or other formulating agents. So, too, homemade explosives (HMEs) may require admixtures with other materials to get a formable formulation, or simply conceal the formulation (See Fig. 1 on the next page).
Understanding how HMEs react with other materials addresses a number of applications: safe handling and storage of HMEs; creation of better swabs; creation of better vapor concentrators; creation of canine training aids; and creation of trace and bulk simulants. This project has focused on finding the most compatible materials for devices such as canine training aids, swab materials, and pre-concentrators. One successful application of our studies is polymer encapsulation to facilitate handling of volatile, sensitive explosives, e.g. triacetone triperoxide (TATP). It has been received with enthusiasm. We are presently negotiating licensing with a commercial vendor.

Along with the discovery of potential applications, metrics for assessment are being developed. Our studies have employed a closed vapor chamber as a metric for sorption; and we are now working with Professor Otto Gregory’s research group (Project R2-B.1) on a more reliable way to create vapor. In any case the amount of explosive vapor sorbed is quantified either by exhaustive solvent extraction or heating. Heating with a thermogravimetric analyzer (TGA) coupled with infrared and/or mass spectrometer determines desorption quantity, purity, and the presence of decomposition products. Atomic Force Microscopy (AFM) has been used as a way to measure the adhesive forces between the polymer and explosive.

R1-C.2 has resulted in two papers authored at the University of Rhode Island (URI) [1, 2], and two papers from our partner at a minority-serving-institution (MSI) [3, 4], as well as a provisional patent [5]. Both our MSI partner and our group have been awarded further Department of Homeland Security (DHS) funding for certain aspects of this research [6, 7]. This work has also resulted in a graduate student award [8] and partnerships with three vendors supporting trace explosives detection.

B. Biennial Review Results and Related Actions to Address

The HSE and other State and Federal law enforcement agencies consider canines to be the gold standard for drug and explosives detection. For the canine explosives training aids, there were about 14 users during initial trials supervised by the Transportation Security Laboratory (TSL). The new generation of training aids have been tested by a limited number of users because of a requirement for a specialized heating device to release the scent from a polymeric material used to encapsulate the explosive. With an industrial partner we are working on a compact heating device for use in the field. Once available, the number of users will increase significantly. The prototype heater was on display at the DHS Innovation Showcase (May 19, 2016).
For the swab development, the most obvious user will be the Transportation Security Administration (TSA). This swab development program is benefiting from the direct involvement of DHS personnel from all divisions.

One reviewer noted the diversity of efforts in this project and suggested creating several projects. Should extra funding become available, this may be possible. However, without that, this project will remain in the cradle where new concepts are investigated.

C. State of the Art and Technical Approach

This project uses a variety of tools to determine compatibility of various materials with explosives. In addition to standard laboratory analysis methods, this project has explored the use of reaction and titration calorimetry, AFM, thermogravimetric analysis with infrared detector (TGA-IR), and various gas and liquid chromatographs as tools to aid this work. This project has also investigated new methods to package sensitive HMEs, and novel ways to collect explosives residues with the goal of an on-off collection methodology. This group produced the first TATP training aids in response to the sudden demand after the failed shoe bomb attempt of December 22, 2001. While these initial aids had many drawbacks, this project has made creation of safe, long-lived canine training aids for peroxide explosives a priority. Scientists at the National Institute of Science and Technology (NIST) have since reported a similar approach and sent us a congratulatory email after seeing our presentation at the Annual Workshop on Trace Explosives Detection (April 2014). NIST sent us a paper for review last year (see reference [10]); in fact, in the past two years we have been asked to review over 40 papers dealing with explosives that demonstrates our expertise is valued in this field.

C.1. Encapsulation and coating of energetic

Bomb-sniffing dogs, and companies manufacturing trace explosive detection instruments must have pure explosives for testing. However, obtaining, handling, and storing these explosives is a significant obstacle. There is a need for an insensitive, storage-stable source of HMEs, in particular, the highly sensitive peroxide explosives. To meet the demand for safe forms of TATP, we have sublimed TATP onto scrupulously clean filter paper. While this approach fulfilled immediate needs of canine trainers and instrument suppliers, preparation was arduous; and the aids were effective for only about 90 minutes. To enhance the work- and shelf-life of the product, we developed a method to encapsulate TATP, creating microspheres which are non-detonable and have long shelf-life [1]. We are now focused on providing non-detonable scent materials for hexamethylene triperoxide diamine (HMTD).

HMTD is a highly sensitive explosive, which has caused a number of injuries in the counterterrorism community. Unfortunately, since it is readily synthesized from easy to obtain ingredients, like TATP, it is a terrorist threat material. Therefore, we have attempted to create safe-scent aids for this material in a fashion analogous to our TATP training aids. To date, we have made microspheres containing the explosive of interest through a solvent evaporation method. The general procedure is as follows: a shell material (polymer) is dissolved in a hydrophobic, volatile solvent with the core material (explosive). This solution of shell and core material is added to a stirring aqueous solution of a surfactant, creating a two phase system. The polymer, being insoluble in water, precipitates around the core material as the volatile solvent slowly evaporates from the solution. The microspheres are collected, washed, and baked at low temperature.

The prerequisite for the solvent is a hydrophobic compound that readily dissolves the polymer and explosive. HMTD has low solubility in most organic solvents but is slightly soluble in chloroform. Therefore, chloroform was the first solvent used to dissolve the HMTD and the polymer. Unfortunately, it proved difficult to remove that material from the microspheres. Since dichloromethane (DCM) was successfully used in the TATP microspheres as an effective volatile solvent, it was the next choice. Because the solubility of HMTD in DCM was very low, a high volume of solvent was needed (500mg of HMTD was dissolved in 135mL of DCM). The volume ratio of polymer, explosive, and solvent solution to surfactant solution required optimization in order
to create the two phase system, because with the wrong ratio, the polymer precipitated from the solution without encapsulating the explosive.

Microspheres of HMTD were synthesized using various polymers and screened using TGA-IR to observe the release of HMTD from the microspheres. In the TGA experiments, about 10 mg of sample were heated at 20°C/min to 300°C by the TGA furnace, and the evolved gases were carried through a transfer line, held at 150°C, to an IR spectrometer for vapor analysis. Many polymers were unsuitable; either they did not encapsulate HMTD, decomposed as HMTD was released, or contained difficult to remove impurities.

Figure 2 (left) shows the thermogram of polymethylmethacrylate (PMMA) microspheres. The first mass loss yields an IR spectrum of chloroform, the solvent used in the synthesis. The second and third mass losses yielded IR spectral library matches (85%) for butyl ester methacrylic acid, suggesting polymer decomposition of heated microspheres. Figure 2 (right) shows the thermogram of polycarbonate (PC) microspheres with only one mass loss starting at 8 minutes. The IR at 11 minutes, which corresponds to this mass loss, directly matches the HMTD spectrum. Proof of this is shown in Figure 3 (on the next page) which shows infrared (IR) spectral overlay of the polycarbonate HMTD microspheres vapor at 11 minutes with the spectra of HMTD vapor. The polycarbonate microspheres achieved a controllable release of the pure HMTD vapor at 150-160°C. This temperature was selected for further testing. Further examination of the vapor released by the HMTD microspheres showed that the main decomposition products of HMTD are trimethylamine and dimethylformamide. The polycarbonate HMTD microsphere, when heated, also exhibited peaks not associated with HMTD. A great deal of effort went into pre-cleaning the polycarbonate by multiple solvent extraction and supercritical CO₂ extraction to remove the impurities. After vacuum drying the HMTD microspheres for 7 days it appeared that both the solvent and the impurities were removed. Nevertheless, further examination of our choice in encapsulation polymers will be performed.
The TATP studies resulted in a paper [9], a student-won National Security Innovation award of $10,000 [8], and partnership with a vendor desiring to design and market the heating device. Future work includes efforts to further improve the encapsulating polymer for HMTD, working with a vendor to design the heating device for TATP and HMTD heating specification, and rigorously calibrating the heating profiles for releasing TATP and HMTD.

C.2. New explosives collection techniques

Current sampling techniques are inefficient and invasive. To counteract inefficient pick-up, swabbing greater surface area may increase the mass of explosive collected but only if there is explosive contamination over the whole surface. Screening of hands, headdresses and medical appliances requires physical contact that can be invasive and may expose passengers and screeners to biohazards. To avoid being intrusive or causing physical harm (medical devices), TSA operators may not swab certain areas otherwise of interest. Swabbing can also damage (scratch) some surfaces. The aim of this work is to create a reversibly switching surface capable of altering adhesive properties. A swab composed of such a material could maximize both pick-up and release of analyte particles for introduction to a detector. Modern explosives swabs suffer from the fact that they can either adhere analyte well and release it poorly, or adhere analyte poorly, but release it well. Both aspects are important to adequate delivery of analyte to a detector system. An adhesion tunable surface controlled by a small electric charge (less than that of a 9V battery) or by a thermal stimulus could be a major accomplishment. Three approaches are being considered. Approaches 1 and 2 do not require direct contact. While not considered "non-contact" by the DHS definition (i.e. standoff of greater than 2 inches), the switchable swab would attract explosive particles from about 3 cm away from the contaminated surface. This prevents the need for actual physical contact with a surface, and therefore speeds up the sampling process; provides for greater privacy; possibly increases the overall swab lifetime; and perhaps minimizes collection of certain types of interfering compounds. These advantages, coupled with higher pick-up and release efficiencies, will make for speedier, more pleasant, and more economical checkpoint operations while improving trace detector performance. Approach 3 involves new material synthesis to improve explosive pick-up; a successful material in this area may serve as a pre-concentrator.
C.2.a. Approach 1

Non-obtrusive detection of trace amounts of illicit materials has long been a goal of detection companies and security firms. Though detector technology continues to improve, a key challenge remains in collection and release of sufficient analyte, e.g., explosives or precursors, into the detector. In fact, many detection companies choose swabs with the best release profile rather than the best collection profile. Hence, materials such as Teflon, Nomex, and metal mesh have been employed. Our premise is that an electrostatically enhanced swab would improve the collection efficiencies of poorly collecting materials. When the swab is placed in the desorber, the charge is dissipated and desorption occurs. Because the collection is done near-field, there is less wear on the swab material, and therefore the swab has a longer life-time. Furthermore, because the swab does not rely on physical adhesion of particles, the particles are readily released when the static field is dissipated. Thus, more residue can be collected, and more residue can be released, facilitating faster and more accurate identification of threat materials. This method is expected to be insensitive to the type of particles attracted. Electrostatically enhanced swabs have been shown to pick-up sugar, salt, 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5—trinitro-s-triazine (RDX), pentaerythritol tetranitrate (PETN), and ammonium nitrate. On the other hand, a non-contact swab, thus enhanced, is unlikely to pick-up oils and lotions, which are pervasive in the environment, and often the source of explosives trace detector (ETD) alarms.

This proposed triboelectric enhancement would require no major change in the swabbing materials nor sensor hardware but would allow a change in the technique as the swab would no longer need to be rubbed over a surface. Triboelectric charging, a subset of contact electrification, is a well-known phenomenon, e.g. children rub balloons in their hair to make the balloon stick to the wall. Therefore, it is surprising that so much of the basic theory is subject to debate, even to the point of whether the charge is generated by transferring electrons, ions, or nanoparticles [11]. Nevertheless, static electricity is exploited in applications from laser jet printers to industrial air cleaners [12]. Electrostatic precipitators have been used for many years for dust and other particle collection [13]. Moreover, though there must be a balance of charge between the two neutral surfaces that are rubbed together to create the positive and negative charges, these charges can persist long after the two surfaces are physically separated [12]. However, the electrostatic precipitator imparts a net charge to the particle [13]. In contrast, our technique charges the collector, which temporarily induces a dipole in the particle. This dipole dissipates as soon as the charge on the collector is neutralized. The precipitator charges the particles; the enhanced swab only redistributes charge temporarily so that the particle is attracted to the collector.

The concept is to enhance the pick-up and release efficiency of current swabs used by the TSA for the collection of particulate explosives from a variety of surfaces. This enhancement approach can be applied to any swab material of low conductivity, e.g. plastic or cloth. Such a material will be statically charged, e.g., by triboelectric effect or corona discharge. The statically charged swab attracts the explosive particulate through space. However, when the swab is inserted into the inlet of the detection instrument, the static charge is dissipated; thus, it is no longer attractive to the particulate and the analyte is readily released into the inlet. Because the particulate was never pressed into the substrate or the material of the swab by rubbing, it is readily collected and released into the detector. Figure 4 (on the next page) shows that an electrostatically charged (-7 kV) Teflon swab easily picks up a visible amount of PETN. Particle size was not critical; flaked and powdered TNT, and sugar of 150 μm, as well as 800 μm adhered to the swabs.
While macroscopic tests are more visual, microscopic pick-up is the focus of the present study. The technique is effective on substrates such as glass, polymer resin, card stock, rough vinyl, and human hair. When strands of hair purposely exposed to explosive vapor were swabbed with a charged and an uncharged swab, the charged swab resulted in detection on the FLIR Fido X3, while the uncharged swab did not (see Fig. 5). Our hypothesis is that the explosive vapor adhered to dust particles, which were subsequently attracted to the charged swab. Additionally, when a C-4 fingerprint was analyzed using a charged swab, it resulted in detection on a Morpho Itemizer IMS (ion mobility spectrometer). It should be noted that all swabbing experiments were performed at 3 mm standoff.

Electrostatically charged swab materials are expected to reduce the introduction of interfering and masking compounds to the detector inlet. Most of these compounds are not very volatile, have high molecular weights, and typically adhere strongly to surfaces, e.g. oils on skin or hair, and common plasticizers. During contact sampling, these compounds are collected from the surface along with the explosive particles. Electrostatically enhanced sampling appears to provide some selectivity based on the strength of surface adherence. Loose explosive particles are more likely to be picked up by electrostatically charged swabs than oils.

Under the new DHS funding, commercial off-the-shelf (COTS) swabs are charged by both triboelectric and inductive charging. Charge degradation due to time and relative humidity was analyzed. Collection efficiency, transfer efficiency, and uncharged swab comparison are assessed by precise quantification of energetic...
materials via Liquid Chromatography Mass Spectrometry (LC-MS) techniques.

C.2.b. Approach 2

Triboelectric charging of swabs presents a number of challenges. Potential for contamination has been overcome by the use of inductive charging, but long-term retention of charge is a problem. If the TSA protocol were to charge at a station before every use, long-term charge retention would not be an issue, but TSA envisions a pre-charged bundle of swabs. That being the case, another approach will be investigated. Creating a swab with an electret surface overcomes these difficulties. An electret is defined as a “piece of dielectric material exhibiting quasi-permanent electrical charge” [14]. Quasi-permanence means that a significant decay in charge does not occur in the time scale of the experiments (years). The electret can extend from the surface into layers of the material (10 to 100 microns). Electrets are created by exposing a dielectric material to an electrical field, thus polarizing it. The magnitude of the charge created on the dielectric material is dependent on the resistance and chemical stability of the material. When heated and exposed to a strong electrostatic field, the polar molecules at the surface of the dielectric (polymer) align themselves (see Fig. 6). The dielectric surface molecules solidify and maintain charge on cooling.

Swabs that are electrets can be created and used in a completely non-contact fashion; thus, reducing the possibility of contamination. The electrets should accept and maintain a charge similar in magnitude to that created by a triboelectric charge (7-12kV). Our initial approach to making electrets would be to charge Teflon, β-PVDF, or Nomex using an external electric field, e.g., a tip-to-plane corona charging apparatus (see Fig. 7). Charging will be performed at elevated temperatures, just under the glass-transition point of the polymer, in order to increase their thermal stability. The apparatus will be purged with dry nitrogen to ensure low humidity. If higher voltage charging is required (> 30 keV), the chamber would be filled with a high dielectric gas such as SF₆; however, need for such high charging is not anticipated.
Swab materials created by Approach 1 (triboelectric charging) will be compared to those created by Approach 2 (electrets). Both of these approaches create a swab that does not require direct contact, and neither approach transfers charge to the operator, or the surface being swabbed.

**C.2.c. Approach 3**

Since the inception of this project, we have been interested in preparing molecules with special sorbative properties. These may be used as swabs, pre-concentrators, or even sensors. Therefore, we have investigated molecularly imprinted polymers (MIPs) and considered carbon nanotubes. Now with the aid of an expert organic chemist, we will examine metal-organic frameworks, porphyrins, and supramolecular complexes.

The two most important properties for gas adsorbents are generally considered to be adsorption capacity and selectivity [17]. Adsorption capacity is dependent upon equilibrium pressure and temperature, the nature of the adsorbate, and the nature of the micropores in the adsorbent [17]. The factors which affect adsorption selectivity are not as well understood. Li et al. describe that they “seem to be an integrative and process-related issue in practical separation, though it is still related to the operational temperature and pressure as well as the nature of the adsorbent and the adsorbate” [17]. When considering chemical sensors; sensitivity, response time, materials stability, and reusability are necessary in addition to selectivity [18].

Porous polymers, e.g. activated carbons and aluminosilicate zeolites, are difficult to tune in terms of specificity. An advanced porous material, metal-organic frameworks (MOFs), or porous coordination polymers combine sorbative capacity and potential for selectivity which make them promising for pre-concentrators, or vapor sensors (Fig. 8) [19].

![Figure 8: Example of Metal-Organic Framework](image)

An intriguing class of compounds are the cyclotrimeratrylenes (CTVs) [21-24]. The DeBoef group has specialized in the synthesis and functionalization of these bowl-shaped molecules. We now intend to probe their potential for selectively binding explosives and their precursors. (see Fig. 9 on the next page).
The chain of atoms defining the cavity can be functionalized to be particularly adept at binding explosives. At this point it is not known whether modifications appropriate for sequestering nitroarenes, e.g. TNT, would also be attractive to nitrate esters, nitramines, and peroxides. In the final application, our approach may resemble MIPs in that each explosive requires specific modifications, and a variety of modifications are within synthetic reach. For example, it is possible to covalently join two CTVs to make a molecular capsule, called a cryptophane, which can selectively bind analytes in its cavity based on size [25]. This may be suitable to sequestering small molecules (e.g. methane). When assembled into an array, these supramolecules could be the key component in rapid explosives collection and detection.

C.2.d. Summary

The enhancement proposed herein would require no major change in the swabbing materials nor sensor hardware, but would require a change in the operational protocol as the swab would no longer need to be rubbed over a surface. Each of the approaches to switchable swabs would require a different operational protocol. Approach 1 would require the swab be charged before each sample collection. Inserting the swab into the detection device would trigger the release of the analyte. In Approach 2, the swab would be permanently charged at the factory, and sample release would be accomplished by heating in a detection device desorber. The swab could be reused immediately. The enhanced swab would attract explosives particles from a distance of about 3 cm from the contaminated surface. This obviates the need for actual physical contact with a surface and, therefore, speeds up the sampling process, provides for greater privacy, may increase the overall swab lifetime and may minimize the collection of certain types of interfering compounds. These advantages, coupled with higher pick-up and release efficiencies, will make for speedier, more pleasant, and more economical checkpoint operations while improving trace detector performance.

This work resulted in a DHS research award under BAA EXD 13-03 (Advanced Swabs for Near-Field Sampling) with subcontractors, FLIR Systems, Inc. and DSA Detection.

D. Major Contributions

A primary motivation for this research is safety. There must be no unanticipated hazards. Also, most
detection instruments contain plastic parts and many ETDs require pre-concentrators or swabs. Not only will this project seek the best way to evaluate the wealth of modern materials available, but it is likely to point to some of the best choices in these areas. This impacts both trace and bulk detection.

TATP has been successfully encapsulated both for canine training aids and for calibration of trace detection equipment. This year HMTD has likewise been successfully tamed.

The concept of a non-contact swab has received additional funding. Initial results suggest it is in most cases more effective than contact swabbing. Furthermore, it is less prone to contamination that may cause explosives trace detector (ETD) alarms or malfunction, and it makes some hard to touch areas assessable.

E. Milestones

Our present approach to TATP canine training aids is being adapted to another peroxide explosive, HMTD. Whether this approach can be adapted to the low-melting, erythritol tetranitrate (ETN), is the subject of ongoing experiments.

Also ongoing, is the development of a heater that rapidly attains and maintains desired temperatures. That specific task is the job of an industrial partner; however, we must determine the most optimal heat profile that accommodates both training aids.

We are also examining charged swabs for their pick-up and release capabilities. We have taken a two-prong approach, using electrostatics for a temporary charge, as well as electrets for a more permanent approach. Both approaches need to be tested for long-term viability.

Specific milestones for the coming years include acquiring a patent on the safe-scent materials; characterizing the release profiles of TATP and HMTD from the microcapsules so that the commercial heater can be designed; and characterizing the decomposition signature of HMTD. Efforts will be made toward the complete commercialization of the safe-scent aids. A method for rapid attribution of HMEs will be investigated. Novel materials/methods for enhanced swabs and vapor concentrators will be investigated. The potential for creating safe simulants of computed tomography (CT) will be probed.

F. Future Plans

The areas outlined above continue to be the subject of active research.

Coating and encapsulation of materials will continue to be of interest. Not only will we investigate encapsulation of energetic materials, but also the encapsulation of potential additives to energetics. For example, we have shown that the addition of parts-per-million (ppm) amounts of generally-recognized-as-safe (GRAS) metals, to 3% or 12% hydrogen peroxide (HP), prevents its concentration by heating, instead promoting its decomposition. Furthermore, at ppm levels, the metals do not affect the stability of hydrogen peroxide at room temperature. Applying the same approach to 30% HP requires elevated levels of metals, which would negatively influence shelf-life. This could be avoided by encapsulating the metals with a coating which can be degraded by heating. Thus, at room temperature, the 30% HP would be stable, but if heated, rather than concentrate the HP, the heat would remove the polymer coating from the metals and expose the HP to their degrading effect. This requires a polymer compatible with both metal and HP, and which can be removed or softened by heating; hence, the need for metrics.

Work on switchable polymers and swabs begun this year will continue under direct DHS funding. Under Center funding, we will explore the possibility that use of electrets as swabs may be more effective than use of electrostatically charged swabs.

Each task requires its own metrics, and development of these metrics is an integral part of these projects. We have investigated and reported on use of vapor chamber exposure. By combining our efforts with the research group of Professor Otto Gregory (R2-B.1), we expect to create a vapor generator.
Presently, we are exploring calorimetry for evaluation of explosive interactions; Raman spectroscopy for rapid attribution of HME; novel materials/methods for enhanced swabs and vapor concentrators; and the potential for creating safe simulants of CT will be considered.

III. RELEVANCE AND TRANSITION

A. Relevance of Research to the DHS Enterprise
   - R1-C.2 “encapsulation/coating” addresses safe samples of explosives. Evidence that this program has importance are as follows:
     - Requests from ETD (explosives trace detection) equipment vendors for product information;
     - Requests to license the vapor scent product;
     - An innovation award from the National Homeland Defense Foundation of $10,000 for the vapor scent product.
   - R1-C.2 novel sampling addresses novel, non-contact, switchable sampling of explosives. Metrics include:
     - New initiative received DHS award (see overview and references therein).

B. Potential for Transition
   - R1-C.2 addresses safe samples of explosive. We receive requests to license the vapor scent product. This product was selected for presentation at the DHS Innovation Showcase (May 2016).
   - R1-C.2 addresses sampling of explosives. A DHS award under BAA EXD 13-03 with transition partners FLIR Systems, Inc. and DSA Detection is presently being negotiated and was kicked off in October 2015.

C. Data and/or IP Acquisition Strategy
   See Section IV.F.

D. Transition Pathway
   - R1-C.2 addresses safe samples of explosives. We receive requests to license the product and are working with Detectachem. Because the need in the HSE community is great, this product is presently distributed freely to those requesting it. This helps the HSE community and aids product development via customer feedback.
   - R1-C.2 addresses sampling partners; FLIR Systems, Inc. and DSA Detection are in place for transitioning this work. Government partners are invited to a monthly phone call with this group.

E. Customer Connections
   See Transition Pathway above.
   We have been distributing the scent product for free to a number of users. This puts a customer base in place for future sales.
IV. PROJECT ACCOMPLISHMENTS AND DOCUMENTATION

A. Education and Workforce Development Activities

1. Course, Seminar, or Workshop Development
   a. In May 2015, a hands-on course entitled “Explosives Analysis” was offered for the first time; six members of the HSE came to URI to attend. This class was offered again in May 2016 and enrollment had to be capped at 23.
   b. “Advanced Hazard Recognition” was offered for the first time to the Massachusetts JHAT team (HazMat specialists who travel with the state bomb squad). Twelve attended on May 12, 2016.
   c. Ten specialist classes were presented and reached about 230 people in the HSE.
   d. Invited Lectures

2. Student Internship, Job, and/or Research Opportunities
   Each URI project supports one or more graduate students. This is their best learning experience. Undergraduates are also supported on the projects as their class schedules permit. Graduated student, Stephanie Rayome obtained a job with Virginia State Forensic Lab in February 2016.

3. Interactions and Outreach to K-12, Community College, and/or Minority Serving Institution Students or Faculty
   We have continued our K-12 outreach by hosting high school teachers in the summer and providing chemical magic shows at K-12 schools. High school teachers conduct research in URI labs for 8 to 10 weeks under the mentorship of a graduate student. As a result, 2 teachers have gone back to seek advanced degrees.
   In summer of 2015, we hosted two Navy midshipmen and a Penn State engineer. A professor of engineering from NMT with two students will spend the summer of 2016 in our lab.

4. Training to Professionals or Others
   We trained 44 TSS-ES in two classes, and approximately 230 people total involved in the HSE in ten classes.
   The Massachusetts State Bomb squad/JHAT team spent May 12, 2016 in our labs for a short course on Advanced Hazards Recognition.
   See additional information in Section IV.E.

B. Peer Reviewed Journal Articles


2. Oxley, Jimmie C.; Smith, James L.; Porter, Matthew; McLennan, Lindsay; Colizza, Kevin; Zeiri, Yehuda;


Pending-


C. Peer Reviewed Conference Proceedings


D. Other Presentations

1. Seminars—See education, invited talks & presentations.

2. Poster Sessions—
   a. For ALERT events & TED.
   b. Graduate student Austin Brown was selected to give a poster titled, In support of Explosive Detection at the Trace Explosive Detection conference for his work on explosive simulants for CT (April 2016, Charlottesville).


4. Short Courses— Listed under Section IV (Education and Training to Professionals and Others

5. Interviews and /or News Articles


E. New and Existing Courses Developed and Student Enrollment

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<th>Description</th>
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Table 1: Courses offered in Year 3

F. Technology Transfer/Patents

1. Patent Applications Filed (Including Provisional Patents)
   a. Jimmie Oxley; James Smith; Jonathan Canino. “Non-Detonable Explosive or Explosive-Simulant Source” is in the process of being converted from provisional to full patent.

G. Requests for Assistance/Advice

1. From DHS
   a. On call for a variety of TSA TSS-ES personnel
   b. Oxley is part of the DHS-formed Inter-Agency Explosive Terrorism Risk Assessment Working Group (IExTRAWG). In addition to group meetings, a representative was sent to URI for 2 days in August so that we could finalize the metric for selecting threat materials.
   c. Commissioner of U.S. Customs & Border Protection and former Director of the Office of National Drug Control Policy, R. Gil Kerlikowske, came to visit on April 13, 2016. He has asked individuals from the CBPs National Targeting Center to follow up with further conversations.

2. From Federal/State/Local Government
   a. The Massachusetts State Bomb Squad and Hazmat (JHAT) team spent May 12, 2016 in our labs for a short course on Advanced Hazards Recognition.
V. REFERENCES


[6] DHS MSI award of $50,000 for “Electrochemically Synthesized Nanocomposites for Explosive Detection and Mitigation” by Dr. Y.X. Gan.

[7] DHS contract for “Advanced Swabs for Near-Field Sampling” under BAA EXD 13-03

[8] First-Place Team 8th Annual National Security Innovation Contest; April 2014 for Safe Training Aids for Bomb-Sniffing Dogs; prize $10,000.


