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Workshop Series

Algorithm Development for Security Applications

April 2009 Workshop
Final Report

Awareness and Localization of Explosives-Related Threats
A Department of Homeland Security Center of Excellence

Northeastern University

FINAL REPORT

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Conducted by:

Awareness and Localization of Explosives-Related Threats (ALERT)

A Department of Homeland Security Center of Excellence

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1. Disclaimers

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This document summarizes a workshop at which a number of people participated and some made presentations. The views in this summary are those of the organizing committee and do not necessarily reflect the views of all the participants. All errors and omissions are the sole responsibility of the organizing committee.

This material is based upon work supported by the U.S. Department of Homeland Security under Award Number 2008-ST-061-ED0001. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Department of Homeland Security.

2. Executive Summary[1]

A workshop was conducted to discuss the generation of advanced algorithms for security applications. The focus of the workshop was to spark the development of new algorithms for detecting explosives at an integrated checkpoint. The objectives of the workshop were to:

- Provide an analysis of the opportunities and research barriers associated with next-generation algorithms for Homeland Security applications, using the integrated checkpoint as a basis of discussion.

Consider the following questions:

- What will be the consequences of maintaining the current trajectory using existing technologies and strategy?
- How can we foster out of the box solutions using new technologies and strategies?
- Facilitate 3rd party involvement, especially academia and the medical imaging community, in an algorithm development strategy that would be effective for DHS.
- Identify 3rd parties who can respond to RFIs and BAAs related to algorithm development.

This report summarizes the workshop content and presents the outcomes that address the objectives. The majority of the material that deals with these objectives can be found in the slides corresponding to presentations made during the workshop and the homework provided in advance of the workshop; the slides and the homework are included in this report as appendices.

The main outcomes of the workshop are as follows.

- Grand challenges should be established for different aspects of threat detection and different modalities. The aspects include reconstruction and processing of sensor data, image segmentation, automated threat detection and improved operator performance. The modalities include x-ray CT for checked and carry-on baggage, whole body imaging, cargo inspection and stand-off detection. Implementing grand challenges will

1 This report is available as a hardcopy, on the Internet and on a CD. Please contact ALERT at Northeastern University (alert-info@ece.neu.edu) for access to these three formats.

entail putting the following information and materials into the public domain: data sets, sensor descriptions and acceptance criteria. People working on grand challenges should be provided financial incentives to advance the state of the art.

- Develop accurate scanner simulators to predict the performance of future systems. The simulators can also be used to provide data for the participants in grand challenges. The scanner simulators may also be considered to be part of sensor or system modeling. We do not mean verbal/written descriptions of sensors. We mean analytical and computation models for mapping parameters of interest (e.g., spatial distributions of Compton scattering and photoelectric parameters) to observed data either for fielded systems or for model systems that approximate those in the field well enough to allow for meaningful evaluation of the processing results. All sensor related effects seen in the field which have an impact on the data (scatter, beam hardening etc), should be included in the model. Preferably, both analytical expressions for the models as well as computational realizations in Matlab or C should be provided or developed.
- Studies should be performed on systems that include a human in the decision making process. Methods should be established to assess and improve the performance of the human while taking into consideration that the prevalence of threats is low at the present time. In that context, the potential reduction of the probability of detection in automated threat detection algorithms in exchange for lower false alarms should be studied to assess the impact of lower probability of false alarms (PFA) on human performance. Algorithms that estimate the amount of clutter in images could be used to send cluttered bags directly to secondary inspection, bypassing the operator, thus allowing the operator more time to view uncluttered bags. Algorithms could be developed to produce threat image projections (and equivalents for other modalities) independent of vendor.
- Advanced reconstruction algorithm approaches should be evaluated for their use on existing x-ray CT equipment to see how they might lead to the design of better CT scanners. An example of this methodology is denoted interior tomography, where the line-integrals are only collected within a region-of-interest that is smaller than the complete object being scanned. Interior tomography may allow for higher quality scans of threats during secondary screening.
- Communication – both formal and informal – between the government, vendors, academia and national laboratories was quite useful and additional communication should be fostered.

- All participants agreed that the involvement of 3rd parties would benefit both the vendors and the government. However, the various stakeholders had different expectations in the time required to make contributions. The government and vendors wanted advanced algorithms developed in the six- to twenty-four-month time-frame. Academia felt that game-changing algorithms would take five to ten years to develop.
- The use of orthogonal technologies (also denoted fused systems or systems of systems) should be explored.
- An open source model should be employed for the distribution of algorithms, code, specification and databases. Standardized image and data formats, such as DICOS, would allow 3rd parties to develop algorithms more quickly.
- Before developing new algorithms based on a specific sensing modality, one should predict the best possible performance (PD/PFA) for that modality. If a modality is currently operating close to its best possible performance, then do not fund additional advanced algorithm research in that arena.
- CT-based explosives detection systems (EDS) were derived from the medical imaging application and as a result have perhaps not been sufficiently optimized for the security application[2]. Numerous opportunities were identified to springboard from medical imaging approaches and develop algorithms targeted specifically for the security application. Examples include:
    - Reconstruction optimized for security scenarios
    - Targeted reconstruction to specific threats
    - Segmentation-oriented reconstruction methods
    - Local reconstructions optimized for a threat found during segmentation
    - Targeted reconstruction for detection versus display
    - Reconstruction algorithms for multi-view line scanners
    - Parametric reconstruction
    - Iterative/statistical reconstruction
    - Artifact reduction such as from scatter and metal
    - Improved dual-energy decomposition

[2] People in the medical imaging field are still expected to have the most expertise to optimize or extend their algorithms for the security application.

- Use video surveillance to identify passengers that should be subjected to increased scrutiny at the check-point. Also use this method to associate divested items with the passenger.
- Vendors should be incentivized to deploy scanners with improved performance.

Recommendations are included in this report on how to continue to get 3rd parties involved with advanced algorithm development. In particular, it is recommended that an initial grand challenge be conducted for image segmentation for CT-based EDS equipment and a second workshop be held on implementing this specific grand challenge. Additional grand challenges can be held for other modalities and applications such as whole body imaging (WBI) and cargo screening.

3. Introduction

The Department of Homeland Security (DHS) has requirements for future scanners that include a larger number of threat categories, higher probability of detection per category, lower false alarm rates, and lower operating costs. These goals could be met with one system or using a system-of-systems. One tactic that the DHS is pursuing is creating an environment where the capabilities of the traditional vendors of security systems could be augmented with the development of algorithms by third parties. A third party in this context means people and organizations other than the traditional vendors. Examples of third parties include academics, national laboratories and companies other than the traditional vendors. Of particular interest to DHS is following the model used in the medical imaging industry, where university researchers have developed numerous algorithms that have eventually been deployed in commercial medical imaging equipment[3].

A tactic that DHS is using to develop algorithms is to issue requests for information (RFIs) for 3rd party algorithm development.[4] RFIs may be followed by broad agency announcements (BAAs), which may lead to the funding of third parties.

Another tactic that the DHS is using to stimulate academic and industrial 3rd party algorithm development is to hold workshops addressing the research opportunities that may enable the development of next generation algorithms for Homeland Security applications. This report discusses the first such workshop, which was entitled "The Algorithm Development for Security Applications (ADSA) Workshop," which was held at Northeastern University (NEU) on April 23rd and 24th, 2009. The workshop was led by Professor Michael B. Silevitch (NEU) as part of the DHS Center of Excellence entitled Awareness and Localization of Explosives-Related Threats[5] (ALERT). The sponsors of the workshop were DHS and NEU.

The objectives of this workshop were to:

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[3] When we speak of an algorithm, we are talking about the mathematical steps. The actual implementation, usually in a general purpose computer, is beyond the scope of this report.

[4] https://www.fbo.gov/spg/DHS/OCPO/DHS-OCPO/OPO-09-00000-RFI/listing.html

[5] http://www.northeastern.edu/alert

- Provide an analysis of the opportunities and research barriers associated with next-generation algorithms for Homeland Security applications, using the integrated checkpoint as a basis of discussion.
- Consider the following questions:
    - What will be the consequences of maintaining the current trajectory using existing technologies and strategy?
    - How can we foster out of the box solutions using new technologies and strategy?
- Facilitate academia's involvement, especially the medical imaging community, in DHS's new algorithm development strategy.
- Identify 3rd parties who can respond to RFIs and BAAs.

The scope of the workshop was limited to the integrated check-point. However, it is expected that the results of the workshop will be extensible to other applications such as checked baggage and standoff detection. Future workshops on other topics are anticipated.

The topic of algorithms for the integrated checkpoint was addressed through discussion of the following four themes (denoted tracks):

- Reconstruction
- Automated threat detection and fusion
- Emerging technologies
- Surveillance and human factors

People skilled in the above topics led specific tracks dealing with these subjects. The specifics of the agenda for the workshop can be found in Section 11.

This report summarizes the workshop and presents the outcomes that address the objectives. The objectives are addressed through the following topics:

- Present issues and gaps in existing technologies
- Identify new algorithms that will address these issues and gaps
- Show applicability to other threats, modalities and venues
- Provide a roadmap for development of new algorithms
- List people and institutions who can contribute 3rd party algorithms
- List what information and funding is required to develop 3rd party algorithms

A group of approximately forty people attended the workshop. The group was split between academia, national laboratories, government and

industry. A complete list of attendees can be found in Section 19. The speakers and leaders at the conference were provided with instructions before the workshop in order to focus their efforts towards the objectives. All attendees were requested to submit preliminary summaries along the lines of the final report as described by homework assignments described in Section 21.2.

The report and its appendices are organized as noted in the following section.

4. Report Organization

The remainder of this report is organized as indicated in the following table.

Sec.	Title	Contents and Notes
Report Body		
5	Outputs	Addresses the specific objectives for the workshop as listed in the Introduction.
6	Grand challenges	Provides additional details about the use of grand challenges for advanced algorithm development.
7	Future efforts	Presents recommendations for projects to implement the ideas generated at this workshop.
8	Lessons learned	A list of topics that could have been implemented better or differently, and recommendations for improvement for future workshops.
9	Notes	Miscellaneous notes about the workshop and this report.
10	Acknowledgements	Identifies people and organizations that were instrumental to implementing this workshop.
Appendices		
11	Agenda	Agenda for the workshop
12	Scope	Topics to be considered at the workshop
13	Overview	Overview of the workshop; used as part of the invitation for participants.
14	Planning committee	List of people who organized the workshop.
15	Invitation	Invitation sent to people to participate. Different versions were sent to speakers and non-speakers.
16	Speaker assignments	Instructions for the speakers (presenters).

Sec.	Title	Contents and Notes
Appendices (continued)		
17	Workstation demo	Description of a medical imaging workstation for displaying the results of breast tomosynthesis. The workstation was exhibited during the reception before the dinner.
18	Acronyms	A glossary of acronyms and terms used in this report and the presentations.
19	Attendee list	A list of people who attended the workshop.
20	Biographies	Biographies of the people who attended the workshop.
21.1	Homework – assignment	Description of the homework that participants were asked to complete before the workshop.
21.2	Homework – deliverables	Homework assignments that were turned in. Note that some of the assignments were turned in after the workshop.
22	Minutes/Notes	Minutes taken by two sets of people during the workshop.
23	Presentations	Slides that were used by the participants in the various sections.

5. Outputs

5.1 Preamble

The meeting organizers planned the homework assignments, presentations and tracks so that charts could be generated that would address the objectives set forth in the Introduction. However, it was decided not to put the information into charts for the following reasons.

1. Many of the participants – mainly people from the medical imaging field – did not understand the requirements and needs for threat detection. They used the workshop in order to learn more about the issues in threat detection.
2. The vendors and the government were not able to discuss many of the specific problems with extant equipment because of proprietary and security issues.
3. There was too much emphasis on detected explosives in checked and carry-on bags using CT-based EDS and not enough discussion of non-CT devices for applications such as whole body imaging. This emphasis was correlated with the expertise of the people who were invited; that is, too many people with CT backgrounds were invited and not enough people with different expertise such as whole body were invited.
4. The organizers of the workshop made the assumption that if good ideas were generated in this workshop, then the process of how to get academia to develop algorithms could be easily addressed in another forum. This process includes funding, testing, access to datasets and scanner simulations, implementation, adoption and incentives. Based on this assumption, process was not on the original agenda. However, process turned out to be one of the most important aspects of the workshop and led to the discussion of grand challenges. Implementing grand challenges will entail putting the following information and materials into the public domain: data sets, comprehensive computational and analytical sensor models and acceptance criteria. People working on grand challenges should be provided financial incentives to advance the state of the art.
5. In spite of the above reasons, the objectives of the workshop were addressed as discussed in the following sections.

5.2 Review of existing technologies

The reviews of existing technologies can be found in the slides, which can be found in Section 23. The following notes apply to the technology review presentations.

1. The reviews were primarily limited to technologies (mainly X-ray CT EDS for checked bags). There was limited information on the other modalities present at the check-point.
2. There was significant discussion during the workshop on how the equipment is acquired and deployed. Additional discussions addressed the lack of incentives for improving equipment.

5.3 Issues and gaps in existing technologies

One issue that was identified is that different modalities may not be able to detect certain explosive categories, with lower masses, with higher PD per category and with lower PFA. However, the reasons why the various modalities (mainly CT-based EDS) may not achieve these specifications were not fully disclosed. It is assumed that the vendors and the government could not discuss the issues because of proprietary and security/classified reasons. It was very well understood that the discrimination capability of x-ray based devices is limited by simple physics, namely the fact that only density and perhaps atomic number are available.

The other issue that was identified was that performance of the human (operator) is not well understood. In particular, a question raised was would the operator's performance be increased if PD was lowered in order to decrease PFA in order to reduce vigilance decrement.

5.4 New algorithms that will address these issues and gaps

The main outcomes of the workshop are described in the following sub-sections.

5.4.1 Grand challenges

Grand challenges should be established for different aspects of improving security inspection with different modalities. The aspects include:

- Sensor modeling
- Pre-processing of sensor data
- Image reconstruction
- Automated threat detection including the steps of
    - Segmentation
    - Classification

- Improved operator performance.

The modalities include:

- X-ray CT for checked and carry-on baggage
- MM-wave and x-ray back-scatter for close proximity whole body imaging
- X-ray radiography and trace for cargo inspection
- Raman for stand-off detection on passengers.

A Grand Challenge enables access to the following information and materials into the public domain:

- Objectives
- Detailed descriptions of technologies
- Data formats
- Data sets divided for training and testing
- Acceptance criteria for the challenge.

People working on grand challenges should be provided financial incentives to advance the state of the art. The next section provides additional details on grand challenges.

5.4.2 Scanner simulators

Develop accurate scanner simulators to predict the performance of future systems. The simulators can also be used to provide data for the participants in grand challenges. We do not mean verbal/written descriptions of sensors. We mean analytical and computation models for mapping parameters of interest (e.g., spatial distributions of Compton scattering and photoelectric parameters) to observed data either for fielded systems or for model systems that approximate those in the field well enough to allow for meaningful evaluation of the processing results. All sensor related effects seen in the field which have an impact on the data (scatter, beam hardening etc), should be included in the model. Preferably, both analytical expressions for the models as well as computational realizations in Matlab or C should be provided or developed.

5.4.3 Operator performance and operator assist algorithms

Studies should be performed on systems that include a human in the decision making process. Methods should be established to assess and improve the performance of the human taking into consideration that the prevalence of threats is low at the present time. In this context, the potential

reduction of the probability of detection in automated threat detection algorithms in exchange for lower false alarms should be studied. Algorithms that estimate the amount of clutter in images could be used to send potential threats directly to secondary inspection, bypassing the operator, thus allowing the operator more time to view images of threats when they may be clearing on-screen. Algorithms could be developed to produce threat image projections (and equivalents for other modalities) independent of vendor.

5.4.4 Reconstruction algorithms leading to scanner design

Advanced reconstruction algorithms should be evaluated for x-ray CT equipment to see how they lead to the design of better CT scanners. An example of this methodology is denoted interior tomography, where the line-integrals are only collected within a region-of-interest smaller than the complete object being scanned. Interior tomography may allow higher quality scans of threats during secondary screening. Other reconstruction algorithms are also applicable as noted in Section 21.2. Accurate sensor models or actual data are required to support this task.

5.4.5 Communication

Communication – both formal and informal – between the government, vendors, academia and national laboratories was quite useful and additional communication should be fostered. It was clear from the workshop that academia and some vendors are not familiar with the DHS process, needs, etc. DHS should make available unclassified requirements.

5.4.6 Benefits

All participants agreed that the involvement of 3rd parties would benefit both the vendors and the government. However, the various stakeholders had different expectations in the time required to make contributions. The government and vendors wanted advanced algorithms developed in the six to twenty-four month time-frame. Academia felt that game-changing algorithms would take five to ten years to develop.

5.4.7 Orthogonal technologies

The use of orthogonal technologies (also denoted fused systems or systems of systems) should be explored. For example using x-ray diffraction after a CT EDS alarms may help with false alarm reduction. Several issues need to be resolved in order to make this practical and 3rd parties could help work on addressing these issues such as registration and combining detection

results from different systems. There are precedents for fusion in the medical imaging and geophysics literature.

5.4.8 Open source

An open source model should be employed for the distribution of algorithms, code, specification and databases. Standardized image and data formats, such as DICOS, would allow 3rd parties to develop algorithms more quickly.

5.4.9 Performance prediction

Develop automatic threat detection algorithms to predict the best possible performance (PD/PFA) from a modality based on the physics of the modality, and material characteristics of the threats and non-threats. If a modality is operating close to its best possible performance, then do not fund additional work on the modality.

5.4.10 Break from medical imaging

CT-based explosive detection systems (EDS) were derived from the medical imaging application and perhaps have not been sufficiently optimized for the security application[6]. Numerous opportunities were identified to break away from medical imaging domain and develop algorithms targeted for the security application. Examples include:

- Reconstruction optimized for security scenarios
- Targeted reconstruction to specific threats
- Segmentation-oriented reconstruction methods
- Local reconstructions optimized for a threat found during segmentation
- Targeted reconstruction for detection versus display
- Reconstruction algorithms for multi-view line scanners
- Parametric reconstruction
- Iterative/statistical reconstruction
- Artifact reduction such as from scatter and metal
- Improved dual-energy decomposition

5.4.11 Video surveillance

6 People in the medical imaging field are still felt to have the most expertise to optimize or extend their algorithms for the security application.

Use video surveillance to identify passengers that should be subjected to increased scrutiny at the check-point. Also use this method to associate divested items with the passenger.

5.4.12 Incentives

Vendors should be incentivized to deploy scanners with improved performance. The 3rd parties should also be incentivized to develop advanced algorithms.

5.5 Applications to other threats, modalities and venues

The participants emphasized that all of the modalities could be represented with the following elements.

- *Source*: This provides the energy for the interrogation of an object. Examples include x-rays and mm-waves.
- *Sensor*: This is the device that receives some form of interrogation energy or material. The forms of energy may be x-rays and electromagnetic radiation. The interrogation may also be air samples in the case of trace detection. The signals that are received are digitized leading to what is denoted raw data.
- *Reconstruction*: Raw data is processed to form an image (in the case of an imaging device) or characteristics about the object being interrogated in the case of a non-imaging device. Reconstruction for trace detection would be the generation of spectra.
- *Segmentation:* The process of organizing the reconstructed data to identify regions containing potential threats. Characteristics (features) are also extracted for the potential threats. Note that some modalities will not have a segmentation step. Examples include NQR and ETD.
- *Classification:* A decision on the presence or absence of threats made based on the output of segmentation. The requirement specifications for classification are classified and set by the TSA. Adherence to the specifications is done by the TSL.
- *False alarm resolution:* False alarms are resolved, typically with human intervention and/or other scanning modalities. The protocol used by the humans is denoted the on-screen-alarm-resolution protocol (OSARP). OSARP is determined by the TSA and the DHS.

Some of the above steps may not be performed by all modalities. The steps of segmentation and classification may be performed by an algorithm running on a computer or by a human. Some of the steps are hardware blocks and some steps are algorithms implemented in computers; hardware

and algorithms are mixed to show that data are generated/detected with hardware and then processed with algorithms.

Since all of the modalities conform to the above representation, the concept of using grand challenges to drive the development of advanced algorithms is applicable to all the modalities.

A large part of implementing classification and false alarm resolution is to understand the requirement specifications for classification and OSARP for false alarm resolution. Therefore, once a 3rd party understands these requirements for one modality, the person may be able to adapt their algorithms to other modalities.

5.6 Roadmap for development of new algorithms

New algorithm methods such as for segmentation could be developed for proof of concept in 3-6 months using grand challenges. Development in this context means that initial algorithms are ready for testing on sensitive security and classified data, and poised for implementation. An advanced development phase may take an additional 9 – 15 months. The overhead of using grand challenges, especially for the first grand challenge, may increase development times; there may be other ways to send extant datasets to 3rd parties.

It appeared that the vendors and the government wanted short-term solutions, i.e., in less than two years. The government also wanted game changers developed; the academic participants felt it would take between five and ten years for the development of game changers.

5.7 List of people and institutions that can contribute 3rd party algorithms

Examples of people and institutions that could contribute 3rd party algorithms include the people listed in the homework assignments in Section 21.2 and the workshop participants from 3rd party institutions as listed in Section 20.

5.8 Requirements for government furnished information and funding

The requirements for government furnished information (GFI) are described in the next section.

6. Grand Challenges

6.1 Overview

This section provides additional information about what the participants at the workshop said about grand challenges (GC). A complete section is devoted to GCs given that people felt it was the best way to get 3rd parties involved in the development of advanced algorithms.

6.2 Background

The following definition for a GC is found on Wikipedia[7]

"Grand Challenges were USA policy terms set as goals in the late 1980s for funding high-performance computing and communications research in part in response to the Japanese 5th Generation (or Next Generation) 10-year project. A grand challenge is a fundamental problem in science or engineering, with broad applications, whose solution would be enabled by the application of high performance computing resources that could become available in the near future."

Examples of GCs are listed on Wikipedia.

Another example of a GC is the Netflix Prize that Netflix used to stimulate the development of advanced algorithms to improve the prediction of what their subscribers would order in the future[8]. The prizes for the contest are as follows:

Contest Prizes:

1. Grand Prize: $1,000,000 (USD) Cash
2. Progress Prizes: $50,000 (USD) Cash each award

6.3 Definition

In this report the term *Grand Challenge* denotes a process wherein participants are provided datasets and requirement specifications related to important DHS problems that require algorithmic solutions. Prizes (i.e., funding) will be provided if the problems are solved. Seed funding may or may not be provided to the participants.

[7] http://en.wikipedia.org/wiki/Grand_Challenge
[8] http://www.netflixprize.com/

6.4 Components of a Grand Challenge

The following list shows the major steps in implementing a GC as envisioned in this document.

1. Define
    a. Problem to be solved
    b. Input and output data
    c. Acceptance criteria
2. Acquire and distribute sample input data
3. Identify and qualify participants
4. Fund participants
5. Participants train algorithm and then validate
6. Participants write a summary report
7. Supervise participants
8. Validate and evaluate algorithms
9. Write report
10. Down selection of a few promising algorithms
11. Iterate development of algorithm using sensitive and classified data
12. Deploy algorithm

6.5 Questions about implementing grand challenges

6.5.1 What algorithms can be addressed?

1. Reconstruction
2. Segmentation
3. Identification of features for use in detection/classification
4. Detection/Classification
5. Operator performance
6. Scanner and scenario (threats and non-threats in bags) modeling
7. Fusion

Notes:

1. The steps of segmentation and detection/classification, when performed automatically by a computer, are sometimes referred to as automated threat detection (ATD).
2. Scanner and scenario models may not be an algorithm topic, but may possibly be part of an algorithm. This is part of implementing a good scanner and scenario simulator.
3. It is recommended that the topics be initially addressed individually. Over time, the interactions between the topics will have to be addressed.

6.5.2 What modalities can be addressed?

1. X-ray CT – transmission and scatter
2. Threat-image-projection (TIP) ready x-ray (TRX) projection line scanner
3. Multi-view line scanners (known as advanced technology [AT])
4. X-ray back-scatter
5. Coherent X-ray scattering (sometimes called X-ray diffraction)
6. Active neutron and X-/Gamma-ray (e.g., Pulsed Fast Neutron Analysis)
7. Explosive trace detection
8. Millimeter wave and Terahertz imagery or spectroscopy
9. Raman spectroscopy

6.5.3 What applications can be addressed?

1. Checked baggage screening
2. Check point screening
    a. Carry-on items
    b. Passengers
    c. Divested items
        i. Liquids
        ii. Shoes
3. Stand-off detection
4. Cargo screening
5. Multi-System fusion

6.5.4 What are the recommended first two grand challenges?

1. CT-based EDS
    a. Segmentation
    b. Reconstruction

6.5.5 How should problems be defined?

1. Specify general problem to be solved
2. Define input data
3. Define output data
4. Define acceptance criteria, which are based on a significant advancement beyond the state of the art

6.5.6 What type of scanners should be used to acquire input data?

1. State-of-the-art security equipment (best case)
2. Legacy security equipment
3. Scanners from other applications such as medical imaging or non-destructive evaluation

4. Custom-designed scanners
5. Scanner simulators (mathematical models)

6.5.7 What information should be provided about scanners used to acquire data?

1. Description of source, sensor and geometry
2. Details of calibration, correction and reconstruction
3. Quality assurance results including scans of quality assurance phantoms
4. Data file formats
5. Scan protocols

6.5.8 What objects should be scanned?

1. A range of common objects carried by passengers
2. Objects may have to be physically scaled to match the resolution of the scanning device

Notes:

1. As algorithms are moved towards possible implementation, then the algorithms should be tested on scans of the following objects:
    a. Real threats (best case)
    b. Simulants (next best)
    c. Objects known to cause false alarms

6.5.9 What information should be provided about objects?

1. Written description
2. Digital picture
3. Dimensions
4. Mass
5. Volume
6. Physical characteristics that are relevant to the scanning device. For example, for transmission x-rays, provide x-ray attenuation, density, texture and effective atomic number.

6.5.10 How should objects be scanned?

1. Bare
2. Within a range of different types and sizes of luggage
3. Concealed
4. With various amounts of clutter and attenuation (many surrounding objects)
5. At different locations and orientation in the scanner

6.5.11 What object scanning information should be provided?

1. Digital pictures of all objects bare and packed
2. Overview of scan (text)
3. List of objects to be distinguished from other objects
4. Labeled versions of images showing which object is in each pixel.
5. Truth data including bounding box key, attenuation, volume (e.g., number of voxels for CT)
6. A log file that will be described in a separate document

6.5.12 Where the information should be archived?

1. ALERT COE
2. DHS S&T EXD Image Database at LLNL

6.5.13 Who should have access to the grand challenge information?

1. Everyone/anyone, without limitation.
2. There are no requirements on:
    a. Having a security clearance
    b. Having access to SSI, FOUO or classified information
    c. Signing an NDA
    d. Having a US citizenship
    e. Working in the US
3. Academia
4. Vendors
5. National laboratories
6. 3rd party industry (not the system vendors)

Notes:

1. It is desirable that all of the above parties have access to the data for grand challenges without restriction.
2. May not be possible to provide seed funding to all participants or be able to formally evaluate all algorithms.

6.5.14 How shall participants be identified?

1. Creation of a website for the grand challenge
2. Word of mouth
3. Advertising in journals and trade magazines
4. Literature review
5. Using the names provided in this report
6. Adding sessions related to security at imaging conferences such as IEEE's Medical Imaging Conference (MIC).

6.5.15 What criteria should be used to choose participants?

1. Domain expertise in
    a. Algorithms used related fields that are applicable to grand challenge
    b. Technology and algorithms in the security field
2. Existence and maturity of related algorithms
3. Resource availability
4. Development time
5. Development cost (personnel and equipment)

Notes:

1. This section applies only to participants that receive seed funding.

6.5.16 How shall participants be funded?

1. Little or no seed funding
2. Larger funding levels for demonstrating significant improvement over state-of-the art
3. Royalties

6.5.17 Who will implement and deploy the algorithms?

1. Vendors (best case)
2. System integrators

6.5.18 How will algorithms be tested?

1. Using input data that has not been provided to the participants
2. Using acceptance metrics that are defined in advance

Notes:

1. The testing described in this section applies to the testing done by the organizers of the grand challenge. The participants will also be required to test their algorithms on datasets that will be provided with the training data.

6.5.19 How will the algorithms be improved?

1. A person with a security clearance will test algorithms with real scans of real threats.
2. Algorithms may have to be tuned to specific threats and scanner

6.5.20 What deliverables are required?

1. Report including
    a. Description of algorithm
    b. Test methodology and results
    c. List of issues and possible mitigations
    d. Recommendations for future work
2. Executable code

6.5.21 What can the participants do with the results?

1. Present at conferences
2. Write journal articles
3. Write dissertations
4. Obtain patents

6.5.22 What non-technical issues have to be resolved?

1. Contracts with people who receive seed funding including ownership and use rights
2. Intellectual property – patents and licenses
3. Testing algorithms with real threats scanned on real scanners
4. Review of publications and presentations
5. Control of information and material by the DHS

Notes:

1. Need to resolve who own the rights to use algorithms if the Government supplies funding.

6.5.23 Who are members of the team that drive grand challenges?

1. DHS S&T
2. ALERT COE
3. National laboratories
    a. LLNL
    b. PNL
    c. Sandia
4. TSA

6.5.24 What other funding vehicles exist to support grand challenges?

1. DoD
2. DARPA
3. NSF
4. SBIR

6.5.25 How could participants be incentivized?

1. Seed funding
2. Follow-on funding
3. Prizes
4. Royalties

Notes:
1. The incentives should be developed so that collaboration is encouraged.

6.6 Grand Challenge Example – Segmentation for Volumetric CT

CT scanners are used to detect explosives in checked baggage. These scanners are certified by the Transportation Security Administration (TSA) and denoted explosive detection systems (EDS). The systems consist of a CT scanner with an automated threat detection algorithm (ATD) for finding explosives in scanned baggage. ATD consists of two portions: segmenting objects from the CT data and then identifying whether the objects as threats or non-threats, they also classify them into a particular category.

EDSs are produced by a number of vendors and deployed at a number of airports. However, there are high labor costs related to clearing the baggage that generate false alarms in the field.

Participants at the workshop indicated that some of the false alarms are due to failures with the segmentation step of ATD. Single objects may be split into multiple smaller objects, each having less than the minimum required mass for a threat. Multiple objects may be combined into a larger object, which is called aggregation and sometimes is denoted as an aggregate or conglomerate object. The physical characteristics (e.g., density and effective atomic number) of the aggregate/conglomerate object containing a threat may be different than the threat contained in the conglomerate object.. Sheets may push resolution limit of scanner. Objects of interest next to/inside of highly attenuating objects (metals) may be obscured by beam hardening/streaking artifacts. Objects can be masked to be shaped like other objects. In all cases, threats may not be detected. Therefore, it is desired to have a grand challenge on segmentation of objects from CT data.

Participants in the GC will be given sets of volumetric data corresponding to scans of baggage containing known non-threat objects. To be an open data set in this GC, the data will only consist of non-threats. Algorithm developers will develop an algorithm to segment all objects of above given mass. It is to be determined if all objects have to be found or only those objects that resemble threats. The algorithms will report on how accurately the objects were segmented on a training set and a validation set, both of which will be

provided with truth data. A third-party will confirm the validated results and also independently evaluate the algorithms on a second dataset, which will not be provided to the algorithm developers.

The following information will be provided to the participants in the grand challenge.

1. CT images of approximately 100 bags. Participants are expected to use the bags for both training and testing, as they see fit. The bags and the objects in the bags may be physically scaled to match the resolution of the scanner.
2. CT images of the approximately 500 items that will be placed in the bags
3. Digital pictures of the objects and the bags
4. Descriptions of the bags and the objects
5. Image format
6. Keys for the locations of the objects in the bags
7. Metrics (e.g., volume and attenuation recoveries) for defining the accuracy of segmentation

The scanners used for this GC may or may not be security scanners. The bags will probably NOT contain threats.

The participants will deliver the following material to the organizer of the grand challenge.

1. Executable segmentation code
2. Report that includes
    a. Description of algorithm
    b. Accuracies
        i. Validation set
        ii. Training set
    c. Description of execution environment
    d. Execution times (mean, min, max)
    e. List of issues
    f. Recommendations for future work

The organizer of the grand challenge will do the following with the deliverables.

1. Run the executable on the validation data and evaluation data (not shared with the participant).

2. Resolve issues with the executable code and any discrepancies between participant and organizer validation results with the participant.
3. Issue a report to DHS about the segmentation algorithm results and describe how much additional work would be required to deploy the algorithm,

The above steps may be iterated in order to help the participant improve the quality of their deliverable.

LLNL recently conducted a grand challenge similar to one described in this section. LLNL supplied scans of liquid explosives on single view line scanners to 3rd parties who have developed segmentation and classification algorithms. It is recommended that LLNL's 3rd Party documents be used as the basis for the grand challenge described in this section.

A grand challenge for segmentation for a medical application was recently described by Heimann *et al.* (*IEEE Transactions on Medical Imaging*, Vol. 28, No. 8, pp. 1251 – 1265, August 2009). The authors of this paper should be contacted to get their advice about segmenting images for a security application.

6.7 Grand Challenge Example – Operator Performance

The following material discusses an example of a grand challenge for assessing the performance of an operator that is required to resolve false alarms[9].

One approach to reducing false alarm and/or increasing throughput in the EDS task would be to propose a grand challenge in which competitors were challenged to improve performance on a specific task with a specific, benchmarked set of images. Such a challenge might have the following steps:

1. Create a set of 1000 bag/images that alarm and, thus, would be examined by a TSO. The set would be designed so that, under present testing conditions, 75% would be correctly cleared and dismissed by the screener. Another 20% would produce false alarms (meaning that these bags would have been brought in for unnecessary inspection). Finally, 5% would be target bags, containing items that alarm and that should require further inspection.

[9] This material was provided by Jeremy Wolfe (Harvard Medical School).

2. This bag set would be tested in order to empirically determine the true and false alarm rates. Moreover, the throughput rate (bags/hr) would be determined.
3. Half of the set would be offered to competitors who would be challenged to produce the greatest reduction in a combined time and error score. Competitors could manipulate the task and/or the images in an effort to improve performance. Each competitor would deliver a protocol to DHS for testing.
4. The other half of the bag set would be reserved for testing. In the evaluation phase, each competitor's method would be tested on the reserved bag set. The best outcome, assuming that the improvement exceeded some threshold, would be awarded the prize and, one presumes, further research and development would follow.

It is recognized that evaluating performance of an operator in the loop would be very difficult. Additional work is required to determine how to perform this type of evaluation.

There are concerns that a tester could learn the data sets. The tests would have to be designed to prevent this from happening.

7. Future Efforts

This section contains recommendations for future efforts to increase the involvement of 3rd parties in the development of advanced algorithms for security applications.

1. Have workshops on the following topics
    a. Grand challenges
    b. Stand-off detection
    c. Automated threat detection
    d. Image reconstruction
    e. Cargo screening
    f. Whole body imaging
    g. Sensor fusion
2. Establish the general process for having grand challenges
3. Have grand challenges for the following topics
    a. X-ray CT
        i. Image segmentation
        ii. Image reconstruction
        iii. Automated threat detection
        iv. Sensor modeling
    b. WBI
        i. Sensor modeling
        ii. Threat detection
    c. Human operator performance
        i. PD versus PFA
        ii. Effect of TIP
4. Publicize grand challenges at conferences and workshops, through announcements in journals, and via word of mouth.
5. Create a website where information and material about threat detection can be exchanged. Use RSS or equivalent to alert people about new content.
6. Establish a method to seed and reward people for developing advanced algorithms.

8. Lessons Learned and Mitigation

Lessons Learned	Mitigation
Some participants did not stay for the complete workshop.	Ask for commitment that participants will stay for complete workshop unless there are extenuating circumstances. If the participant is also a speaker, make sure that a backup is available.
Informal discussion among the participants is important, but there was not enough time for these types of discussions.	Increase the time for breaks and receptions. Do not make meals working sessions.
The presentations could have been more tightly coupled to the objectives of the workshop.	Spend more time discussing objectives of workshop in advance with speakers. Review presentations and abstracts in advance. Have 3rd parties (not vendors) give more presentations so that issues with extant equipment do not have to be disclosed by vendors. Provide detailed templates and instructions in advance. Make sure that the speakers have direct knowledge of a topic. Narrow the scope of the workshop and the presentations.
Not enough introductory material was presented in order to familiarize 3rd parties with the issues facing explosives detection.	Give tutorials perhaps at sessions without the people who are familiar with the topic.

Lessons Learned	Mitigation
Distribution policy for completed homework assignments and presentations were not defined in advance of the workshop. Some presentations were blocked from being distributed or had to be cleansed of proprietary material before distribution.	State policy clearly before workshop. Participants must accept policy before agreeing to participate. Policy should be that be that all material has to be the public domain. Some material (for example, homework assignments) might be made anonymous by removing names or by aggregating with other material.
Break-out sessions did not add enough value to achieve the goals of the conference. (They did increase the interaction time among participants.)	Either make the break-out sessions more specific or eliminate them.
Indemnification policy was not clearly stated in advance.	State policy in advance. Policy should be that organizers bear all responsibility for the final report.
Suppression of process did not work in order to focus on technology. The goal of the workshop was to assume that the process would be worked out if the ideas were generated.	Allow process to be discussed. However, do not allow unsolved issues to prevent discussion of other topics.
The homework assignment was not as valuable as expected. Many people indicated that they did not have enough knowledge of the field to comment. Other people indicated that they did not have enough time to work on the assignment.	Target a sub-set of the attendees with preparatory work. Ask participants to review written material that will be used at the workshop.

Lessons Learned	Mitigation
There was too much emphasis on CT and not much on WBI.	Make sure people in attendance have sufficient knowledge of the topics to be covered. Limit the scope of the workshop to a small number of topics.
Acceptance criteria not presented.	Present them.
Issues and gaps were minimally presented because of proprietary and secrecy issues.	Have issues and gaps presented by someone not from the vendors or from the Government. Find a way to present the problems without disclosing proprietary or classified information. See the section on grand challenges for additional information. Hold break-out sessions where the vendors and the Government are not present.
Schedule did not permit enough questions/answers and discussion.	Double the time slot for each speaker/session.
Some participants were quiet during the workshop.	Have more "round the room" sessions.
Minute takers were not designated in advance and the use of the minutes was not specified.	Designate two people in advance and say that their minutes will be included in the final report.

9. Notes

This section contains miscellaneous notes about the workshop itself and the final report.

The final report will be distributed as a hardcopy, via the Internet and a CD.[10]

1. The following comments are in regards to the slides that accompanied the presentations given at the workshop, provided in Section 23.
2. The slides can also be found at ftp://ftp.censsis.neu.edu/ADSA/.
    a. Some of the slides were edited after the workshop to remove proprietary information.
    b. We did not receive permission from all the speakers to distribute their slides.
    c. The slides from the dinner presentations are not included because they did not contain information directly related to the workshop.
    d. Some of speakers gave two presentations and then combined their slides into one file.
3. The agenda was followed for the most part. The most significant change was the addition of a final session where all participants were invited to make closing comments.
4. Comments about the logistics and the reimbursement policy are beyond the scope of this report.
5. All the material that was distributed before the meeting and during the meeting is included as appendices for reference and archival purposes.
6. The workshop was not recorded on audio or video in order to encourage discussion, and in particular to discuss problems and issues with threat detection technologies.

[10] Subject to DHS approval.

10. Acknowledgements

The planning committee would like to thank the following people and organizations for their involvement in the workshop.

- DHS S&T for funding ALERT and sponsoring the workshop.
- Doug Bauer, DHS, and George Zarur, TSA, for their vision to involve 3rd parties in the development of technologies for security applications.
- Suriyun Whitehead for coordinating the participation of DHS and TSA.
- Northeastern University for hosting the workshop.
- Mariah Nóbrega for handling logistics before and during the workshop.
- Amy Lehrmitt and Brian Loughlin for providing audio-visual assistance.
- Richard Moore and Dan Kopans for setting up a Wiki-based website for algorithm development.
- Jeremy Wolfe and Dan Kopans for speaking during the dinner session.
- Mariah Nóbrega, Harry Martz and David Castañón for editing this report.
- Harry Martz, Mariah Nóbrega and Amy Lehrmitt for taking the minutes.
- Harry Martz for proving feedback at every stage of the workshop.
- Jeremy Wolfe for providing the material on grand challenges for human factors.
- Jeremy Wolfe, Eric Miller, Home Pien, Matthew Merzbacher, Jim Connelly and Sondre Skatter for reviewing the final report.
- Rachel Harger for formatting the final version of the report.

The workshop would not have been a success without the participants and the speakers. The technical content of this report is due mostly to them. We extend our heartfelt thanks to them for their contributions.

11. Appendix: Agenda for workshop

Thursday, April 23, 2009

10:00 AM Registration (coffee/drinks/snacks)
11:00 AM Welcoming remarks
- Michael Silevitch, Northeastern University

11:10 AM DHS Objectives for Workshop
- Suriyun Whitehead, DHS S&T

11:30 AM Workshop goals, deliverables and process
- Carl Crawford, Csuptwo

12:00 PM Break and get box lunch
12:15 PM Overview of Integrated Check Point Algorithms: Issues of today and tomorrow
- Jason Martin, TSA
- Matthew Merzbacher, GE Security

1:15 PM Reconstruction: State of the Art and Issues
- David Schafer, Analogic

1:45 PM Automated threat detection and fusion: State of the Art and Issues
- Sondre Skatter, GE Security

2:15 PM Break
2:30 PM Emerging technologies: State of the Art and Issues
- Richard Bijjani, Reveal

3:00 PM Surveillance and human factors: State of the Art and Issues
- John Pearson, Siemens Corporate Research

3:30 PM Instructions for breakout sessions
- Carl Crawford, Csuptwo

4:00 PM Breakout sessions: Gap Analysis and Recommendations

Session #1: Reconstruction

- Leader: David Schafer, Analogic
- Location: Stearns 421

Session #2: Automated threat detection and fusion

- Leader: Sondre Skatter, GE Security
- Location: Stearns 012

Session #3: Emerging technologies

- Leader: Richard Bijjani, Reveal Imaging
- Location: Stearns 402

Session #4: Surveillance and human factors

- John Pearson, Siemens Corporate Research
- Location: Stearns 318

5:15 PM Break

5:45 PM Reception (sponsored by Csuptwo)
Location: Stearns Center, Room 415

- Demonstration: Mammography workstation.

6:30 PM Working Dinner
Location: Stearns Center, Room 431

- Remarks: Doug Bauer, Department of Homeland Security
- Talk: Daniel Kopans, Harvard Medical School, "Seeing Below the Surface"
- Talk: Jeremy Wolfe, Harvard Medical School, "Human factors and experiences working with DHS"

Friday, April 24, 2009

7:15 AM Breakfast

8:00 AM Introduction to day two
- Carl Crawford, Csuptwo

8:10 AM Reconstruction: Gap analysis and technology roadmaps
- David Schafer, Analogic

8:45 AM Automated threat detection and fusion: Gap analysis and technology roadmap
- Sondre Skatter, GE Security

9:20 AM Emerging technologies: Gap analysis and technology roadmap
- Richard Bijjani, Reveal Imaging

9:55 AM Surveillance and human factors: Gap analysis and technology roadmap
- John Pearson, Siemens Corporate Research

10:30 AM Break

10:45 AM Recommendations for Research Roadmap

Moderator: Carl Crawford, Csuptwo

Panel members:
- David Castañón, Boston University
- Carey Rappaport, Northeastern University
- Michael Ellenbogan, Reveal Imaging
- Harry Martz, Lawrence Livermore National Laboratory
- Michael Lanzaro, L-3 Communications

12:15 PM Break and get box lunch

12:30 PM Development of framework and process for research roadmap

Moderator: Carl Crawford, Csuptwo

2:00 PM Closing remarks
- Suriyun Whitehead, DHS S&T
- Michael Silevitch, Northeastern University

2:30 PM End of workshop

12. Appendix: Scope

The following topics are to be considered at the workshop.

1. Potential threats at integrated checkpoint
    a. Explosives
        i. Military
        ii. Commercial
        iii. Home made explosives (HME)
        iv. Pre-cursors
        v. IED
    b. Weapons
2. Applications that may be deployed at integrated checkpoint
    a. Liquid scanner
    b. Shoe scanner
    c. Whole body imaging (WBI)
    d. Checked bag and other divested items scanner
    e. Visual inspection of people
    f. External information sources
        i. About passenger
        ii. About potential threats
        iii. Integrating sub-critical masses at or post checkpoint
3. Modalities that may be used at integrated checkpoint (or in association)
    a. CT (large number of views)
    b. Line scanners
    c. Multi-view line scanners
    d. Nuclear quadrupole resonance (NQR)
    e. Diffraction x-ray
    f. T-wave (THZ)
    g. Millimeter wave
    h. X-ray backscatter
    i. Trace (whole body and swipe)
    j. Integrated systems (system of systems)
        i. Video surveillance
        ii. License plate scanner
        iii. Driver's license scanner
    k. Biometrics
    l. Metal detectors
4. Examples of algorithms
    a. Reconstruction algorithms
        i. Limited views

   ii. Dual energy (and multiple energy) decomposition
   iii. Iterative reconstruction
   iv. Artifact correction
   v. Resolution enhancement
   vi. Compressed sensing
b. Automated detection algorithms
   i. PD/PFA improvements
   ii. General purpose automated threat detection
   iii. Liquid
   iv. Extensible
   v. WBI
c. Operator assistance and replacement
   i. Human factors
   ii. Displays
   iii. Operator assistance
d. Other
   i. Scanner fusion, system of systems (interoperability)
   ii. Risk assessment
   iii. Performance prediction for policy decisions (ROC generation)
   iv. Extensibility
   v. CAPPS

13. Appendix: Overview[11]

The Department of Homeland Security (DHS) has requirements for future scanners that include a larger list of threats, higher probability of detection, lower false alarm rates, creating systems-of-systems and lower operating costs. One tactic that the DHS is pursuing is creating an environment where the capabilities of the traditional vendors of security systems could be augmented with the development of algorithms by third parties. Of particular interest is following the model used in the medical imaging industry, where university researchers have developed numerous algorithms that have been eventually deployed in commercial medical imaging equipment.

A tactic that DHS is using to develop 3rd party algorithms is to issue a request for information[12] (RFI) for 3rd party algorithm development. The RFI will be followed by a broad agency announcement (BAA), which may lead to the funding of third parties.

Another tactic that the DHS is using to stimulate 3rd party algorithm development is to hold a workshop addressing the research opportunities that may enable the development of next generation algorithms for Homeland Security applications. The Algorithm Development for Security Applications (ADSA) Workshop will be held at Northeastern University (NEU) on April 23rd and 24th, 2009. The workshop is being lead by Professor Michael B. Silevitch (NEU) as part of a Center of Excellence award from the DHS entitled Awareness and Localization of Explosives-Related Threats[13] (ALERT). The sponsors of the workshop are NEU and DHS.

The objectives of this workshop are to:

- Provide an analysis of the opportunities and research barriers associated with next-generation algorithms for Homeland Security applications, using the integrated checkpoint as a basis of discussion.
- Consider the following questions:
    - What will be the consequences of maintaining the current trajectory using existing technologies and strategy?

---

[11] This overview was distributed to the participants before the workshop began. This material has been adapted for the introduction of this report.

[12] https://www.fbo.gov/spg/DHS/OCPO/DHS-OCPO/OPO-09-00000-RFI/listing.html

[13] http://www.northeastern.edu/alert

    - How can we foster innovative solutions using new technologies and strategy?
- Facilitate academia's involvement, especially the medical imaging community, in DHS's new algorithm development strategy.
- Address specific questions posed by DHS.
- Identify 3rd parties who can submit to the RFI and BAA.

The scope of the workshop has been limited to the integrated checkpoint. However, it is expected that the results of the workshop will be extensible to other applications such as checked baggage and standoff detection. Future workshops on other topics are anticipated.

The topic of algorithms for the integrated checkpoint will be addressed through discussion of the following four themes:

- Reconstruction
- Automated threat detection and fusion
- Emerging technologies
- Surveillance and human factors

People skilled in the above topics will lead specific tracks dealing with these subjects. The specifics of the agenda for the workshop can be found in an attachment.

The deliverable from this workshop will be a report that discusses the following topics related to the integrated checkpoint:

- Review of existing technologies
- Issues and gaps in existing technologies
- New algorithms that will address these issues and gaps
- Applications to other threats, modalities and venues
- Roadmap for development of new algorithms
- List of people and institutions that can contribute 3rd party algorithms
- Requirements for government furnished information and funding

A group of approximately forty people are planning to attend the workshop. The group is split between academia, national laboratories, government and industry. A complete list of attendees can be found in an attachment. The speakers and leaders at the conference will be provided with instructions before the workshop in order to focus their efforts towards the objectives. All attendees will submit preliminary summaries along the lines of the final report as described by homework assignments described in an attachment.

14. Appendix: Planning Committee

The planning committee for the workshop consisted of the following people:

- Michael Silevitch, Northeastern University
- Carey Rappaport, Northeastern University
- David Castañón, Boston University
- Horst Wittmann, Northeastern University
- John Beaty, Northeastern University
- Carl Crawford, Csuptwo, LLC

The final report was edited by:

- Michael Silevitch, Northeastern University
- Carl Crawford, Csuptwo, LLC
- Harry Martz, LLNL

Logistics for the workshop were handled by:

- Mariah Nóbrega, Northeastern University

15. Appendix: Invitation

The purpose of this email is to invite you to participate in a workshop addressing the research opportunities that may enable the development of next generation algorithms for Homeland Security applications. If possible, could you please reply to this invitation by Friday, January 30th?

The workshop will be held at Northeastern University (NEU) on April 23rd and 24th, 2009. The workshop is being lead by Professor Michael B. Silevitch (NEU) as part of a Center of Excellence award from the DHS entitled Awareness and Localization of Explosives-Related Threats (ALERT, www.northeastern.edu/alert). I will be the moderator for the workshop.

The Department of Homeland Security (DHS) has requirements for future scanners that include a larger list of threats, higher probability of detection, lower false alarm rates, creating systems-of-systems and lower operating costs. One tactic that the DHS is pursuing is creating an environment where the capabilities of the traditional vendors of security systems could be augmented with the development of algorithms by third parties. Of particular interest is following the model used in the medical imaging industry, where university researchers have developed numerous algorithms that have been eventually deployed in commercial medical imaging equipment.

The DHS has issued a request for information (RFI) for 3rd party algorithm development. The RFI will be followed by a broad agency announcement (BAA), which may lead to the funding of third parties.

The objectives of this workshop are:

- Provide an analysis of the opportunities and research barriers associated with next-generation algorithms for Homeland Security applications, using the integrated checkpoint as a basis of discussion.
- Consideration of the following questions:
    - What will be the consequences of maintaining the current trajectory using existing technologies and strategy?
    - How can we foster innovative solutions using new technologies and strategy?
- Facilitate academia's involvement, especially the medical imaging community, in DHS's new algorithm development strategy.
- Address specific questions posed by DHS.

Enclosed is a provisional outline of the workshop, including the agenda and list of participants. Please note that all participants have homework assignments due before the workshop. I, as the moderator, will edit a report based on the workshop for the DHS.

I have the following questions for you.

- Will you be able to participate?
- Can you suggest other people who should attend the workshop as participants, speakers or session chairs?
- Can you suggest people who would want to receive information about the RFI, BAA, and the final report from the workshop?
- Do you have suggestions on changes to the enclosed outline?

Travel expenses will be reimbursed. However, an honorarium will not be paid.

Please email me your replies to the questions.

Please feel free to contact me (see below for contact information) or Michael B. Silevitch (msilevit@ece.neu.edu or 617-373-3033) on all matters related to the workshop.

Thank you for your consideration of the workshop and I look forward to your participation.

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16. Appendix: Speaker assignments

The following sections show the instructions sent to the speakers and presenters in advance of the workshop.

16.1 All speakers

The purpose of this document is to provide general instructions to the people who will be speaking at the workshop. These instructions are provided to ensure that the primary goal of the conference is achieved: Provide an analysis of the opportunities and research barriers associated with next-generation algorithms for Homeland Security applications, using the integrated checkpoint as a basis of discussion. Specific instructions for most of the speakers will be provided in a separate document.

1. Concentrate material on integrated check point. However, extension to other applications is desired. See the separate document on scope for examples of items that may be considered.
2. Presentations should follow objectives set in the final report. This will minimize the effort required to generate the report.
3. All presentations will be become part of the record of the workshop. They may be distributed, but they will not be posted on the Internet.
4. Proprietary information should not be presented.
5. Classified or sensitive or sensitive security information (SSI) may not be presented.
6. Stick to the time limits set forth in the agenda.
7. Questions and discussion should be solicited during your time slot.
8. Mariah Nóbrega will be sending you audio-visual (AV) instructions for making your presentation.
9. Minimize advertisement of present technology.
10. Discuss technologies and equipment outside of your area of expertise or company.
11. Speakers in sessions with multiple speakers are encouraged to discuss their presentations before they present in order to reduce overlap.
12. Concentrate on algorithmic solutions.
13. May address, albeit for ~5% of time, requirements for government furnished information (GFI), deployment and funding.
14. Minimize advertisement of present products and solutions.
15. Present products and solutions from other vendors.
16. Minimize discussion of adoption issues on how a 3rd party's work would be deployed in your systems both from a technical and financial point of

view.
17. State objectives for short- and long-term.
18. Emphasize that funding vehicles will be designed to support 3rd party algorithmic development.
19. Focus discussions on technical solutions versus adoption issues.

16.2 DHS speakers

1. Overview of state-of-art from DHS/TSA point of view including discussion of issues.
2. Discuss future requirements (cost, threats, PD, PFA)
3. Present reasons for 3rd party algorithm development
4. Present expectations for outcome of workshop.
5. Costs associated with equipment including processing false alarm

16.3 Overview sections speakers

1. History of threats and technology
2. State of the art deployed
3. Review of procurement process
4. Emerging threats
5. Role of 3rd party algorithms
6. Issues related to development and procurement
7. Two speakers should coordinate talks before workshop

16.4 Track leaders

1. Tracks:
    a. Reconstruction
    b. Automated threat detection and fusion
    c. Emerging technologies
    d. Surveillance and human factors
2. General
    a. Focus of checkpoint, but discuss extensions to other applications
    b. Address all relevant modalities and applications noted above
3. Presentations on first day
    a. Review state of the art
    b. Identify issues with state of the art
    c. Predict new issues with future requirements
4. Breakout sessions on first day
    a. Discuss presentation with group
    b. Expand on presentation
    c. Reduce material to form specified for final report

   d. Prepare presentation for Day 2.
   e. Ask moderator to coordinate scope issues between different tracks
5. Presentations of the second day
   a. Present results of breakout in format consistent with final report

16.5 Panel members

1. Give 10 minute presentation on your vision of the research roadmap
2. Discuss gaps and potential solutions
3. Critique, compliment and complement results of breakout sessions
4. PPT presentation would be beneficial, but can be raw/provisional
5. Promote discussion among rest of panel and with all participants

16.6 Dinner speakers

1. Problems with human in the loop
   a. Detection of rare objects
   b. Vigilance decrement
   c. Incentives and disincentives
   d. Role of advanced displayed
2. Personal experience in working with FAA/TSA/DHS
   a. Acquiring funding
   b. Testing
   c. Publications
   d. Institutional requirements (publications, patents, classified material)
3. Make the session into a discussion versus a formal presentation.
4. The total time – talk and discussion – should be 45'

17. Appendix: Workstation Demo

The MGH BI Lab has implemented an ultra high-speed dataflow management system and Advanced Tomosynthesis Workstation (ATW), which automatically processes and cues the case datasets for review at very high native resolution. Optionally employing 2 to 4 IBM 9-megapixel LCD displays driven by dual NVIDIA graphics engines we are able to present the tomosynthesis and the conventional 2-view mammography (CTVM) pairs scrolling together in a full resolution workspace while meeting our speed requirements.

Coherent, fast, case presentation is required for efficient radiologist function. ABTS generates about 50-fold more data than CTVM. Very specific and individualized rendering specifications (hanging protocol) have to be met with under 1-second case-to-case transition time. Real-time interactive control of the contrast, baseline, and synchronized slice, mirrored zoom and roam permit using ABTS in a screening environment, our fundamental project goal.

Breast screening requires direct (usually side-by-side) comparison of the left and right tomosynthesis volumes, as well as the side-by-side prior CTVM and DBT, left and right in each projection commonly employed. Left and right Cranial-Caudal (CC) and left and right Medial-Lateral-Oblique (MLO) views are the norm for 2D mammography. For the present study CTVM film images, CTVM digital images and prior DBT volumes are available in a mixture. The MGH clinical practice converted to all digital CTVM over 2 years ago. Therefore, a mixture of mostly CTVM digital images and a minority of CTVM films must be used for the one and two-year prior comparison for the reading of screening studies. We accomplish this with CTVM digital workstations, a film alternator and the ATW. The radiologist sits in the center of these devices, pivoting to face each one as needed. Using the latest version of Windows-XP-64 Operating system, 10-disk RAID-1 striped storage, and 16 gigabytes of system caching onto solid-state drives, , we are able to prefetch four complete mixed datasets (2 or 4-TOMOs, 2-CTVM-CCs and 2-CTVM-MLOs) using the worklist order. Loading proceeds with the next datasets while the radiologist is reading a given dataset. This produces case-to-case access speed of under 500 milliseconds (for about 2 gigabyte of data). Random unplanned access mode is still fairly fast, averaging 7 seconds for a full mixed dataset. This is much faster than the access speeds seen on some commercial CTVM digital mammography workstations

ATW was demonstrated in the invited educational exhibit area at the Radiological Society of North America and fully functional MGH ATWs have been available for "test drives" in commercial booths and educational exhibits. This enabled thousands of meeting participants to see and use the ATWs themselves. Luminaries were able to review and comment on the notable cases from the subjects collected under USAMRC CTR DAMD17-98-8309 (D. Kopans, PI, funding 1999-2003) and NCI-300-woen trial (2005-present, 5R33 CA107863- 03). Initially, some RSNA attendees were concerned that reading DBT would be much slower compared to reading CTVM. MGHBI presented a study on DBT workflow at RSNA to address this issue and showed that DBT is read with a median reading time of under 40 seconds, quite comparable to CTVM. This and other presentations have met with enthusiasm and GE and Hologic report multiple requests to purchase DBT systems.

18. Appendix: Acronyms

Term	Definition
AAPM	American Association of Physicists in Medicine
ADSA	Algorithm Development for Security Applications
ALERT	Awareness and Localization of Explosives-Related Threats, A Department of Homeland Security Center of Excellence at NEU
ASTM	American Society for Testing and Materials
AT	Advanced technology
ATD	Automated threat detection
ATR	Automated threat resolution; a synonym of ATD.
BAA	Broad agency announcement
BHS	Baggage handling system
BIR	Baggage inspection room
BLS	Bottled Liquids Scanners
BPSS	Boarding Pass Scanning Systems
BU	Boston University
CAD	Computer aided or assisted detection
Cambria	TSA procurement program for next-generation check-point scanners
CAPPS	Computer Assisted Passenger Prescreening System
CAT	Credential Authentication Technology
CENSIS	Center for Subsurface Sensing and Imaging Systems, a program at NEU
CERT	Certification testing at the TSL
CIA	Central Intelligence Agency
COE	Center of excellence, a DHS designation
CONOP	Concept of operations
COP	Concept of Operation
CPI	Cast & Prosthesis Imagers
CRT	Certification readiness testing
CT	Computed tomography
DAS	Data acquisition system
DHS	Department of Homeland Security
DHS S&T	DHS Science & Technology division
DICOM	Digital Imaging and Communications in Medicine; http://medical.nema.org

Term	Definition
DICOS	Digital Imaging and Communications in Security. NEMA standard for image format for security; NEMA IIC Industrial Imaging and Communications Technical Committee.
DOD	Department of Defense
DOD	Department of Defense
DR	Digital radiology
EDS	Explosive detection scanner that passes TSL's CERT.
ETD	Explosive trace detection
FA	False alarm
FAA	Federal Aviation Administration
FAT	Factory acceptance testing
FBI	Federal Bureau of Intelligence
FOUO	For official use only
FOV	Field of view
GC	Grand challenge
HME	Homemade explosive
HMS	Harvard Medical School
HVPS	High voltage power supply
IED	Improvised explosive device
IGT	Image guided therapy
IHE	Integrating the Healthcare Enterprise
INL	Idaho National Laboratory
IQ	Image quality
JND	Just noticeable difference
L-3	L-3 Communications
LAC	Linear Attenuation Coefficient
LLNL	Lawrence Livermore National Laboratory
LS	Line scanners (projection scanners)
Manhattan II	TSA procurement program for next-generation EDS
MC	Monte Carlo [modeling]
MIC	Medical Imaging Conference (IEEE)
MMW	Millimeter wave
MRI	Magnetic resonance imaging
MV	Multiple view
NDA	Non-disclosure agreement
NDE	Non-destructive evaluation
NEMA	National Electrical Manufacturers Association
NEU	Northeastern University

Term	Definition
NIST	National Institute of Standards and Technology
NQR	Nuclear Quadrupole Resonance
ONR	Office of Naval Research
OSARP	On screen alarm resolution protocol/process
OSR	On screen resolution
PD	Probability of detection
PET	Positron emission tomography
PFA	Probability of false alarm
PPV	Positive predictive value
QR	Quadruple resonance
RED	Remote explosive detection (stand-off)
RFI	Request for information
ROC	Receiver operator characteristic
RPI	Rensselaer Polytechnic Institute
RSNA	Radiology Society of North America
SAT	Site acceptance testing
SBIR	Small business innovation research
SCS	Standard Communication in Security
Sensitivity	Probability of true positive
SOP	Standard operating procedure
SOP	Standard operating procedure
Specificity	1 – probability of false positive
SPECT	Single photon emission computed tomography
SPIE	International society for optics and photonics
SSI	Sensitive security information
SSI	Sensitive security information
STIP	Security Technology Integrated Program
TBD	To be determined
THZ	Tera-Hertz imaging
TIP	Threat image projection
TQ	Threat quantity; minimum mass required for detection. Value(s) is classified.
TRX	TIP-ready x-ray line scanners
TSA	Transportation Security Administration
TSL	Transportation Security Lab, Atlantic City, NJ
TSO	Transportation security officer; scanner operator
WBI	Whole body imaging
XRD	X-ray diffraction

19. Appendix: Attendee List

Track:	
R: Reconstruction	**A: Automated threat detection and fusion**
E: Emerging technologies	**S: Surveillance and human factors**
V: Visitor	**F: Freelance**

Name	Affiliation	Track
Omar Al-Kofahi	American Science and Engineering	S
Doug Bauer	Department of Homeland Security	V
John Beaty	Northeastern University	E
Richard Bijjani	Reveal Imaging	E
Charles Bouman	Purdue University	R
David Castanon	Boston University	A
Philip Cheney	Northeastern University	S
Matt Clark	Department of Homeland Security	V
Jim Connelly	L-3 Communications	A
Carl Crawford	Csuptwo	F
Michael Ellenbogen	Reveal Imaging	A
David Gerts	Idaho National Laboratory	A
Ted Grant	Department of Homeland Security	A
Grant Gullberg	Lawrence Berkeley National Laboratory	R
Alex Hudson	Rapiscan	E
David Isaacson	Rensselaer Polytechnic Institute	E
W. Clem Karl	Boston University	R
Alexander Katsevich	University of Central Florida	R
Ron Kikinis	Harvard Medical School	A
Daniel Kopans	Harvard Medical School	V
Patrick La Riviere	University of Chicago	R
Michael Lanzaro	L-3 Communications	E
Edwin Marengo	Northeastern University	R
Jason Martin	Transportation Security Administration	A
Harry Martz	Lawrence Livermore National Laboratory	A
Matthew Merzbacher	GE Security	E
Eric Miller	Tufts University	R
Rick Moore	Massachusetts General Hospital	V
Robert Nishikawa	University of Chicago	A

Name	Affiliation	Track
Laura Parker	Department of Homeland Security	E
John Pearson	Siemens Corporate Research	S
Homer Pien	Massachusetts General Hospital	R
Rich Radke	Rensselaer Polytechnic Institute	S
Carey Rappaport	Northeastern University	R
Kris Roe	Smiths Detection	E
David Schafer	Analogic	R
Michael Silevitch	Northeastern University	F
Sondre Skatter	GE Security	A
Carl Smith	Guardian Technologies	A
Ben Tsui	Johns Hopkins	R
Ge Wang	Virginia Tech	E
Tim White	Pacific Northwest National Laboratory	A
Suriyun Whitehead	Department of Homeland Security	S
Horst Wittmann	Northeastern University	S
Jeremy Wolfe	Harvard Medical School	S
Birsen Yazici	Rensselaer Polytechnic Institute	A

20. Appendix: Participant Biographies

Omar Al-Kofahi

John Beaty

Richard Bijjani

Charles Bouman

David Castañón

Phil Cheney

Jim Connelly

Matt Clark

Carl Crawford

Michael Ellenbogen

David Gerts

Ted Grant

Grant Gullberg

Alex Hudson

David Isaacson

W. Clem Karl

Alex Katsevich

Ron Kikinis

Daniel Kopans

Mike Lanzaro

Patrick La Riviere

Edwin Marengo

Jason Martin

Harry Martz, Jr.

Matthew Merzbacher

Eric Miller

Rick Moore

Robert Nishikawa

John Pearson

Homer Pien

Rich Radke

Carey Rappaport

Kristofer Roe

David Schafer

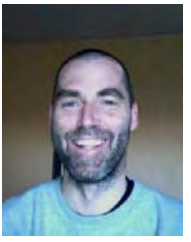
Michael Silevitch

Sondre Skatter

Carl Smith

Benjamin Tsui

Ge Wang


Timothy White

Horst Wittmann

Jeremy Wolfe

Birsen Yazici

Laura Parker

Omar al-Kofahi

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Dr. al-Kofahi received his B.S. from Jordan University of Science and Technology and his M.S. and Ph.D. in Computer and Systems Engineering from Rensselaer Polytechnic Institute. His Ph.D. work involved the design and implementation of a broadly applicable framework to automated scoring of changes in image sequences, designed to mimic the conclusions of a domain expert analyzing the same data. Dr. al-Kofahi joined AS&E in 2005, where he lead efforts to build advanced operator assist capabilities to help users identify anomalies in images and increase throughput. He also designed various algorithms for signal and image processing and enhancement, as well as building new X-ray imaging systems using concepts like coded aperture imaging.

Douglas C. Bauer

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Dr. Bauer is the Program Executive for Basic Research within the Explosives Division of the Science and Technology Directorate at the Department of Homeland Security (DHS). He has management responsibility for a multi-million dollar program in explosives basic and applied research, homemade explosives (HME) characterization, detection and damage assessment, development of the next generation EDS x-ray technologies, and counter IED basic research in prevention, detection, response and mitigation. Dr. Bauer also has management responsibility for two new university-based Centers of Excellence addressing explosive threats in transportation through fundamental research. Previously, Dr. Bauer was Acting Director of the Countermeasures Test Beds (CMTB), an activity to carry out Operational Test and Evaluation (OT&E) for counter terrorism technologies. Legacy CMTB projects for which he is still responsible include the Air Cargo Explosives Detection Pilot Project (ACEDPP) in three different airports and consultation on security systems for surface transportation application.

Dr. Bauer holds engineering degrees from Cornell and Carnegie Mellon Universities (where he received his PhD), a law degree from Georgetown University Law Center, and a theology degree from Virginia Theological Seminary. He served in the U.S. Navy as a line officer aboard surface ships,

including service in DESERT STORM, and is now retired as a naval Captain. He is a registered professional engineer in two states (New York, Pennsylvania) and a member of the D.C. bar, admitted to practice before federal courts. He is a certified Program Manager Level I and received the Under Secretary's award for Program Management and the Secretary's award for Excellence in 2007.

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John is the Industrial Liaison and Director of Technology Development for Awareness and Localization of Explosives Related Threats (ALERT). He is also the Director of Technology Development for the Bernard M. Gordon Center for Subsurface Sensing and Imaging Systems. Mr. Beaty has extensive experience managing research and development for the scientific instrument, semiconductor, and government contract industries. John spent 30 years with three companies, Thermo Electron Corporation, Schlumberger Test and Transactions, and FEI Company developing a wide variety of instruments and tools, using diverse technologies. In most instances, John procured development resources from a variety of sources: government, industry, industry consortia, and venture capital.

Richard Bijjani

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Dr. Richard Bijjani, Chief Technology Officer, has been in the security business for over 12 years. In 1990 he managed R&D during the development of a dynamic signature verification product at Kumahira Inc. In 1994 Dr. Bijjani joined InVision Technologies as head of the Algorithm and Machine Vision group. He oversaw the algorithm development effort that led to the successful certification by the FAA of multiple EDS systems. Dr. Bijjani joined Vivid Technologies in 1997 where he led the design and development of the additional EDS systems. Dr. Bijjani has a Ph.D. in Electrical Engineering from Rensselaer Polytechnic Institute.

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Charles A. Bouman is the Michael J. and Katherine R. Birck Professor of Electrical and Computer Engineering at Purdue University where he also holds a courtesy appointment in the School of Biomedical Engineering and serves has a co-director of Purdue's Magnetic Resonance Imaging Facility. He received his B.S.E.E. degree from the University of Pennsylvania, M.S. degree from the University of California at Berkeley, and Ph.D. from Princeton University in 1989. Professor Bouman's research focuses on inverse problems, stochastic modeling, and their application in a wide variety of imaging problems including tomographic reconstruction and image processing and rendering. Prof. Bouman is the Editor-in-Chief of the IEEE Transactions on Image Processing and a member of the IEEE Signal Processing Society's Board of Governors. He also is a Fellow of the IEEE, AIMBE, IS&T, and SPIE and has served Vice President of Publications for the IS&T Society.

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Prof. David Castañón received his B.S. degree in Electrical Engineering from Tulane University in 1971, and his Ph.D. degree in Applied Mathematics from the Massachusetts Institute of Technology in 1976. From 1976 to 1981, he was a research associate with the Laboratory for Information and Decision Systems at the Massachusetts Institute of Technology in Cambridge, MA. From 1982-1990, he was Chief Scientist at Alphatech, Inc. in Burlington, MA. He joined the Department of Electrical and Computer Engineering at Boston University, Boston, MA in 1990, where is currently professor and served as department Chair in 2007. Prof. Castañón is Associate Director of the National Science Foundation Center for Subsurface Sensing and Imaging, co-Director of Boston University's Center for Information and Systems Engineering and a member of the Air Force's Scientific Advisory Board. He is also a member of the IEEE Control System Society's Board of Governors, and has served as President of the IEEE Control Systems in 2008. His research interests include stochastic control, optimization, detection and inverse problems with applications to defense, medical diagnosis and homeland security.

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Philip is the Senior Consultant for Corporate and Government Partnerships for Awareness and Localization of Explosives Related Threats (ALERT). He is also the Visiting Professor and Engineering Executive in Residence at Northeastern University and the Senior Consultant for Corporate and Government Partnerships for the Bernard M. Gordon Center for Subsurface Sensing and Imaging Systems. Dr. Cheney has 40 years of experience in applying leading-edge technology to solutions for complicated engineering problems. He has worked as an individual research contributor, engineering project leader, laboratories manager and government programs manager. He retired in 2001 as Vice President of Engineering for Raytheon Company including responsibility for Engineering, Program Management, and Quality Management. He received the BSEE and MSEE from MIT in 1957 and 1958, respectively, and the Ph.D in EE from Stanford University in 1961.

Jim Connelly

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Jim Connelly is currently a Sr. Director of Engineering with L-3 Communications, Security and Detection Systems Division. He has 19 years of experience in explosives detection, starting at the Transportation Security Laboratory's predecessor, the FAA's Aviation Security Laboratory. While working at the FAA, Jim participated in the development of CT based detection systems, mm-wave based body scanners, and other technologies. He also played a major role in deploying the first CT systems to U.S. Airports. Jim joined L-3 in 1998 leading the detection algorithm development efforts for the eXaminer 6000, which was Certified in October of 1998. While at L-3, Jim has led efforts to continue to improve the detection algorithm achieving detection of lower mass levels and reducing false alarms while increasing detection. He currently co-chairs the ANSI N42.45 subcommittee developing the American National Standard for Evaluating the Image Quality of X-ray Computed Tomography (CT) Security-Screening Systems. Jim continues to play a major role in the development of new systems at L-3 for application to US as well as international markets. Jim earned his PhD in Electrical and Computer Engineering from Carnegie Mellon University and his BS in Electrical Engineering from Penn State.

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Matthew Clark, Ph.D is Director of DHS's Office University Programs. He is the author of over 50 papers, reports, and regulatory and policy analyses. At DHS, Dr. Clark is responsible for managing, integrating and delivering research of the DHS Research and Education Centers, a $50 million per year grant program. Prior to joining DHS, Dr. Clark spent eleven years as an economist with the U.S. Environmental Protection Agency. He established, planned and managed an Economics and Decision Sciences grant program that generate some of the most significant and widely used research results ever supported by USEPA. He also led a USEPA-wide effort to establish measures of program benefits and cost-effectiveness across all Agency programs. Dr. Clark also managed the quality control and release of all regulatory economics products for the Office of Water and was an industry economist in EPA's Office of Science and Technology. Earlier, he was and energy and environmental economics consultant for public and private clients, an economist and budget planner for the Washington State Department of Ecology, and a land use and environmental planner for the two largest counties in Washington State. He received his Ph.D from the University of Washington, his Masters from Washington State University, and his Bachelors degree from the University of Massachusetts.

Carl Crawford

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Carl Crawford is president of Csuptwo, LLC, a technology development and consulting company in the fields of medical imaging and Homeland Security. He has been a technical innovator in the fields of medical and industrial imaging for more than 25 years. Dr. Crawford was the Technical Vice President of Corporate Imaging Systems at Analogic Corporation, Peabody, Massachusetts, where he led the application of signal and image processing techniques for medical and security scanners. He developed the reconstruction and explosive detection algorithms for the Examiner 6000, a computerized tomographic (CT) scanner deployed in airports worldwide. He was also employed at General Electric Medical Systems, Milwaukee, Wisconsin, where he invented the enabling technology for helical (spiral) scanning for medical CT scanners, and at Elscint, where he developed

technology for cardiac CT scanners. He also has developed technology for magnetic resonance imaging (MRI), single photon emission tomography (SPECT), positron emission tomography (PET), ultrasound imaging (U/S), and dual energy imaging and automated threat detection algorithms based on computer aided detection (CAD). Dr. Crawford has a doctorate in electrical engineering from Purdue University, is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) and an associate editor of IEEE Transactions on Medical Imaging.

Michael Ellenbogen

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Mr. Michael Ellenbogen, President & Chief Executive Officer, co-founded Reveal and has successfully led the company, achieving double digit growth in both revenue and profitability since its inception. Mr. Ellenbogen has spent more than 15 years shaping the explosives detection industry through his contributions. Prior to Reveal, he served as vice president of product and business development for PerkinElmer Detection Systems where he oversaw the R&D, engineering and marketing efforts. As director of marketing for Vivid Technologies, Inc., Mr. Ellenbogen was instrumental in the transition following Vivid's acquisition by PerkinElmer. At both companies, he was responsible for market research, definition and development of new products and product enhancements. Mr. Ellenbogen holds a Physics degree from Colgate University, has been issued five patents in the field of X-ray inspection and automated detection technology and has been broadly published within the security industry.

David Gerts

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Dr. David Gerts is a senior scientist at the Idaho National Laboratory. His current focus of research is on data fusion and transport theory to examine air cargo containers for explosive materials. Previously, Dr. Gerts has worked in nuclear non-proliferations using active interrogation techniques for locating and identifying nuclear material at significant standoff distances.

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Ted Grant is the Checkpoint Program Manager for the Science and Technology Directorate of the Department of Homeland Security, which is developing the next generation of aviation checkpoint technologies. He has participated in the development, evaluation and qualification of numerous personnel inspection systems. He served as primary technical monitor on TSA's Camden program, which developed Backscatter X-Ray Whole Body Imagers from AS&E and Rapiscan for airport checkpoint use. Investigated numerous systems in development, including active millimeter wave Whole Body Imager, Quadrupole Resonance bulk explosive detection systems, , the CastScope, walk-through and handheld Metal Detectors, bottle screening devices, passive millimeter wave imagers, and Raman scattering systems. He has been the system architect and team leader for several large integrated hardware / software systems, including the Drivers Enhanced Vision System, which combines infrared imaging, moving-map displays, wireless communications, and Differential GPS to track and control airport vehicles and received the Technology Innovation Award presented by Aviation Week and Space Technology. He also led the effort to develop a regional tracking system in Shenyang China, and founded a nationwide tracking service in the US. He holds a bachelor's degree in Physics from the University of Vermont, and a master's degree from Cornell University.

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During the past 35 years I have worked in the field of Medical Imaging in both industry and academia. My professional research interests are in the field of physics and nuclear instrumentation and their application to medical problems and medical imaging. I received my PhD in Biophysics from the University of California, Berkeley (1979) where I also worked as a staff scientist at the Lawrence Berkeley National Laboratory. After my PhD studies I worked in the Applied Science Lab of the General Electric Company for 5 years before taking a position at the University of Utah where I was Professor of Radiology and Director of the Medical Imaging Research Laboratory for 17 years. In 2002 I returned to the Lawrence Berkeley National Laboratory as a Senior Staff Scientist and I am also Adjunct Professor of Radiology at the University of California San Francisco.

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Currently VP of Global Engineering for Rapiscan Systems Inc. Previously Technical Project Manager on the RTT project for Rapiscan Laboratories Inc. Prior to Rapiscan, Dr. Hudson worked as an R&D Manager in Advanced Development at Varian Inc. Before this he worked as the Supervisor of the Advanced Systems Design Group with Quantum Magnetics (a subsidiary of InVision Technologies, now a part of GE Security). Dr. Hudson has nine years of high tech product development experience, with 5 in the field of aviation security, developing technologies and sensors for various applications based on quadrupole resonance (QR), magnetic resonance (MR), computed tomography (CT) and data fusion. At Varian, Inc. his role was to lead a research group, developing cutting-edge cryogenic RF antenna products and to manage a portfolio of R&D projects created to deliver competitive new magnetic resonance spectroscopy systems. While at Quantum Magnetics, Dr. Hudson was Principle Investigator of a multi-million dollar Quadrupole Resonance (QR) explosive detection grant funded by the Transportation Security Laboratory. As part of this work, he developed a safe test material for QR explosive detection machines, in collaboration with LLNL, which is now commercially available from XM Products. Dr. Hudson holds a BS in Physics from Bristol University, UK and a PhD from Nottingham University, UK in Magnetic Resonance Imaging.

David Isaacson

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David Isaacson is a Professor of Mathematical Sciences at Rensselaer Polytechnic Institute in Troy New York. He received his Ph.D. in Mathematics from the Courant Institute of Mathematical Sciences in 1976. In the early years of his career he worked on developing numerical methods to approximately solve problems arising in Statistical Mechanics, Quantum Mechanics, and Quantum Field theory. Since 1986 he has devoted his career to applying mathematics to the solution of problems in medicine and biology. Along with his collaborators at RPI he has developed Adaptive Current Tomography systems for monitoring heart and lung function. He is currently collaborating on the construction of an Electrical Impedance

Tomography system specifically designed to improve the diagnosis of breast cancer.

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William Clem Karl received the Ph.D. degree in Electrical Engineering and Computer Science in 1991 from the Massachusetts Institute of Technology, Cambridge, where he also received the S.M., E.E., and S.B. degrees. He held the position of Staff Research Scientist with the Brown-Harvard-M.I.T. Center for Intelligent Control Systems and the M.I.T. Laboratory for Information and Decision Systems from 1992 to 1994. He joined the faculty of Boston University in 1995, where he is currently Professor of Electrical and Computer Engineering and Biomedical Engineering. He has served as an Associate Editor of the IEEE Transactions on Image Processing as well as in various organizational capacities, including session organizer and chair for the Asilomar Conference on Signals, Systems and Computers special session on Inverse Problems in Imaging, session organizer and chair for the Conference in Information Sciences and Systems special session on Medical Imaging, and as part of the organizing committee for the First SIAM Conference on the Life Sciences. He is currently the general chair of the 2009 IEEE International Symposium on Biomedical Imaging. He is a member of the IEEE Image, Video, and Multidimensional Signal Processing and Biomedical Image and Signal Processing Technical Committees, or which he is the vice-chair. Dr. Karl's research interests are in the areas statistical signal and image processing, estimation, detection, and medical signal and image processing.

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Alexander Katsevich is Professor of Mathematics at the University of Central Florida. He has been working in the field of tomography since getting his doctorate degree in mathematics from Kansas State University in 1994. Dr. Katsevich worked from 1994-1996 at the Los Alamos National Laboratory, and he has been with the Department of Mathematics at the University of Central Florida since 1996. Dr. Katsevich's main area of expertise is tomographic image reconstruction. His most significant accomplishment is

the development of a new class of exact and efficient image reconstruction algorithms for helical CT in 2001. Dr. Katsevich worked also on algorithm development in other areas of CT, e.g. local tomography, cardiac image reconstruction (motion estimation/compensation). Additionally, he studied some theoretical aspects of tomography (analysis of artifacts, resolution ability, etc.). Dr. Katsevich has extensive experience of collaborating with industrial partners, such as General Electric Medical Systems, Siemens Medical, and Toshiba Medical Research Institute.

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Dr. Kikinis is the founding Director of the Surgical Planning Laboratory, Department of Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, and a Professor of Radiology at Harvard Medical School. This laboratory was founded in 1990. Dr. Kikinis is the Principal Investigator of the National Alliance for Medical Image Computing (NA-MIC, a National Center for Biomedical Computing, an effort which is part of the NIH Roadmap Initiative), and of the Neuroimage Analysis Center (NAC a National Resource Center funded by NCRR). He is also the Research Director of the National Center for Image Guided Therapy (NCIGT), which is jointly sponsored by NCRR, NCI, and NIBIB and co-director of the IGT program at CIMIT. During the mid-80's, Dr. Kikinis developed a scientific interest in image processing algorithms and their use for extracting relevant information from medical imaging data. Since then, this topic has matured from a fairly exotic topic to a field of science. This is due to the explosive increase of both the quantity and complexity of imaging data. Dr. Kikinis has led and has participated in research in different areas of science. His activities include technological research (segmentation, registration, visualization, high performance computing), software system development (most recently the 3D Slicer software package), and biomedical research in a variety of biomedical specialties. The majority of his research is interdisciplinary in nature and is conducted by multidisciplinary teams. The results of this research have been reported in a variety of peer-reviewed journal articles. He is the author and co-author of more than 260 peer-reviewed articles. Before joining Brigham & Women's Hospital in 1988, he trained as a resident in radiology at the University Hospital in Zurich, and as a researcher in computer vision at the ETH in Zurich, Switzerland. He received his M.D. degree from the University of Zurich, Switzerland, in 1982.

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Daniel B. Kopans, M.D., F.A.C.R., Professor of Radiology - Harvard Medical School, Senior Radiologist and Founder of the Breast Imaging Division Massachusetts General Hospital. Dr. Daniel B. Kopans has authored more than 200 papers in peer reviewed journals, written the major textbook in the field of Breast Imaging, now in its 3rd edition, has made major innovations in the field and has several patents.

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Mike Lanzaro currently serves as the Vice President of Engineering for the Security and Detection Systems Division of L3 Communications, where he oversees all product development activities, including R&D and program management. Prior to joining L3 in late 2004, Mike spent over seventeen years at Symbol Technologies and was the VP of Mobile Computing Systems, a $700M business at the time. Mike has over twenty-plus years of experience in leading and managing large high-tech product development organizations with accompanying P&L responsibility. He holds A Bachelor of Engineering Degree in Electrical Engineering from Stevens Institute, a Masters in Computer Science from New York Institute, and a Masters of Management from Polytechnic University. He is a holder of nine U.S. Patents and resides in the Boston, Massachusetts area.

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Patrick J. La Riviere received the A.B. degree in physics from Harvard University in 1994 and the Ph.D. degree from the Graduate Programs in Medical Physics in the Department of Radiology at the University of Chicago in 2000. In between, he studied the history and philosophy of physics while on the Lionel de Jersey-Harvard scholarship to Cambridge University. He is currently an Assistant Professor in the Department of Radiology at the University of Chicago, where his research interests include algorithm

development for tomographic reconstruction in computed tomography, x-ray fluorescence computed tomography, and optoacoustic tomography. In 2005, he received the IEEE Young Investigator Medical Imaging Scientist Award, then given every two years to a young investigator within 6 years of the Ph.D. for significant contributions to medical imaging research. He is an author of more than 30 peer-reviewed articles and peer reviewed conference proceedings and 8 book chapters.

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Edwin Marengo is a tenure-track assistant professor in the Department of Electrical and Computer Engineering at Northeastern University in Boston. He obtained the Ph.D. in Electrical Engineering at Northeastern in 1997 working under the direction of Professor Anthony Devaney. From 1997-2004 he did several postdocs at the University of Arizona, Arizona State University, Northeastern University, and the Technological University of Panama. Since 2004 he has been at Northeastern where he works on electromagnetic inverse scattering, wave-based signal processing and compressive sensing. He is a recipient of the NSF CAREER Award, is a senior member of the IEEE and a member of URSI, the Optical Society of America and the American Physical Society, is a member of Phi Kappa Phi and Eta Kappa Nu, and has been a Fulbright scholar sponsored by the USA Department of State.

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Jason Martin currently serves as the Acting Program Manager for the Passenger Screening Program (PSP) in the Office of Security Technology (OST) at the Transportation Security Administration (TSA). Before assuming his current position, Mr. Martin served as PSP Project Manager for various security technologies at TSA, including Bottled Liquids Scanners (BLS), Explosive Trace Detectors (ETD), Cast & Prosthesis Imagers (CPI), and Credential Authentication Technology - Boarding Pass Scanning Systems (CAT-BPSS). In addition, Mr. Martin has served as IT Emerging Technologies Manager for the Defense Advanced Research Projects Agency (DARPA), Emerging Technologies Management Consultant to the Director of IT

Innovation at the Office of Naval Research (ONR), and as a Director and Program Manager for several government contracting firms. Mr. Martin possesses a Master's Degree in International Affairs from the Elliott School of International Affairs at the George Washington University, and a Bachelor's Degree in Economics from the University of Tennessee at Chattanooga.

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Dr. Harry E. Martz, Jr. is the Director for the Center for Nondestructive Characterization (CNDC) and lead of the Measurement Technologies focus area in the Science and Technology Department at the Lawrence Livermore National Laboratory (LLNL). He is responsible for leading the research and development efforts of different nondestructive measurement science and technology methods including but not limited to X- and gamma-ray digital radiography and computed tomography (CT), visual and infrared imaging, ultrasonics, micropower impulse radar imaging, and signal and image processing. This research and development includes the design and construction of instruments, and preprocessing, image reconstruction, analysis and visualization algorithms. Harry received a B.S. degree in chemistry from Siena College, Loudonville, NY, in 1979. In 1983, he received a masters degree and in 1986 a Ph.D. degree both in nuclear/inorganic chemistry and physics from Florida State University, Tallahassee, FL. After receiving his Ph.D. in 1986, he became a full-time employee at LLNL. From 1986 to 1988 he was engaged in X-ray and proton radiography and CT techniques for material characterization, and gamma-ray gauge studies for Treaty Verification applications. From 1988 to 1990 he was the computed tomography project leader and in 1991 he became the CT project manager in the NDE Section. In 1994 Harry became the NDE Thrust Area/Research Leader and became the Director of the Center for Nondestructive Characterization in 1999. In 2006 he became the lead of the Measurement Technologies focus area. Dr. Martz received a 2000 R&D 100 award in the area of Waste Inspection Tomography using Nondestructive Assay. He received the LLNL 1998 Director’s Performance Award for Active and Passive Computed Tomography. He was given the Federal Laboratory Consortium for Technology Transfer 1990 Award of Merit. Dr. Martz is a member of Alpha Chi Sigma and Sigma Pi Sigma—the National Physics Honor Society.

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Dr. Matthew Merzbacher has managed the Machine Vision group - responsible for detection and image processing algorithms - since January 2005. He originally joined InVision Technologies (subsequently aquired by GE) in January 2003, where he applied his doctoral expertise in data mining to image processing and the problem of identifying and eliminating false positives. He works closely with the TSL on certification and explosives detection and testing. Prior to joining InVision, Dr. Merzbacher was a distinguished visiting research scholar in Computer Science at the University of California, Berkeley. There, he was part of the Recovery-Oriented Computing group, studying software and network reliability. Dr. Merzbacher also spent ten years as a collegiate computer science faculty member and corporate training consultant. Dr. Merzbacher has a B.S. in Applied Mathematics and an M.S. in Computer Science, both from Brown University. He has a Ph.D. in Computer Science from UCLA. His specializations are databases (particularly data mining), artificial intelligence, and computer graphics.

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Eric L. Miller received the S.B. in 1990, the S.M. in 1992, and the Ph.D. degree in 1994 all in Electrical Engineering and Computer Science at the Massachusetts Institute of Technology, Cambridge, MA. He is currently a professor in the Department of Electrical and Computer Engineering at Tufts University and hold an adjunct position as Professor of Computer Science at Tufts. Dr. Miller's research interests include physics-based tomographic image formation and object characterization, inverse problems in general and inverse scattering in particular, regularization, statistical signal and imaging processing, and computational physical modeling. This work has been carried out in the context of applications including medical imaging, nondestructive evaluation, environmental monitoring and remediation, landmine and unexploded ordnance remediation, and automatic target detection and classification. Dr. Miller is a member of Tau Beta Pi, Phi Beta Kappa and Eta Kappa Nu. He received the CAREER Award from the National

Science Foundation in 1996 and the Outstanding Research Award from the College of Engineering at Northeastern University in 2002. He is currently serving as an Associate editor for the IEEE Transactions on Geoscience and Remote Sensing and was in the same position at the IEEE Transactions on Image Processing from 1998-2002. Dr. Miller was the co-general chair of the 2008 IEEE International Geoscience and Remote Sensing Symposium held in Boston, MA.

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Rick Moore joined Massachusetts General Hospital (MGH) in 1974, initially working on radiopharmeceutical development, including the positron imaging of 18-F-FDG. In 1982 he embarked on developing radiology workstations for the hospital.Starting in 1984, he created patient-outcome tracking systems to measure clinical performance and then took on the leadership of the Breast Imaging Research laboratory at MGH with Dr. Daniel Kopans. Over the period of 21 years, they built a robust research program, co-developing many imaging and non-imaging diagnostic and screening systems including Digital Breast Tomosynthesis (3D mammography), clinical Patient Reporting Systems, the Ambulatory Cardiac Function monitor, the Ambulatory Renal Monitor, ultra-performing, GPU-based MLEM parallel reconstructors and the design and clinical evaluation cycles for other instruments.Rick collaborates on design, development and analysis of devices and methods that employ biomarkers and morphology to detect, characterize and predict disease. He consults on data acquisition, database management, transmission presentation and interpretation of medical content. This includes managing collaboration sites, project coordination, technologist and physician training and supervision. Rick has co-authored more than 42 peer-reviewed papers, co-holds 8 patents, and lives with parrots.

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Robert M. Nishikawa received his B.Sc. in physics in 1981 and his M.Sc. and Ph.D. in Medical Biophysics in 1984 and 1990, respectively, all from the University of Toronto. He is currently an Associate Professor in the

Department of Radiology and the Committee on Medical Physics at the University of Chicago. He is director of the Carl J. Vyborny Translational Laboratory for Breast Imaging Research. He is also a fellow of the American Association of Physicists in Medicine (AAPM). Robert M. Nishikawa's principal areas of research have three intertwining themes. The first is the development of computer-aided diagnosis (CAD) techniques for x-ray imaging of the breast, in particular for digital breast tomosynthesis, full-field digital mammography (FFDM), and breast CT. The second is the image quality assessment and evaluation of imaging technologies, specifically, the clinical effectiveness of CAD. The evaluations include Monte Carlo modeling of using computer-aided detection in screening mammography, observer studies to understand how effectively radiologists can use computers as aids when interpreting mammograms, and clinical studies to directly measure the effectiveness of CAD. The third is the investigation of the performance of new breast x-ray imaging systems. These studies include the evaluation of new clinical systems, such as phase contrast mammography, advanced computed radiography detectors, and the optimization of digital breast tomosynthesis.

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Laura Parker is the Basic Research Program Manager in the Explosives Division of the Science and Technology Directorate at the Department of Homeland Security (DHS). She works on the Basic Research Program within the Explosives Division to identify critical and enabling science and technology (S&T) to improve S&T customer capabilities to prevent, detect, respond, and mitigate explosives threats. She is also working with the two DHS-sponsored university-based Centers of Excellence that address explosive threats through fundamental research. Prior to her present position at DHS, Dr. Parker worked as a contractor providing technical and programmatic support of chemical and biological defense and explosives programs for various Department of Defense (DoD) offices; the Office of the Special Assistant for Chemical and Biological Defense and Chemical Demilitarization Programs in the Office of the Secretary of Defense which overseas the DoD chemical and biological defense programs; the Defense Advanced Research Project Agency; and the Defense Threat Reduction Agency. Dr. Parker has also worked in several DoD laboratories in the field of energetic materials. She was a research chemist at the Naval Surface Warfare Center - Indian Head Division, Indian Head, MD and provided part-

time technical and programmatic support for the Undersea Warheads & Energetic Materials, Mechanics and Energy Conversion S&T Division, at the Office of Naval Research (ONR). She also worked at the Naval Research Laboratory in Washington, DC, as a National Research Council Post-doctoral Fellow where she investigated energetic materials under pressure. She obtained her Ph.D. from the Pennsylvania State University in 1997 and conducted research synthesizing and characterizing novel, new alkali metal – transition metal intermetallic compounds at high pressures and temperatures.

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John Pearson leads initiatives at Siemens Corporate Research that seek to leverage commercial innovations for government interests. Examples include: video analytics for pedestrian-borne improvised explosive devices and critical infrastructure protection; cyber-security for the power grid; sensor fusion and data-mining for condition-based bridge maintenance; and open-architecture software platforms for multi-vendor interoperable imaging systems, both medical and baggage screening. He received a PhD in Physics from the University of California, for research that applied the mathematical models of cooperative phenomena to neocortical sensory function. Basic research in computational neuroscience continued at Rockefeller University and at Sarnoff Corporation, where more applied topics and management responsibilities began. With Siemens since 2002, Dr. Pearson leads the Government Research Program.

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Rich Radke joined the Electrical, Computer, and Systems Engineering department at Rensselaer Polytechnic Institute in August, 2001, where he is now an Associate Professor. He has a dual B.A. degree in math and computational and applied math from Rice University, an M.A. in computational and applied math from Rice University, and M.A. and Ph.D. degrees in electrical engineering from Princeton University. He was an intern at the Mathworks, developing numerical linear algebra and signal processing routines. During his Ph.D. he investigated several estimation problems in digital video, including the efficient estimation of projective transformations and the synthesis of photorealistic "virtual video", in collaboration with IBM's Tokyo Research Laboratory. His current research interests include deformable registration and segmentation of three- and four-dimensional biomedical volumes, machine learning for radiotherapy applications, distributed computer vision problems on large camera networks, and modeling 3D environments with visual and range imagery. At Rensselaer, he is associated with the NSF ERC for Subsurface Sensing and Imaging Systems (CenSSIS) as well as the Center for Automation Technologies and Systems (CATS). He received an NSF CAREER award in March 2003 and is a member of the 2007 DARPA Computer Science Study Group.

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Carey is Deputy Director for Awareness and Localization of Explosives Related Threats (ALERT). He is also Associate Director of the Bernard M. Gordon Center for Subsurface Sensing and Imaging Systems. He has been a professor at Northeastern University since 1987. He received dual SBs, SM, and Eng from MIT in 1982 and the Ph.D. from MIT in 1987. Professor Rappaport was the Principal Investigator of a $5M ARO-sponsored Multidisciplinary University Research Initiative in humanitarian demining, the lead researcher supporting Alion Science and Technology, Inc's. $130M Omnibus Task Order with US Army Night Vision and the Electronic Sensors Directorate, as well as the Principal Investigator for a $4.9M Dept. of Homeland Security Advanced Spectrographic Radiation Portal Monitor for special radioactive materials.

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Dr. Kristofer Roe is currently Director, Security and Inspection Technology, Smiths Detection. In this position, Dr. Roe is responsible for imaging technology research and development for Smiths Detection's Security and Inspection business in the Americas. In addition, Dr. Roe leads a technology experts group which provides technical oversight for various programs and efforts with the Department of Homeland Security. Recently, Dr. Roe was the principal investigator of the NextGen Checked Baggage Program (Manhattan II) program with TSA which was awarded "Best Presentation" at the Gordon Research Conference (2007). In addition to his work at Smiths Detection, Dr. Roe collaborates with the Electrical Engineering Department at the University of Delaware in developing advanced technology imaging, sensor, and detection techniques. Dr. Roe earned his Ph.D., MSEE, and BSEE degrees from the University of Delaware.

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Dr. Schafer is a physicist turned engineer with a physics and mathematics degree from Bowdoin College and an M.A and Ph.D. in physics from Rice University. Dr. Schafer has worked mainly in the area of technology development for inspection of items with x-rays. Items range from baggage to large trucks and rocket motors. His recent work has been in the area of automatic detection of explosives in baggage using x-ray CT. He currently leads a large team working on several programs that will bring to market the next generation of automatic detection security technology.

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Michael is co-Director of Awareness and Localization of Explosives Related Threats (ALERT), a Department of Homeland Security Center of Excellence currently in its first year of funding. He is also Director of the Bernard M. Gordon Center for Subsurface Sensing and Imaging Systems, a National Science Foundation Engineering Research Center, and the Director of the Gordon Engineering Leadership Program, an innovative model for training engineering leaders. He received the BSEE, MSEE, and PhD from

Northeastern University in 1965, 1966, and 1971, respectively. He joined the faculty of Northeastern in 1972, and was appointed to the Robert D. Black Endowed Chair in Engineering at Northeastern in 2003. Previously he directed of the Center for Electromagnetics Research (an NSF Industry-University Center) and the Center for the Enhancement of Science and Mathematics education (CESAME). He is an elected life fellow of the IEEE.

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Sondre Skatter, Ph.D., Manager Systems Engineering in the Newark office of GE Security, received the Diploma degree in physics from the Norwegian University of Science and Technology and a Ph.D. from the Norwegian University of Life Sciences. Sondre joined InVision in 1998 to start the adaptation of the CTX technology to the wood industry (WoodVision). Sondre later developed and tuned the data fusion system for the QRCT project, which was a TSA funded program to integrate CTX technology with Quadrupole Resonance explosive detection. After the YXLON acquisition he lead the data fusion efforts in the Phoenix XRD program, integrating the CTX 9000 with the YXLON 3500. He later took on the role as technical lead and program manager for the same project.

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Mr. Smith holds a Bachelor of Science from the US Naval Academy and a MS in Systems Management from the University of Southern California. He joined Guardian Technologies in June 2005 as the Director and then Vice President of Operations responsible for all program management efforts. He developed processes and procedures from product initiation through production and support. Significant efforts included: planning and implementing Quality Management Process that resulted in the company's Quality Management Program certification to the ISO 9001: 2000 with Design Standard; responsible for all research and development activities for adapting explosive detection software to additional scanning systems; and, developed field data collection and test procedures for US laboratory tests and overseas field trials. Prior to joining Guardian Mr. Smith was Vice President Systems Engineering Division for Delex Systems, Inc. His division provided engineering, management, and

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Ge Wang received BE in electrical engineering from Xidian University, Xian, China, in 1982, MS in remote sensing from Graduate School of Academia Sinica, Beijing, China, in 1985, and MS and PhD in electrical and computer engineering from State University of New York, Buffalo, in 1991 and 1992. He was Instructor and Assistant Professor with Department of Electrical Engineering, Graduate School of Academia Sinica in 1984–1988, Instructor and Assistant Professor with Mallinckrodt Institute of Radiology, Washington University, St. Louis, MO, in 1992-1996. He was Associate Professor with University of Iowa from 1997-2002, and then Professor with Departments of Radiology, Biomedical Engineering, Mathematics, Civil Engineering, Electrical and Computer Engineering, and Director of the Center for X-Ray and Optical Tomography, University of Iowa. Currently, he is Director of the Biomedical Imaging Division and Samuel Reynolds Pritchard professor, WFU-VT School of Biomedical Engineering and Sciences at Virginia Polytechnic Institute and State University, Blacksburg, VA. His interests include x-ray computed tomography and optical molecular tomography. He and his coauthors have published over 500 journal articles and conference papers (h-index=26), including the first paper on spiral/helical cone-beam CT, the first paper on bioluminescence tomography and the first paper on interior tomography. He is the founding Editor-in-Chief for *International Journal of Biomedical Imaging*, and Associate Editors for *IEEE Trans. Medical Imaging* and *Medical Physics*. He is an IEEE Fellow, SPIE Fellow and an AIMBE Fellow. He is also recognized by a number of awards for academic achievements.

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Dr. Timothy White is Research Scientist in the Radiation Detection and Nuclear Sciences groups at PNNL. Previously, Dr. White worked for 14 years in the Materials Characterization department at the Idaho National Laboratory (INL). At the INL, he was involved in a number of digital radiography (DR) and computed tomography (CT) projects covering a broad range of applications, including: development of a field portable, fan-beam DR and CT system for the characterization and remediation of chemical

munitions; characterization and modeling of cargo x-ray scanners in order to generate accurate synthetic radiographs; development of lightweight, portable x-ray imaging systems and visualization tools for examination of improvised explosive devices; and the demonstration of CT techniques for materials characterization in hot cells. His research interests are in helical cone-beam x-ray tomography, three-dimensional x-ray imaging from limited-view data, visualization and interpretation of radiographic data, and applications of low-field nuclear magnetic resonance for contaminant detection. Dr. White received his PhD in Optical Sciences from the University of Arizona.

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Suriyun is a Booz Allen Hamilton consultant who provides SETA support to the Explosives division of the DHS Science and Technology Directorate. He is focused on the Manhattan II Next Generation EDS, Whole Body Imaging, and Basic Research Programs into enabling technologies, common standards and detection requirements. Suriyun received his Masters degree in Computer Systems Engineering from the University of Bristol, in the United Kingdom. Over the past 10 years, Suriyun has been involved in the design and development of large scale systems of systems, advanced security and sensing systems, enterprise data management, data fusion, and related airport security programs.

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Dr. Wittmann is the Research Evaluation Advisory Panel Leader for Awareness and Localization of Explosives Related Threats (ALERT). He is also Senior Research Development Officer in the Office of the Provost of Northeastern University. In 2001 he retired from the federal Senior Executive Service as Associate Director of the Sensors Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, OH, and from his position as Lead US Representative at the NATO Research and Technology Board, Sensors and Electronics Technology Panel. Dr. Wittmann's field of scientific specialization is solid-state physics; he received the B.S in 1959 and the Ph.D. in 1964. He is a fellow of the IEEE and AAAS.

Jeremy Wolfe

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Jeremy Wolfe became interested in visual perception during the course of a summer job at Bell Labs in New Jersey after his senior year in high school. He graduated summa cum laude from Princeton in 1977 with a degree in Psychology and went on to obtain his PhD in 1981 from MIT, studying with Richard Held. His PhD thesis was entitled "On Binocular Single Vision". Wolfe remained at MIT as a lecture, assistant professor, and associate professor until 1991. During that period, he published papers on binocular rivalry, visual aftereffects, and accommodation. In the late 1980s, the focus of the lab shifted to visual attention. Since that time, he has published numerous articles on visual search and visual attention. He is, perhaps, best known for the development of the Guided Search theory of visual search. In 1991, Wolfe moved to Brigham and Women's Hospital and Harvard Medical School where he is Professor of Ophthalmology. At present, the lab works on basic problems in visual attention and their application to airport security and medical screening issues. The lab is funded by the US National Institutes of Health and Department of Homeland Security. Wolfe also teaches several Psychology courses at MIT & Harvard. Jeremy Wolfe editor of the journal, Attention, Perception and Psychophysics (AP&P, formerly P&P). He is Past-President of the Eastern Psychological Association. He won the Baker Memorial Prize for teaching at MIT in 1989. He is a fellow of the American Assoc. for the Advancement of Science, the American Psychological Association (Div. 3 & 6), the American Psychological Society, and a member of the Society for Experimental Psychologists.

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Birsen Yazıcı received the B.S. degrees in electrical engineering and mathematics from Bogazici University, Istanbul, Turkey, in 1988, and the M.S. and Ph.D. degrees in mathematics and electrical engineering from Purdue University, West Lafayette IN, in 1990 and 1994, respectively. From September 1994 until 2000, she was a research engineer at the General Electric Company Global Research Center, Schenectady, NY. During her tenure in industry, she worked on radar, transportation, industrial, and medical imaging systems. From 1996 until 1999, she was a member of the

GE Research, L3 and Analogic team that developed the 3D X-ray CT explosive detection system for airport check-luggage. In 2001 she joined Drexel University as an assistant professor. In 2003, she joined Rensselaer Polytechnic Institute, Troy, NY, where she is currently an Associate Professor in the Department of Electrical, Computer, and Systems Engineering and in the Department of Biomedical Engineering. Her research interests span the areas of statistical signal processing, inverse problems in imaging, biomedical optics, and radar. She holds 11 U.S. patents. Dr. Yazıcı is the recipient of the Rensselaer Polytechnic Institute 2007 School of Engineering Research Excellence Award. Her work on industrial systems received the 2nd best paper award in 1997 given by IEEE Transactions in Industrial Applications.

21. Appendix: Homework

This section contains the assignment and the returned homework. The following people returned homework.

Name	*Affiliation*
Omar Al-Kofahi	American Science and Engineering
Jim Connelly	L-3 Communications
David Gerts	Idaho National Laboratory
Ted Grant	Department of Homeland Security
Grant Gullberg	Lawrence Berkeley National Laboratory
Alex Hudson	Rapiscan
David Isaacson	Rensselaer Polytechnic Institute
W. Clem Karl	Boston University
Alexander Katsevich	University of Central Florida
Patrick La Riviere	University of Chicago
Michael Lanzaro	L-3 Communications
Harry Martz	Lawrence Livermore National Laboratory
Matthew Merzbacher	GE Security
Kris Roe	Smiths Detection
Sondre Skatter	GE Security
Ge Wang	Virginia Tech
Tim White	Pacific Northwest National Laboratory
Jeremy Wolfe	Harvard Medical School

Some of the homework assignments were modified to obfuscate authorship. The formatting changes were made.

The subsection numbers do not match the order of people listed in the previous table; the numbers are provided for cross-referencing purposes.

Most of the assignments were turned in before the workshop. However, at least one assignment was turned in after the conference.

21.1 Homework assignment

All participants must provide the following information in advance of the workshop.

1. Description of desirable and realistic DHS research goal(s).
2. State of the art: listings of highly relevant, leading publications and patents.
3. State of the art: who are the real experts by name, discipline, location, address.
4. What are the fundamental gaps: current knowledge vs. DHS R&D goals vs. research state of the art
    a. Approaches to close the gaps.
    b. Assume availability of $1M, what research goal should be pursued to have the highest return on investment?
        i. What would be the approach?
        ii. What would be the impact on DHS?
5. A list of people who should be notified about DHS's request for information (RFI) for 3rd party algorithm development and future DHS funding announcements.

Notes:

1. Homework will not be distributed in their original form to all of the participants, unless permission to do so is given. Please indicate if permission is not given.
2. Homework may be distilled and aggregated, and then distributed to all of the participants.

21.2 Homework

21.2.1 Homework #1

Homework Assignment:

1. Description of desirable and realistic DHS research goal(s).

I believe that one of the greatest issues facing explosive detection and many other related techniques is the complexity of the system of detection. Much research has been performed in the laboratory without adequate funding and construction of appropriate forward and inverse problem models. In a sense, a significant amount of data falls in the proverbial bit-bucket due to inadequate investment in high fidelity modeling of the physical process. Therefore, I believe that a desirable and realistic DHS research goal should be a reexamination of the fundamental methods used to model the physical processes involved in detecting threat materials using the full uncertainty quantification.

2. State of the art: listings of highly relevant, leading publications and patents.

In the area of data fusion:

- G. Chen, G. Bennett, and D. Perticone, "Dual-energy X-ray radiography for automatic high-Z material detection." Nuclear Instruments and Methods in Physics Research B, vol. 261, 2007.
- J. E. Eberhardt, S. Rainey, R. J. Stevens, B. D. Sowerby, and J. R. Tickner, "Fast neutron radiography scanner for the detection of contraband in air cargo containers." Applied Radiation and Isotopes, vol. 63, 2005.
- X. E. Gros, "Pixel Level NDT Data Fusion." Applications of NDT Data Fusion, Kulwer Academic Publishers, 2001.
- Y. Liu, B. D. Sowerby, and J. R. Tickner, "Comparison of neutron and high-energy X-ray dual-beam radiography for air cargo inspection." Applied Radiation and Isotopes, vol. 66, 2008.
- L. Liu and R. P. Yager, "Classic Works of Dempster-Shafer Theory of Belief Functions: An Introduction." Classic Works of Dempster-Shafer Theory of Belief Functions, Springer Publishing, 2008.
- N. Milisavljevic and I. Bloch, "Possibilistic Versus Belief Function Fusion for Antipersonnel Mine Detection." IEEE Transactions on Geoscience and Remote Sensing, vol. 46, No. 5, May 2008.

- R. C. Runkle, et al, "Photon and neutron interrogation techniques for explosives detection in air cargo: a critical review." DRAFT, Nuclear Instruments and Methods in Physics Research A. 2009.
- B. D. Sowerby, and J. R. Tickner, "Recent advances in fast neutron radiography for cargo inspection." Nuclear Instruments and Methods in Physics Research A, vol. 580, 2007.
- R. P. Srivastrava and G. Shafer, "Belief-Function Formulas for Audit Risk." The Accounting Review, vol. 67, no. 2, 1992.
- R. Yager, "Decision Making under Dempster-Shafer Uncertainties." International Journal of General Systems, vol. 20, 1992.

3. State of the art: who are the real experts by name, discipline, location, address.

Professor X. C. Zhang, terahertz imaging, RPI, zhangxc@rpi.edu

4. What are the fundamental gaps: current knowledge vs. DHS R&D goals vs. research state of the art?

In the area of data fusion, there is a fundamental gap of how to develop basic probability distributions that are representative of the data being collected. Furthermore, because all expert systems fall prey to "garbage-in garbage-out" fallacies, there must be significantly more understanding of the limitations of fed data. This is, I believe, a gap in the current knowledge vs. research state of the art. DHS R&D has not adequately addressed this need that I have recognized.

   a. Approaches to close the gaps.

Two methods exist for closing the gap in probabilistic data fusion techniques—more experiments and more simulation. Due to significant resource limitations, appropriate funding must recognize the dynamic tension between the two methods. I recommend more high fidelity simulation (of course, I am a computational physicist). One area of significant concern that needs more funding is uncertainty quantification.

   b. Assume availability of $1M, what research goals should be pursued to have the highest return on investment?

I would invest $1M in developing a data fusion technique that is applicable across a very large variety of modalities. I have listed several references in the above that could be used to support these modalities.

      i. What would be the approach?

Because $1M is not a significant amount of money, I would leverage some research at universities (~25%) and some research at the national laboratories or DoD research laboratories (75%).

ii. What would be the impact on DHS?

There would be two impacts on DHS—increased research interest in DHS's R&D goals in the form of long-term investment through the universities, and improvements in the data fusion for current programs pursued by DHS.

5. A list of people who should be notified about DHS's request for information (RFI) for 3rd party algorithm development and future DHS funding announcements.

N/A

21.2.2 Homework #2

1. Description of desirable and realistic DHS research goals.

Algorithms that reconstruct energy and position from nuclear detectors placed at far fields.

2. State of the art: listings of highly relevant, leading publications and patents.

- Basko R, Zeng GL, Gullberg GT: Image Reconstruction From V-Projections Acquired by Compton Camera, U. S. Patent No. 5,841,141, November 24, 1998, (U-2313, U-2452), PKR 2 408.
- Basko R, Zeng GL, Gullberg GT: Image Reconstruction for Compton Camera Including Spherical Harmonics, U. S. Patent No. 5,861,627, January 19, 1999, (U-2453), PKR 2 428.
- Basko R, Zeng GL, Gullberg GT: Application of spherical harmonics to image reconstruction for the Compton camera. Phys Med Biol 43:887-894, 1998.
- Basko R, Zeng GL, Gullberg GT: Analytical reconstruction formula for one-dimensional Compton camera. IEEE Trans on Nucl Sci 44:1342-1346, 1997.
- Basko R, Zeng GL, Gullberg GT: Fully three dimensional image reconstruction from V-projections acquired by Compton camera with three vertex electronic collimation. In 1997 IEEE Nuclear Science Symposium Conference Record, Nov. 9-15, 1997, Albuquerque, New Mexico, pp. 1077-1081.
- Taguchi K, Zeng GL, Gullberg GT: Cone-beam image reconstruction using spherical harmonics. Phys Med Biol 46:N127-N138, 2001.
- Xu D, He Z: Gamma-ray energy-imaging integrated spectral deconvolution. Nuclear Instruments and Methods in Physics Research A 574: 98–109, 2007.

3. State of the art: who are the real experts by name, discipline, location, address.

Kai Vetter
kvetter@nuc.berkeley.edu
Nuclear Engineering and Homeland Security Professor
University of California and Lawrence Berkeley National Laboratory
Berkeley, CA 94720

Lucian Mihailescu
LMihailescu@lbl.gov

Nuclear Detector Physics and Homeland Security
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

Jonathan S. Maltz
JSMaltz@lbl.gov
Medical Imaging and Radiation Therapy
Siemens Medical Solutions and Lawrence Berkeley National Laboratory
Concord, CA 94520

Grant T. Gullberg, Ph. D
gtgullberg@lbl.gov
Medical Imaging
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

4. What are the fundamental gaps: current knowledge vs. DHS R&D goals vs. research state of the art
    a. Approaches to close the gaps.
        i. Improved detector design, along with that goes the development of new models of the physics of the image detection process and development of new algorithms for modeling the geometry and physics.
        ii. For nuclear detection, the development of list mode algorithms for the reconstruction of the position and the energy of the source.
    b. Assume availability of $1M, what research goal should be pursued to have the highest return on investment?
        i. What would be the approach?

$1M is not very much money to make an impact. What one could hope for is the accomplishment of computer simulations to evaluate possible design concepts.

        ii. What would be the impact on DHS?

The work would allow DHS narrow down the possible research avenues for future more extensive funding.

5. A list of people who should be notified about DHS's request for information (RFI) for 3rd party algorithm development and future DHS funding announcements.

    a. Kai Vetter
    b. Lucian Mihailescu

c. Jonathan Maltz
d. Grant T. Gullberg
e. Donald Gunter
f. Randy Brill
g. Neal Clinthorne

21.2.3 Homework #3

1. Description of desirable and realistic DHS research goal(s).

Foster enabling technologies, not incremental development. Invest in areas where the time frame of product opportunity is too long term to attract significant industry investment or interest. Invest in approaches that are not viable with current technology e.g. reconstruction approaches that are too slow for current vendors - reduce the image artifacts caused by metal and reduce shield alarms.

2. State of the art: listings of highly relevant, leading publications and patents.

- Peschmann et al., Automatic concealed object detection system having a pre-scan stage, #5,182,764, Jan. 26 1993
- Hiraoglu et al., Multiple-stage apparatus and method for detecting objects in tomographic data, #6,035,014, Mar. 7 2000
- Simanovsky et al., Apparatus and method for detecting object in tomography data using erosion and dilation of objects, #6,067,366, May 23 2000.
- Simanovsky et al., Apparatus and method for eroding objects in computed tomography data, #6,075,871, June 13 2000
- Simanovsky et al., Apparatus and method for density discrimination of objects in computer tomography data using multiple density ranges, #6,078,642. June 20 2000
- Bechwati et al., Apparatus and method for correcting object density in computer tomography data, #6,108,396. August 22, 2000.
- Hiraoglus et al., Apparatus and method for detecting sheet objects in computer tomography data, #6,111,974. August 29, 2000.
- Crawford et al., Apparatus and method for processing object data in computer tomography data using object projections, #6,345,113 B1. Feb 5, 2002.
- Ying et al., Method of and system for adaptive scatter correction in multi-energy computed tomography, #7,136,450 B2. November 14, 2006.
- Crawford et al., Apparatus and method for processing objects in computed tomography data using object projections, #WO 00/42566. July 20 2000.

3. State of the art: who are the real experts by name, discipline, location, address

Dimitrios Ioannou (DIoannou@rapiscansystems.com, inspection), Carl Crawford, Rick Avila (rick.avila@kitware.com, Inspection), Todd Gable (Todd.Gable@ge.com, Inspection, Newark, CA), Eugene Ingerman (Eugene.Ingerman@ge.com, Reconstruction, Newark, CA), Sammit Basu (Sammit.Basu@ge.com, Reconstruction, Newark, CA)

4. What are the fundamental gaps: current knowledge vs. DHS R&D goals vs. research state of the art

Currently the incentive is for the EDS vendors to pass EDS certification. If there was greater incentive placed on image quality (for example medical imaging) better data will result. However, there must be a fundamental limit to the number of false alarm items of a given threat size/density. There should be greater incentives to further reduce the automated false alarm rates – for example by other complementary technologies. There is a lack of understanding of the effects of shields on image quality. This includes shield object placement and shield object size. Given the variety of machines and reconstruction engines it is unlikely there is a generalized result – more likely to be machine specific.

Data fusion with non-orthogonal sensors (real-world technologies have large overlap and are not truly orthogonal). Higher resolution imaging. Higher quality (less artifacts) reconstruction. Iterative reconstruction methods.

For a relatively modest sum of $1M, the problem must be confined in scope, and the investment in existing technology leveraged. For example use an existing hardware platform and develop only a portion of the software.

Limited with only $1M investment. To maximize impact, confine problem to false alarm mitigation. This should offer the greatest return on investment.

5. A list of people who should be notified about DHS's request for information (RFI) for 3rd party algorithm development and future DHS funding announcements.
    a. Rick Avila [rick.avila@kitware.com]
    IBM Alan Eisen [eisen@us.ibm.com]
    b. Mercury Computers, Liz Wilcox [lwilcox@mc.com]

Notes:

Permission not given for original form distribution.

21.2.4 Homework #4

Long Range Algorithm Development Workshop.
Home Work assignment #1.
David Isaacson
Rensselaer Polytechnic Institute
Permission: Yes

1. Desirable and realistic research goals:

i. Develop a mathematical theory of "electromagnetic imaging" that determines which quantities inside a region can be uniquely determined in principle from boundary measurements made on a part of the surface of that region. The theory will cover Maxwell's equations coupled to the Bloch equations. For this reason Electrical Impedance tomography, Microwave imaging, Magnetic induction tomography, and Magnetic resonance imaging would all be special cases of this more general theory.

ii. Given the electromagnetic properties that can be uniquely determined from boundary measurements develop a theory for the design of a system to make the optimal measurements needed for imaging these quantities. Optimal measurements would be those that contain the maximum information about the desired interior properties that the measurement precision and available power limits permit.

iii. Develop practical reconstruction algorithms to form useful images from the data that could be acquired by the Electromagnetic Imaging systems designed in ii.

2. Publications on Electrical Impedance Imaging, Inverse boundary value problems for Maxwell's equations, Current Density Imaging, Magnetic Resonance EIT, Complex Geometrical Optics, Inverse Scattering theory, DBar Inversion methods:

- Isaacson, D. Distinguishability of conductivities by electric current computed tomography. IEEE Trans. on medical Imaging MI-5(2):92-95, 1986.
- Isaacson, D. Process and apparatus for distinguishing conductivities by electric current computed tomography. United States Patent #4920490, April 24, 1990.
- Gisser, D.G., D. Isaacson and J.C. Newell. Electric current computed tomography and eigenvalues. SIAM J. Appl. Math. 50:1623-1634, 1990.

- Isaacson, D., E. Somersalo and M. Cheney. A linearized inverse boundary-value problem for Maxwell's Equations. J. Comp. & Appl. Math 42:123-136, 1992.
- Saulnier, G.J., D. G. Gisser, D. Isaacson and J.C. Newell. High-speed electric tomography. U.S. Patent # 5,544,662 August 13, 1996.
- Isaacson, D., J. L. Mueller, J. C. Newell, and S. Siltanen. Imaging cardiac activity by the D-bar method for electrical impedance tomography. Physiol. Meas. 27(5):S43-S50, 2006
- Colton, D. and R. Kress. Inverse Acoustic and Electromagnetic Scattering Theory. Springer, 1998.
- Cornean, H., K.Knudsen, and S. Siltanen. Towards a d-bar reconstruction method for threedimensional EIT. J. Inv. Ill-Posed Problems, V. 14, N. 2, p111-134 (2006).
- Kenig, C., J. Sjostrand, and G. Uhlmann, The Calderon problem with partial data Ann. Math. To appear.
- Nachman, A. Reconstructions from boundary measurements, Ann. of Math. 128 (1988), 531-576.
- Ola, P., L. Paivarinta and E. Somersalo. An inverse boundary value problem in electrodynamics. Duke Math. J. 70:617-653, 1993.
- Ola, P. and E. Somersalo. Electromagnetic inverse problems and generalized Sommerfeld potentials, SIAM J. Appl. Math. Vol. 56, No. 4, pp1129-1145, 1996.
- Sylvester, J. and G. Uhlmann, A global uniqueness for an inverse boundary value problem, Annals of Mathematics. 125 (1987), 153-169.
- C. Park, O. Kwon, E.J. Woo, J.K. Seo. Electrical conductivity imaging using gradient Bz decomposition algorithm in magnetic resonance electrical impedance tomography (MREIT). *IEEE Trans Med Imaging*, Vol. 23, No. 3, pp. 388-94, March 2004.
- E.J. Woo and J.K. Seo. Magnetic Resonance Electrical Impedance Tomography (MREIT) for High-resolution Conductivity Imaging, *Physiological Measurement*, Vol. 29, pp. R1-R26, 2008.
- Adrian Nachman, Dinghui Wang, Weijing Ma, and Michael Joy, "A Local Formula for Inhomogeneous Complex Conductivity as a Function of the RF Magnetic Field", in *Proc. 15th Annu. ISMRM Int. Conf.*, Berlin, 2007

3. State of the Art in impedance imaging, Magnetic Resonance EIT, inverse boundary value and scattering problems for Maxwell's Equations:

- David Isaacson, Mathematician, Rensselaer Polytechnic Institute, Troy NY.

- Gunther Uhlmann, Mathematician, University of Washington, Seattle WA.
- Adrian Nachman, Mathematician, University of Toronto, Toronto Canada.
- Erkki Somersalo, Mathematician, Case Western Reserve University, Cleveland OH.
- David Colton, Mathematician, University of Delaware, Newark DE.
- Jennifer Mueller, Mathematician, Colorado State University, Fort Collins Colo.

4. Fundamental Problems:

i. Which electromagnetic properties of a body's interior can be uniquely determined by boundary measurements; Electrical Conductivity, Electrical Permittivity, Magnetic Permeability, Spin density, Relaxation times, Diffusion Tensor, … ?

ii. Need Contact for EIT usually.

iii. Need high fields for MRI usually.

iv. Can not easily make high resolution images of the interior of bodies from low frequency or Microwaves usually.

a. & b. Approaches to close the gaps and yield the highest return on investment:

i. Develop a systematic and rigorous understanding of what can be uniquely determined inside a body from all possible electromagnetic measurements made outside the body.

ii. Develop theory to enable the design of practical systems, given DHS constraints, which could achieve the maximum signal to noise possible. In other words how to design a system that could measure the data that would best distinguish the objects of interest inside a body from those internal properties that are not of interest.

iii. Develop practical reconstruction algorithms for imaging items of interest using these measurements.

The approach to solving these problems will be to use the state of the art in the mathematical theory of inverse boundary value and scattering problems. This includes direct or non-iterative methods based on the theory of Complex Geometrical Optics and, the D-bar inverse scattering theory, as well as the state of the art in Statistical Inversion methods.

The potential impact of a large short term investment in the basic mathematical theory of inverse problems for Electromagnetic Imaging could have a long term pay off in the development of the theory for a new generation of imaging systems with increased detection sensitivity and specificity under a wider array of conditions then presently exist.

5. A partial list of people who should be notified about DHS's RFI.

- David Isaacson, Mathematician, Rensselaer Polytechnic Institute, Troy NY.
- Gunther Uhlmann, Mathematician, University of Washington, Seattle WA.
- Adrian Nachman, Mathematician, University of Toronto, Toronto Canada.
- Erkki Somersalo, Mathematician, Case Western Reserve University, Cleveland OH.
- David Colton, Mathematician, University of Delaware, Newark DE.
- Jennifer Mueller, Mathematician, Colorado State University, Fort Collins Colo.

21.2.5 Homework #5

As for gaps, goals, and directions in the CT area for DHS, I believe the biggest thing is to move towards more unified frameworks for modeling, processing, and detection.

In particular, starting from modeling what we can in the sensing process (sensor, object, etc) and including these models to the extent possible in the information extraction process. Historically, device and algorithm design made idealized assumptions (e.g. FBP assumptions of complete uniform, line integral coverage). This made sense in the context of limited computation, but I believe we are approaching a new paradigm where hundreds of cores will be common and this can enable more precise modeling and processing. From an algorithmic standpoint, I think we are in a position to exploit explicit and specific sensor models involving effects ranging from finite source size to energy-specific energy dependence as well as various forms of prior information in unified frameworks for inversion and inference.

21.2.6 Homework #6

1. Highly relevant papers

- Noo, F. , Hornegger, J. ,Lauritsch, G. ,Dennerlein, F. ,Hoppe, S.

"A new scheme for view-dependent data differentiation in fan-beam and cone-beam computed tomography," Physics in Medicine and Biology vol.52, no.17 (7 Sept. 2007),p.5393-414

- Pack, J.D. , Noo, F. , Clackdoyle, R.

"Cone-beam reconstruction using the backprojection of locally filtered projections," IEEE Transactions on Medical Imaging vol.24, no.1 (Jan. 2005), p.70-85

- Pack, J.D. , Noo, F.

"Cone-beam reconstruction using 1D filtering along the projection of M-lines," Inverse Problems vol.21, no.3 (June 2005),p.1105-20

- Katsevich, A.

Analysis of an exact inversion algorithm for spiral cone-beam CT, Physics in Medicine and Biology vol.47, no.15 (7 Aug. 2002),p.2583-97

- Katsevich, A. ,Basu, S. , Jiang Hsieh,

"Exact filtered backprojection reconstruction for dynamic pitch helical cone beam computed tomography," Physics in Medicine and Biology vol.49, no.14 (21 July 2004),p.3089-103

Patents:

- 7,477,720 (Cone-beam reconstruction using backprojection of locally filtered projections and X-ray CT apparatus, by Pack, Noo, Clackdoyle)
- 7,242,749 (Methods and systems for dynamic pitch helical scanning, by Hsieh, Katsevich, Basu)
- 6,804,321 (Filtered back projection (FBP) algorithm for computer tomography, by Katsevich)

2. Experts:

Michel Defrise
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area: image reconstruction in transmission and emission tomographies

A. Katsevich
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Area: CT image reconstruction

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Areas: biomedical imaging, non-destructive testing, image reconstruction in tomography

Fred Noo
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e-mail: noo@ucair.med.utah.edu
area: image reconstruction in transmission and emission tomographies

Todd Quinto
Robinson Professor of Mathematics
Tufts University
Medford, MA 02155 USA
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areas: algorithms for transmission and emission tomographies as well as electron microscopy

Ge Wang
Director of Biomedical Imaging Division
VT-WFU School of Biomedical Engineering & Sciences
Virginia Polytechnic Institute & State University
1880 Pratt Drive, Suite 2000, MC-0493
Blacksburg, VA 24061, USA
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wangg@vt.edu
Areas: Bioluminescence/fluorescence tomography; Cone-beam x-ray CT, Grating-based x-ray imaging

21.2.7 Homework #7

1. Description of desirable and realistic DHS research goal(s)

- Novel and / or New Image Processing improvements (including perhaps new segmentation approaches)
- New sensor fusion techniques and algorithmic approaches towards it
- Achieving "operationally viable" liquids detection performance (including leaving liquids in the carry-on bag)
- Identification and validation of new technology approaches (i.e. beyond current x-ray based systems, millimeter-wave, IMS systems, etc…)

2. State of the art: listings of highly relevant, leading publications and patents

- Application of terahertz-band technology for whole body imaging, explosives detection, and stand-off detection
- Application of EBEAM-based technology towards explosives detection (number of GE and L3 patents)

3. State of the art: who are the real experts by name, discipline, location, and address?

- OptoSecurity: Image Processing and Liquids Detection experts
- Doug Boyd / TeleSecurity Sciences: Image Reconstruction algorithms
- RPI (terahertz-based research)

4. What are the fundamental gaps: current knowledge vs. DHS R&D goals vs. research state of art

The main gap between what DHS wants and what we've currently got is a scanning technology that is highly specific for explosives, but does not require physical sample collection.

   a. Approaches to close the gaps

Invest a portion of the DHS R&D budget in exploring more unique, longer term concepts rather than just looking at projects that produce a system in a short term.

   b. Assume availability of $1M, what research goal should be pursued to have the highest ROI ?

      i. What would be the approach ?

With only $1M, you're not going to fund very many new technology investigations. It would probably be best invested in incremental improvement of current systems. Looking at better segmentation techniques through an academic/industry team would probably be the best bet for ROI.

ii. What would be the impact on DHS ?

For CT image processing, better segmentation would result in fewer false alarms, lowering the operational costs of scanning operations.

5. A list of people who should be notified about DHS's request for information (RFI) for 3rd party algorithm development and future DHS funding announcements

- TeleSecurity Sciences
- Current industry incumbents (GE, L3, Smiths Rapiscan, Reveal, Analogic)

21.2.8 Homework #8

I would rather not have this homework distributed as is, but only in aggregate form, since I do not wish to offend anyone I have left off the list of key players or references, inadvertently or otherwise. Note that all of my answers will focus on CT reconstruction since that is the field I know best.

1. Description of desirable and realistic research goals

- Fast and accurate material identification through real time dual-energy, multi-energy, or photon-counting CT.
- Order-of-magnitude acceleration of iterative reconstruction algorithms. I think it is not yet feasible to consider doing real time iterative reconstruction but it could be deployed to improve image quality on images requiring further review.
- Deploying new advances in analytic CT reconstruction that allow for region of interest reconstruction from truncated and minimal datasets.

2. State of the art: listings of highly relevant, leading publications and patents

Dual energy CT/Spectral CT

First a classic:

- R. E. Alvarez and A. Macovski, "Energy-selective reconstructions in x-ray computerised tomography," Phys Med Biol 21, pp. 733–744, 1976.

One of the better papers on fully iterative reconstruction for dual energy:

- J. A. Fessler, I. Elbakri, P. Sukovic, and N. H. Clinthorne., "Maximum-likelihood dual-energy tomographic image reconstruction," in Proc. SPIE, 4684, pp. 38–49, 2002.

Some recent papers of interest on photon-counting spectral CT:

- K-edge imaging in x-ray computed tomography using multi-bin photon counting detectors, E Roessl, R Proksa - Physics in Medicine and Biology, 2007
- On the influence of noise correlations in measurement data on basis image noise in dual-energylike x … E Roessl, A Ziegler, R Proksa - Medical Physics, 2007
- Experimental feasibility of multi-energy photon-counting K-edge imaging in pre-clinical computed … - JP Schlomka, E Roessl, R Dorscheid, S Dill, G … - Physics in Medicine and Biology, 2008

Iterative image reconstruction

Almost everything I know about iterative image reconstruction I have learned from reading and studying Jeff Fessler's papers.

Here are some classics:

- I A Elbakri, J A Fessler. Segmentation-free statistical image reconstruction for polyenergetic X-ray computed tomography with experimental validation. Phys. Med. Biol., 48(15):2543-78, Aug. 2003. (PubMed 12953909)
- I A Elbakri, J A Fessler. Statistical image reconstruction for polyenergetic X-ray computed tomography. IEEE Trans. Med. Imag., 21(2):89-99, Feb. 2002. (PubMed 11929108)
- H Erdogan, J A Fessler. Monotonic algorithms for transmission tomography. IEEE Trans. Med. Imag., 18(9):801-14, Sep. 1999.
- H Erdogan, J A Fessler. Ordered subsets algorithms for transmission tomography. Phys. Med. Biol., 44(11):2835-51, Nov. 1999.
- D F Yu, J A Fessler, E P Ficaro. Maximum likelihood transmission image reconstruction for overlapping transmission beams. IEEE Trans. Med. Imag., 19(11):1094-1105, Nov. 2000.
- J W Stayman, J A Fessler. Regularization for uniform spatial resolution properties in penalized-likelihood image reconstruction. IEEE Trans. Med. Imag., 19(6):601-15, Jun. 2000.

Analytic image reconstruction

A few recent classics

- Y. Zou and X. Pan: Exact image reconstruction on PI-lines from minimum data in helical cone-beam CT, Phys. Med. Biol., 49:941-959, 2004.
- Pan, X., Zou, Y., and Xia, D., "Image reconstruction in peripheral and central regions-of-interest and data redundancy," Med. Phys. 32, 673–684 (2005).
- A. Katsevich, "Analysis of an exact inversion algorithm for spiral cone-beam CT," Phys. Med. Biol. 47, 2583–2597 (2002).
- F. Noo, R. Clackdoyle, and J. Pack, "A two-step Hilbert transform method for 2D image reconstruction," Phys Med Biol 49, pp. 3903–3923, Sep 2004.

Sinogram smoothing and restoration

One of my research directions focuses on applying penalized likelihood techniques in the sinogram domain for smotthing and artifact correction.

- La Rivière, P. J., "Penalized-likelihood sinogram smoothing for low-dose CT," *Med. Phys.,* **32,** pp. 1676–1683, 2005.
- La Rivière, P. J., and Bian, J., and Vargas, P. A., "Penalized-likelihood sinogram restoration for computed tomography," *IEEE Trans. Med. Imag.,* **25,** pp. 1022–1036, 2006.
- T. Li, X. Li, J. Wang, J. Wen, H. Lu, J. Hsieh, and Z. Liang, "Nonlinear sinogram smoothing for low-dose X-ray CT," IEEE Trans. Nucl. Sci., vol. 51, no. 5, pp. 2505–2513, Oct. 2004.

3. State of the art: who are the real experts by name, discipline, location, address

Dual energy CT/Spectral CT

Roland Proksa
Philips Research Europe
Hamburg, Germany

Ewald Roessl
Philips Research Europe
Hamburg, Germany

Marc Kachelreiss
Institue of Medical Physics
Erlangen, Germany

Iterative image reconstruction

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Analytic image reconstruction

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General image reconstruction, artifact correction, implementation details

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Jiang Hsieh
GE Healthcare

Samit Basu
GE Security

4. What are the fundamental gaps: current knowledge vs DHS R&D goals vs research state of the art

I don't think I can answer this question very well since I don't have a keen sense of DHS R&D goals or even what is state-of-the-art in the security screening industry, which seem to be the fulcrum of this question. I imagine the workshop will provide some of this background, which will help me to revise this answer.

   a. Approaches to close the gaps

Frankly I think this workshop alone will be helpful in framing the problems for a group of influential algorithm developers.

   b. Assume availability of $1M, what research goal should be pursued to have the highest ROI.

Improved and accelerated image reconstruction algorithms for dual-energy and spectral CT. It seems that they key to efficient security screening will be material identification and that this is extremely challenging when working from a single energy or polychromatic illumination. Multi-energy and especially spectral techniques provide additional information

      i. What would be the approach?

I am personally partial to applying maximum likelihood/penalized likelihood techniques in the raw data domain to solve for idealized line integrals that can then be reconstructed using fast analytic algorithms.

      ii. What would be the impact on DHS?

It would provide them with a set of fast and validated algorithms for deploying in multi-energy/spectral CT baggage scanners.

5. A list of people who should be notified about DHS's request for information for 3rd party algorithm development and future DHS funding announcements.

- Everyone in the list of key people above,
- Everyone who attends the ISBI meeting.
- Everyone who attends the IEEE Medical imaging Conference

21.2.9 Homework #9

1. Description of desirable and realistic DHS research goal(s).

There should be near, mid and long term goals. The near-term R&D would have an impact on the ManII (both checked and carry-on) design and fabrication. The mid-term R&D would have impact on and focus on upgrades to the ManII systems in the field. The long term would be used in the next buy 10 yrs. from now. Given this near is within 1 yr., mid-term is 3-7 yrs. from now and long term is 7-9 yrs from now.

Research is needed in CT image pre-processing, image reconstruction, segmentation and automatic threat detection.

2. State of the art: listings of highly relevant, leading publications and patents.
3. State of the art: who are the real experts by name, discipline, location, address.
4. What are the fundamental gaps: current knowledge vs. DHS R&D goals vs. research state of the art

The biggest gap is how little those outside of the current EDS vendors know about this problem. Another gap is how to get R&D done by universities without using SSI data. Many will think they have the solution but they do not know the problem until they get the data and try to pass cert.

   a. Approaches to close the gaps.

If one can determine how to replicate passing cert but in a non-SSI world that could help bridge both of these gaps. Easier said then done.

   b. Assume availability of $1M, what research goal should be pursued to have the highest return on investment?

R&D on optimum energy, spatial resolution, segmentation and ATD for the ManII systems.

      i. What would be the approach?

Use modeling and some empirical results to determine if there is an optimum energy, investigate higher energies to overcome noise in low-energy data.
Determine the relationship between PD and PFA wrt MTF and SNR.
Better methods to segment objects.
New methods to ATD.

ii. What would be the impact on DHS?

Better overall security by increased PD and lower PFA.

5. A list of people who should be notified about DHS's request for information (RFI) for 3rd party algorithm development and future DHS funding announcements.

21.2.10 Homework #10

As for the homework, my comments have not really changed since I provided some feedback in January. I am afraid that I do not really have the DHS-specific knowledge to to answer questions regarding topics such as "fundamental gaps" and DHS-specific state of the art. I would however be willing, after the workshop (where presumably, I would be able to get a better idea about DHS' needs), to provide feedback concerning how the idea, models and algorithms with which I am familiar from medical and geophysical imaging might be able to help DHS meet goals in a realistic manner. One thing that you may want to discuss explicitly is personnel transfer. The model of training grad students who eventually go off to work in industry may not be the best one for DHS. It tends to be slow and inefficient. Perhaps alternate models may be more appropriate. Industrial scientists might want to spend extended time in the ivory tower where they, in collaboration with faculty and post docs could devote focused time on developing the next great thing.

Alternatively, capturing faculty and post docs in industry for a while night also be of use. My personal opinion is that so long as the effort can result in publications (which, like it or not, is a major metric by which faculty are reviewed and post docs get permanent jobs) people should be willing to explore these types of arrangements. If you feel that any of these comments would be of interest to others at the workshop, please feel free to use them as you see fit.

21.2.11 Homework #11

1. Description of desirable DHS research goal(s) - goals need to be reasonable

In the area of advanced algorithms, research goals might include the following:

- Develop a universal listing of algorithms and the functions they provide in image analysis
- Create a relational database that correlates major characteristics of imaging algorithms with their ability to be used across types and brands of systems
- Institute a common documentation system that contains releasable salient features of various algorithms
- Create a lexicon of image manipulation terms and filters to be used across all inspection systems
- Provide a common platform and format for algorithm development

2. State of the art: listings of highly relevant, leading publications and patents

- L. Snidaro, I. Visentini, G.L. Foresti, "Dynamic Models for People Detection and Tracking," *IEEE Fifth International Conference on Advanced Video and Signal Based Surveillance*, pp. 29-35, 2008.
- K. Toyama, J. Krumm, B. Brumitt, and B. Meyers, "Wallflower: Principles and practice of background maintenance," *Proc. ICCV '99*, pp. 255–261, 1999.
- L. J. Latecki, X. Wen, and N. Ghubade, "Detection of changes in surveillance videos," *Proc. IEEE Conference on Advanced Video and Signal Based Surveillance*, pp. 237–242, 2003.
- I. Haritaoglu, D. Harwood, and L. S. Davis, "*W4: Real-time surveillance of people and their activities*," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 22, no. 8, pp. 809–830, 2000.
- T. Wada and T. Matsuyama, "Multiobject behavior recognition by event driven selective attention method," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 22, no. 8, pp. 873–887, 2000.
- Z. Kim and R. Nevatia, "Automatic description of complex buildings from multiple images," *Computer Vision and Image Understanding*, vol. 96, no. 1, pp. 60–95, 2004.
- M. Goldbaum, S. Moezzi, A. Taylor, S. Chatterjee, J. Boyd, E. Hunter, and R. Jain, "Automated diagnosis and image understanding with object

extraction, object classification, and inferencing in retinal images," *IEEE International Conference on Image Processing*, pp. 695–698. 1996.

- A. Huertas and R. Nevatia, "Detecting changes in aerial views of man-made structures," *Image and Vision Computing*, vol. 18, no. 8, pp. 583–596, 2000.
- C.-Y. Fang, S.-W. Chen, and C.-S. Fuh, "Automatic change detection of driving environments in a vision-based driver assistance system," *IEEE Transactions on Neural Networks*, vol. 14, no. 3, pp. 646–657, 2003.
- A.M. Cheriyadat and R.J. Radke, "Detecting Dominant Motions in Dense Crowds," *IEEE Journal of Special Topics in Signal Processing, Special Issue on Distributed Processing in Vision Networks*, vol. 2, no. 4, pp. 568-581, 2008.
- T. Yapo, C.V. Stewart, and R.J. Radke, "A Probabilistic Representation of LiDAR Range Data for Efficient 3D Object Detection," *Proceedings of the S3D (Search in 3D) Workshop 2008*.

3. State of the art: who are the real experts by name, discipline, location, address

Badri Roysam
Electrical, Computer, and Systems Engineering
Rensselaer Polytechnic Institute

Richard Radke
Electrical, Computer, and Systems Engineering
Rensselaer Polytechnic Institute.

4. What are the fundamental gaps: current knowledge vs. DHS R&D goals vs. research state of the art

Currently, data generated by security inspection systems is proprietary to the manufacturers of these systems. The hardware and software are highly integrated making it hard to apply third party algorithms to security inspection data. In addition, the data processing algorithms used on these systems are well protected by their respective manufacturers, making it even harder to utilize third party algorithms. Ideally, data created by security inspection systems would have standard format allowing for a wider community of researchers to apply their algorithms and advance the state of the art.

c. Approaches to close the gaps.

A good way to move forward is work with vendors of inspection systems to make the data created by their systems available to third parties. Also, a

common platform where third parties could load images from different vendors and apply different algorithms on them is needed. A good example is the NIH ImageJ software (http://rsb.info.nih.gov/ij/), which is focused on Medical images. ImageJ allows users to read images from different formats and apply different image processing algorithms on them. Vendors can provide their images in a standard format (e.g., TIFF or JPG), or provide a plug-in to ImageJ that enables it to reading that image format. Third parties, as well as vendors, can provide their algorithms as plug-ins to ImageJ. For DHS purposes, they can leverage ImageJ as is and promote it as the standard platform or they could sponsor developing a similar platform.

d. Assume availability of $1M, what research goal should be pursued to have the highest return on investment?

Develop advanced operator assist algorithms for high-throughput X-ray personnel scanner.

i. What would be the approach?

For a personnel scanner, the background against which threats can be overlaid is the human body. While images of different people are not exactly the same, they have many things in common. For example, it is safe to assume with very high probability that images should show a pair of legs and a pair of arms. With this, model-based segmentation can be used to fit a human body model (head, arms, torso, legs, …) to the image, allowing context-aware anomaly detection algorithms. Based on the context, a metallic object around the wrist is likely to be a watch and should not alarm, while a metallic object on the side of a person is probably a gun or a knife and should alarm.

ii. What would be the impact on DHS?

Enable high-throughput personal scanning while addressing privacy concerns for people being scanned.

21.2.12 Homework #12

I'm writing this in response to the Algorithm Workshop Homework Assignment.

I'd like to begin with a caveat – I don't frankly know what the DHS objectives are (I can imagine what they are, but I can't say for sure what they are), and my viewpoints are severely influences by analogous problems I see in the medical domain.

For baggage screening, I see one main objective as that of driving down false alarm rates while maintaining near-zero leakage rates. I see this task as consisting of four topics: (i) sensor design; (ii) signal and image formation; (iii) pattern recognition, and (iv) computation and throughput. From my observations, there are two fundamental gaps in the work that are being pursued – lack of vertical integration among these disciplines, and lack of "high information content" signal/image formation. In the case of integration, the need to optimize functionality in the context of up- and down-stream processing is obvious. In the case of high information content, the exploitation of one or two target identification features can always be defeated; robustness can only come from having multiple dimensions of independent data types in order to defeat countermeasures.

Although it's easy to talk about integration and optimization, the fact is that it's difficult to do when all the disparate pieces are in flux. As such, I would recommend a "phased program" consisting of:

1. Phase I: demonstration target identification IOC using existing scanners.
    a. Image and signal processing – DHS has to decide whether target identification has a better likelihood of succeeding in the image domain or in the signal (i.e., non-spatially-localized) domain. I am personally of the opinion that betting on the signal-domain path is premature at this time. DHS also has to identify 1 or 2 modalities – likely x-ray CT is an option.
    b. Image reconstruction free of artifacts, likely multi-spectral, incorporating shape, attenuation, material property, volatile material sampling will be needed. From the medical perspective, there are a few places which excel at this – the group supporting GE CT systems include Charlie Bouman from Indiana and Jeff Fessler from Michigan; the group supporting Siemens includes Homer Pien of MGH and Clem Karl of Boston University. The Institute of Medical Physics (University of Erlangan, with Willie Kalendar) has also supported Siemens, and were one of the early

CT physics groups to examine multi-energy. Philips R&D has their own group in Hamberg, Germany. From an artifact reduction perspective, the MGH-BU group is the only one we're aware of.

c. Pattern recognition must be tightly integrated with signal/information. At this point the MGH-BU group has not performed CAD (computer aided diagnosis) on artifact-reduced CT data, although MGH has an active group on CAD for other applications (trauma, virtual colonoscopy, stroke, etc). Some of the best pattern recognition activities take place at the AI Lab at MIT.
d. IOC using a dataset of DHS's prescription, without regard to computation time.

5. Phase II: integration of sensor design, signal/image formation, pattern recognition, and computation
    a. System optimization
    b. Workflow issues (ie, passing of information from automatic screening to human second opinion)
    c. Computation time and acceleration.
    d. IOC at the end of Phase II.
6. Not sure what timeline DHS is assuming, but I can see this being a 3-year effort, with Phase I receiving 2 yrs of funding (IOC at 18 months), and Phase II receiving 1-1/2 yrs of funding, beginning with the Phase I IOC. I think realistically, $1M is too small to fund both phases of this suggested effort.

There is one more issue that I'd like to point out. From the medical imaging side, there is no doubt in my mind that the current trend of pushing for more detectors and more detector rows (without substantially altering the intrinsic size of the detectors) is an overkill. Overspecification of the sensing system not only drives up cost, but also imposes undue burden on the processing. Some degree of sanity from the perspective of sensing capacity or compressive sensing – presumably tied into Phase I above (it's a nice-to-have, not a requirement) – would be desirable.

21.2.13 Homework #13

1. Description of desirable and realistic DHS research goal(s).

Research into liquid threats – properties, danger, how to detect, known mixes

2. State of the art: listings of highly relevant, leading publications and patents.

- There are many publications – many are NOT published due to trade secrets
- There are no relevant publications which we have made public at this time.

3. State of the art: who are the real experts by name, discipline, location, address.

Most we are aware of are invited to this meeting

4. What are the fundamental gaps: current knowledge vs. DHS R&D goals vs. research state of the art

Data regarding emerging threats

   a. Approaches to close the gaps.

Setup data collection and research available to community
Collaboration with International groups

   b. Assume availability of $1M, what research goal should be pursued to have the highest return on investment?

See #1 above

      i. What would be the approach?

Setup threat study and data collection facility

      ii. What would be the impact on DHS?

- Benefits of greater access allowing more people to work on problem
- Quicker turnaround of detection capability

5. A list of people who should be notified about DHS's request for information (RFI) for 3rd party algorithm development and future DHS funding announcements.

- Most who are interested will follow DHS and FedBizOpps

21.2.14 Homework #14

1. Research Goal

Create a legal/funding scenario where equipment providers and third parties are incentivized to cooperate, or at least accommodate one another. This would entail defining some interfaces, and creation of "sandboxes" for third parties to play within. The equipment manufacturer, on the other hand, needs to secure a domain as the sensor expert. It will be critical that the regulators define and enforce these interfaces.

2. Publications

In the field of data fusion, there is a International Journal of Information Fusion

- http://www.elsevier.com/wps/find/journaldescription.cws_home/620862/description#description

3. State of the art: who are the real experts by name, discipline, location, address.

Todd.gable@ge.com
CT detection

Matthew.merzbacher@ge.com
CT detection

Helmut.strecker@ge.com
X-ray diffraction detection

Holger.Fleckenstein@ge.com
X-ray diffraction detection

Chris.w.Crowley@ge.com
NQR detection

Kurt.bistany@ge.com
trace detection

Data fusion:

DR. BELUR V. DASARATHY, Ph. D, FIEEE
fusion-consultant@ieee.org
Editor-in-Chief, International Journal of Information Fusion

4. What are the fundamental gaps: current knowledge vs. DHS R&D goals

vs. research state of the art?

Creating clear requirements to equipment manufacturers that allows system development more decoupled from the certification process. Example, Understanding how to develop technology with high detection performance, but with the flexibility

a. Approaches to close the gaps.

For CT, define requirements on image quality and general accuracy. Also define requirements to identify objects (not only threats), and extract physical properties (and derived features) from these. This would allow create an opportunity for downstream consumers of the data to work on algorithms, and collect data with new threats while gaining useful information from them. It would also give clear incentives to the equipment manufacturers to optimize the data quality and the interpretation of the sensor data to a point where the data can be useful to third parties.

b. Assume availability of $1M, what research goals should be pursued to have the highest return on investment?

I would spend the money on establishing ground rules for data formats and requirements. Something like DICOS, but really make sure that an adequate representation of the data at a meso-level is specified – between the sensor/image data itself, and the decision.

The impact could be a clear spec to existing vendors that redefine the end deliverable. It also would open up the space for third-parties to develop algorithms, particularly down-stream, that is close to the decision.

21.2.15 Homework #15

1. Description of desirable and realistic DHS research goal(s).

Develop novel algorithms for security applications.

2. State of the art: listings of highly relevant, leading publications and patents.

- Ye Y, Yu H, Wei Y, Wang G: A general local reconstruction approach on a truncated Hilbert transform. International Journal of Biomedical Imaging 2007:Article ID 63634, 8 pages, 2007
- Ye Y, Yu H, Wang G: Exact interior reconstruction with cone-beam CT. International Journal of Biomedical Imaging, 2008:Article ID 10693, 5 pages, 2008
- Yu H, Ye Y, Wang G: Interior reconstruction using the truncated Hilbert transform via singular value decomposition. Journal of X-ray Sciences and Technology 16:243-251, 2008
- Yu HY, Wang G: Compressive sensing based interior tomography. To appear in International Journal of Biomedical Imaging, 2009
- Wang G, Yu H, Ye YB: General VOI/ROI reconstruction methods and systems using a truncated Hilbert transform. Virginia Tech Patent Disclosure (May 15, 2007), Provisional Patent Application, 2007

3. State of the art: who are the real experts by name, discipline, location, address.

Dr. Yu Zou
Toshiba Medical Research Institute USA, Inc.
706 N. Deerpath Drive
Vernon Hill, IL 60061, USA
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Dr. Bruno De Man
CT Systems and Applications Laboratory
GE Global Research Center (KW-C1307)
1 Research Circle, Niskayuna, NY 12309
Tel : (518) 387-7730
Fax : (518) 387-5975
Email : deman@research.ge.com

4. What are the fundamental gaps: current knowledge vs. DHS R&D goals vs. research state of the art
    a. Approaches to close the gaps.

Interior tomography, compressive sampling, statistical reconstruction techniques

    b. Assume availability of $1M, what research goal should be pursued to have the highest return on investment?

Develop the above mentioned new methods etc.

        i. What would be the approach?

Interior tomography, compressive sampling, statistical reconstruction techniques

        ii. What would be the impact on DHS?

More flexible imaging system capabilities at less dose, less data and higher quality

5. A list of people who should be notified about DHS's request for information (RFI) for 3rd party algorithm development and future DHS funding announcements.

See the answer to Item 3.

21.2.16 Homework #16

Remembering the human in the loop

Jeremy M Wolfe,
Brigham & Women's Hospital / Harvard Medical School

Preamble

My response to the 'homework assignment' will be a bit different. I will assume the existence / development of clever threat detection algorithms and I will assume that those algorithms are not clever enough to eliminate the need for a human in the loop. I will focus on the human.

Desirable and realistic DHS research goal(s):

Computer aided detection (CAD) systems are increasingly deployed as aids in complex search tasks from the airport to the radiology suite. CAD systems can be quite sensitive, but they are not able to replace human observers. A set of choices has to be made when imperfect human observers use imperfect CAD systems. Current choices may or may not be optimal. We simply do not know because there is inadequate applied research and virtually no basic research in this area. Many required experiments cannot be done in the field for reasons of time, cost, and/or risk. It would be desirable and realistic to create a process for testing CAD choices in the lab so as to inform deployment of CAD in the field. Experience in the field then drives the next set of lab studies.

A brief example

Imagine a CAD system with a respectable d' of 2.6. At a neutral criterion this would mark 90% of all targets and just 10% of candidate non-targets. Now suppose that there are an average of 10 possible regions/objects that could be marked on each image. Imagine a run of 10,000 bags. If the target prevalence is 50%, the run will contain 5000 threats, of which the system will mark 90%, or 4500 targets. However, there are also 95,000 candidate non-targets, of which 10%, or 9500, will be marked. The validity of each CAD mark will be 4500/(9500 + 4500), or 32.1%, which is not bad. But suppose that targets are present on just 1% of cases (as it might be at the airport, even with test threats added). This run contains only 100 threats, of which 90 will be marked, along with 9990 non-targets. Now the validity (90/(9990+90)) is only .9%. Little is known about human response to signals of such low validity.

Closing the gap

A modest proposal: To speed the loop between basic human research and applications in the field, establish small lab at a major airport. Connect it with an established academic lab. Fund this with one postdoctoral level person, perhaps a research assistant, a percentage of the academic PI's effort, and some funds for the running of the lab. Critically, fund one screener FTE. The goal would be to have a steady stream of screeners rotating through for 1-2 hr experiments. No screener would be "assigned" to the lab. Screeners would just be assigned to the lab for a shift the way they might be sent to Terminal A checked baggage. The budgeted addition of a screener FTE means that the airport wouldn't be shorthanded. This would enable a novel combination of lab and field studies.

Forging connections

DHS should also be working to facilitate research linkages between industry, academia, and the airport. Industry is going to develop new machines & algorithms. Evaluation of the human/machine interaction should be done by labs with an interest in the fundamental science and without an interest in specific machines. This research needs to be done in consultation with people at the airport who need to make this work in the field.

State of the art

I am discussing human cognition/behavior rather than the CAD algorithm literature. There are a host of relevant researchers and many possible literatures. I will spare you a list here but will be happy to respond to questions about specific people and topics.

21.2.17 Homework #17

1. Desirable and realistic goals

I think that an outstanding question is how do we enable / optimize the processing of information at existing checkpoints / chokepoints and checkpoints of the future? Not necessarily image processing, or automated detection, but presentation of the information/data to the decision maker. An ultimate goal for screening systems is the development of automated algorithms for anomaly / threat detection. In my opinion, our ability to do fully automated detection has been oversold, and, in some sense, underestimates the ability of a human observer to make complicated connections between disparate data types. So, I think that an important question is, how do we present data in a more intuitive fashion to an observer, or a group of observers? ("intuitive" is probably a poor choice of words.)

Take the most common checkpoint – checked bags at the airport. There are separate people who:

- check my ID against my ticket;
- watch me through the metal detector (and recheck my ticket);
- examine the radiographs of my bags and shoes;
- frisk me when I fail the metal detector;
- swipe my bag for trace explosives.

I am not privy to the full ConOps of the checkpoint, but my guess is that this data is independently evaluated (the metal detector kicks me to the frisker, and the radiography may send me to trace, so it could be modeled it as a primary/secondary scenario). Short of the neural net that brings all these data streams together (and automatically finds the threat), does it make sense to examine how we present all this data to a single observer, or perhaps share the data between multiple observers? For instance, often the x-ray-system operator will appear confused and call over another operator to help review – it seems like there is an argument here for a shared workspace that can display these data streams to multiple observers.

(which perhaps raises issues of privacy – does the operator of the x-ray system need to know that I am going to the beach; I think that we are avoiding those issues here.)

It also seems like this is a common problem across disciplines – many are swamped with data and could use better tools for visualization.

2. State of the art (pubs)

- An example of data fusion (correlated neutron and x-ray radiography for explosives detection): Y. Liu, B.D. Sowerby, J.R. Tickner, Applied Radiation and Isotopes, 66(4) (2008) 463 472.
- Dual/multiple-energy CT, R.E. Alvarez, A. Macovski, Physics in Medicine and Biology, 21(5) (1976) 733 744.
- Z. Ying, R. Naidu, C.R. Crawford, Journal of X-ray Science and Technology, 14 (2006) 235 256.
- Image-domain material decomposition using photon-counting CT, K. Taguchi, M. Zhang, E.C. Frey, J. Xu, W.P. Segars, B. Tsui, Proc. Of SPIE, VOl. 6510, 651008, (2007).
- Beam hardening artefacts in computed tomography with photon counting, charge integrating and energy weighting detectors: a simulation study, P.M. Shikhaliev, Phys. Med. Biol., 50 (2005).

3. State of the art (people)

It seems like the x-ray CT community is well represented at the workshop. Is there a strong PET presence – seems like that is where the iterative reconstruction information will come from.

I recently saw a talk from Jake Koloejchick (http://www.gdviz.com/infocentricity.html) on information-centric collaborative tools. The tools that they develop are not directly applicable to checkpoint security problems, but their approach of information sharing among a small group of decision makers is worth examining

4. Fundamental gaps

If Zeff and ρ are the only discriminate for x-ray imaging, do we improve the detector system (coarse spectroscopy capability at high count rates) and develop algorithms to take advantage of the additional information, or do we continue to tweak the present dual-energy algorithms?

Are we at the point that we need better image processing (segmentation, assignment, visualization of 3D data) or do we need better reconstruction tools (in the absence of improved source/detector technology).

My million dollars:

On the x-ray side, I would spend my money on algorithms to optimally use additional energy information (bremstrahlung source with a detector that has coarse energy resolution) under the assumption that the detector technology will be here (soon?).

Visualization of 3D data (even multiple projections from a radiography system) and visualization of disparate data types – tools to aid the end user

i. Close the gaps
ii. If I had a million dollars

5. People to notify

mm-Wave: Doug McMakin (doug.mcmakin@pnl.gov)

data fusion: Kris Jarman (kristin.jarman@pnl.gov)

explosives screening: Philip Bingham (binghampr@onrl.gov)

CT reconstruction: Fred Noo (noo@ucair.med.utah.edu)

21.2.18 Homework #18

The Playground

There was a lot of talk about developing a "playground" or "challenge problems" to engage academic researchers without having vendors give away the farm, or DHS lose the deterrence advantage. This is a tricky problem, but there are probably some potential solutions:

if the "toys" in the "playground" consisted of simulation data, then the data would have to include sufficient real-world effects (e.g., Compton scatter) and scanner-specific geometry and electronics information (e.g., limited dynamic range, finite pixel sizes) in order to test the ability to discriminate threat from benign material. This may require scanner-specific simulation capabilities, or at least good models of detector response (decouple the object and detector interactions); it is unlikely that the vendors have put much effort into this or that they would be willing to share specific information with a large community. (as an alternative, see 4)

The "toys" could consist of real data from a (or multiple) vendor's scanner(s). But at what level of processing would these data be provided? Raw sinograms would require sharing of system specific information to make the data useful. Processed images limits what the community can do with the data. Obviously one cannot contribute to reconstruction code if that part of the processing has already been performed; there was talk that some of the material identification or image segmentation may be performed on the raw data, or as part of the reconstruction process, sharing of only the reconstructed data may be limiting. For instance, iterative reconstruction on dual-energy data would require access to sinograms (perhaps corrected sinograms, which potentially could eliminate vendor-specific information).

The toys could be just a set of images (this is a subset of the point above). This data has been collected and archived (according to LLNL), but is not yet available for our consumption. This allows segmentation / identification games to be played (which I think still represent a significant challenge).

Or maybe there are not really any toys, but a set of games – this is the challenge-problem scenario. Can problems be set up that are sufficiently ambiguous to be distanced from classification issues and yet be close enough to real-world problems to allow advances to be made. For example, a set of parameters could be:

- Discriminate material of density 1.8g/cm3 and Zeff of 7.44 in a sea of materials of varying densities and Zeff's (these would need to be specified)
- Specification of the object dimensions (the whole object and the threat – this can stay away from classification issues?)
- Bremstrahlung radiation with endpoint energy of XXkVp (and YYkVp for the dual-energy case) – probably need to specify the total number of photons to set a noise threshold
- Specify detector material, thickness, pitch, and source/detector geometry – these do not have to mimic a real system; my guess is that they are all pretty close and a nominal value could be used)
- Specify the dynamic range (or digitization) of the detector – is a discussion about which effects – digitization and detection-chain noise or object physical effects like Compton scatter -- are a bigger hindrance to material outside the bounds of what the vendors would like to divulge? It is this type of info that could be shared with the academics to know how much fidelity to put in the forward-problem model, or mre generally, where to focus the fidelity of the simulation of the fwd problem.

This game would probably result in different simulations of the forward problem as well as reconstruction/analysis routines; if done properly, then the forward simulations could be shared (e.g., test Researcher A's reconstruction on Researcher B's simulated projections, and the reverse). This puts the full onus of the work on the academics and only requires the vendors and DHS set up the problem (in a way that can be worked on by the community).

The toys could consist of a equipment similar to deployed systems (without all the bells and whistles) – maybe a prototype system from a vendor that is a few generations old. This would allow data to be collected (perhaps slowly, but that is not a concern here) on real items, would allow full characterization of a system that does not get too close to giving away secrets, and allow access to any level of processed data. Experiments on this system may not help a vendor on a specific problem, but could address general problems that could be exported to specific systems.

Both 5 and 6 point toward the need for some standard objects that can be modeled and built for testing. These are possibly different than the standards used to qualify systems, and are maybe reconfigurable (for the "come to the meeting and we will give you a new test object to simulate and reconstruct" challenge-problem scenario).

It seems that the default alternative would be to have individual vendors contract with individual researchers. Which leads to …

Getting The Word Out

For whatever reason, there seems to be a disconnection between the academic world and the vendor world in the arena of security-screening applications. It would seem that one function of the ALERT COE would be to be the repository of a database of researchers and what they work on (maybe an archive of publications) that the vendor community could draw on for help or collaboration on proposal calls.

At the very least, it would seem that a role for the COE would be to take the responses to the recent algorithms RFI and act as a match maker – hook up the academic folks (who probably proposed medical-imaging algorithms and did not show preliminary data for baggage) with the proper vendor folks to answer the proposal call when it comes out. There should be some way to use the RFI response to start the connection process. The default response from DHS – your proposal failed – seems inadequate in this case; the purpose of the RFI should be to hook people up.

Open Source?

The "open source" or "open architecture" model that is often mentioned seems to have some holes. The medical model that I think is correct is that the medical-device manufacturers use algorithms and processing techniques that are developed by university researchers. This is very different than a model in which third parties develop algorithms that can be used on any machine (because the data from all the machines is in some "open source" format and is thus accessible). Processing routines are often – perhaps always – intimately tied to physical device (engineering) characteristics, information that the manufacturers really do not want to share with anyone (much less their competitors). I think that the way that the collaborative process works in the medical-imaging community is:

a. Company A sees that Reseacher 1 is working on a general problem (or a specific problem for a generic piece of hardware)
    i. What is the best geometry for detection of cirrhosis in planar emission radiography?
    ii. How can I create a more efficient reconstruction algorithm for the detection of microcalcifications in mammography?

The connection is made possible because

- There are clinical and research scanners that researchers have access to all over the country (world)
- But usually they only have access to the final image, not the preprocessed data. This is important.
- The research is done using NIH (or similar) funding. This is important, too.
- The researchers publish their results. There are a lot of medical-imaging journals.

So how does the transfer happen?

Company A goes to Researcher 1 and asks if they would help develop an algorithm for use in their scanner. NDAs ensue, and these often end up in long-term collaborations (or slave labor), funds going directly from Company A to the researcher (and the grad students do the work)

Company A reads the paper and develops their own algorithm based on the research (the researchers already got "credit" for publishing and often only really want to see their work used)

Researcher 1's institute protects the algorithm and Company A needs to license it in order to use it (I think that this is only recently becoming common, and a source of complaint at this meeting)

The point is that there is no "open architecture" system in the sense that everyone knows what everyone else's data looks like, and academics write programs that "plug and play" in any scanning system. If an academic develops (publishes) a sooper-hootie algorithm that changes the game, then all the vendors will implement it (or a variant).

How is the security-scanning world different?

There is less access to scanners by researchers. There are a lot fewer security CT scanners (EDS) than there are medical CT systems (although it is probably the case that there are a lot more CT scans of baggage than of people), and the security scanners are not in "academic" environments.

There is a security / classification element. There are no secrecy issues regarding the size of the smallest tumor that can be detected by Company A's scanner. How do you tell a researcher that you need to do a better job detecting something when you do not tell them what the something is, or what the current system limitation is (this is not an impossible problem to overcome, but it is a difference and a limitation)

There is a different metric of "quality". Security scanners are qualified (and thus allowed to be purchased, allowed to exist) if they can prove that they can detect something in some maximum amount of time with some acceptable false-positive rate. There is no such qualification process in medical imaging (that I can think of; maybe the FDA sets limits on that kind of thing for stuff like pregnancy tests).

If you can hit the rate, you are done. Is there any incentive to improve? If you can scan faster than Company A, maybe you will sell more machines. How will you prove a lower false-alarm rate?

The probability of occurrence of an event is much lower than the medical case. The probability of a tumor is low; the occurrence of explosives approaches 0. On the other hand, the probability of banned items in carry-on baggage is probably much higher than tumor incidence is in the medical case.

As a corollary, the diversity of items in both density and spatial frequency (heterogeneity) is much higher for the security application than for the medical application

It seems like the "industrial" CT inverse problem is fundamentally different from the medical problem in the sense that industrial / security objects have defined boundaries, whereas in the medical case we are often trying to discern small differences in density for objects that have blurry boundaries, or tendrils. (Someone more clever than me can work the true meaning of "artifact" in here.) It seems that projection data from objects with distinct boundaries offer a new challenge for CT reconstruction, and for explosives detection (objects in a relatively unique spot in the density-Zeff plane), a chance to incorporate some unique a-priori information. My guess is that this is a place where the academics / national labs would love to play.

21.2.19 Homework #19

Workshop Homework

Ted Grant
OK to distribute

1. Description of desirable and realistic DHS research goal(s).
    a. Carry-on Bag Automatic Detection:

Algorithms to reliably detect weapons, explosives and all prohibited items in carry-on bags. Note, although this is very challenging due to the wide array of possible prohibited items, saving graces are the availability of multiple views from AT machines, in some cases dual-energy images allowing characterization of materials, and perhaps most importantly the acceptability of high false alarm rates.

I suspect that for automatic detection in carry-on bags, a good approach would be to pattern-match on the items to be detected.

    b. Similar algorithms for detecting weapons and explosives on people using Whole Body Imagers.

Again, although challenging, in the case of people, the saving grace here is the relative lack of clutter, images should consist of people's bodies alone.

In the case of personnel scanning, I suspect the approach would be to pattern-match on the body as "normal", and to look for anomalies.

2. State of the art: listings of highly relevant, leading publications and patents.
3. State of the art: who are the real experts by name, discipline, location, address.
4. What are the fundamental gaps: current knowledge vs. DHS R&D goals vs. research state of the art.
    a. Approaches to close the gaps.
    b. Assume availability of $1M, what research goal should be pursued to have the highest return on investment?
        i. What would be the approach?
        ii. What would be the impact on DHS?
6. A list of people who should be notified about DHS's request for information (RFI) for 3rd party algorithm development and future DHS funding announcements.

I was contacted by the gentleman below, who represents a group that does anomaly detection for quality control in the semiconductor industry.

Jay Rathert
Sr. Director
Business Development
KLA-Tencor
408-875-5675 (w)
408-930-9452 (c)
804-779-3423 (h)
jay.rathert@kla-tencor.com

21.2.20 Homework #20

Existing explosive detection machines that pass EDS certification have widely differing image quality (resolution, artifact corrections, signal to noise ratio). If the intent is to improve the state of the art and underlying technology of explosive threat detection, the existing 'challenge project', EDS certification, does not provide sufficient motivation/direction to innovate the technology.

From the discussions at the ALERT algorithm symposium, it is clear that new, up to date 'challenge problems' need to be presented to the community to improve specific and useful areas of the technology that can be directly linked to specific measurable performance improvement (e.g. signal to noise). In this way a third party does not have to create a full EDS solution and pass certification to show their improvement.

Setting tighter detection and false alarm targets will motivate technology improvement but requires a full solution which is not practical for 3rd party participants. Instead goals need to be set that stretch the participants in smaller, but technically valuable areas. Once a number of these technology areas have been improved, the results can be put together and a more innovative, full performance solution will result that meets improved detection standards.

The important part is to create meaningful challenge projects that create the building blocks of the final improved technology solution.

(Improved sensor/hardware) + (improved reconstruction algorithm) + (improved detection algorithm) + (improved user interface) = improved full solution

Challenge projects

- Hold baggage screening
- Improved sensor/hardware: "CT sensor with 1mm isotropic voxel resolution"
- Improved sensor/hardware: "Sensor that can distinguish between maple syrup and Explosives"
- Improved sensor/hardware: "Re-registration for sensor fusion. Identify the 3D spatial position of a target object within a bag for re-scanning based on a 3D volumetric CT data set. Account for bag rotation, flipping and movement of items inside the bag."

- Improved reconstruction algorithm: "Reconstruct data of a 100x100x2mm delrin sheet placed in 27 orientations within the imaging tunnel. Reconstruct the density to within 90% of the actual value for all orientations."
- Improved reconstruction algorithm: "Reconstruction algorithm that reconstructs data at the highest resolution with the minimum artifacts and the most accurate density in the presence of metal objects."
- Improved detection algorithm: "Segment a 100x100x2mm delrin sheet placed in 27 orientations within the imaging tunnel. Recover 90% of the actual mass for all orientations."
- Improved detection algorithm: "Liquid threat: Identify liquids and classify the contents into threat / benign for volumes in excess of 100cc."
- Improved user interface: "Present 3D data to the operator with image controls that allow the high-resolution OSARP to be applied with an average decision time of 10s"

Multi-view HBS and checkpoint

- Improved sensor/hardware: "Re-registration for sensor fusion. Identify the 3D spatial position of a target object within a bag for re-scanning based on 2 x 2D line scan images. Account for bag rotation, flipping and movement of items inside the bag."
- Improved sensor/hardware: "Confirmation sensor that can generate a unique signature from the contents of a liquid >100cc in volume that is contained within a bag"
- Improved reconstruction algorithm: "Reconstruct sparse data set comprising of multiple 2D linescan images. Generate limited data reconstruction that permits overlapping objects to be separated"
- Improved reconstruction algorithm: "Reconstruct sparse data set comprising of multiple 2D linescan images. Recover density if a chosen object better than 60% average density accuracy."
- Improved detection algorithm: "Identify sheet-like objects from multiple 2D images of a bag containing a 100x100x2mm delrin sheet placed in one of different 27 orientations. Arbitrate objects across the multiple images, and distinguish from non-threat clutter."
- Improved detection algorithm: "Liquid threat: Identify liquids contained within bags using multi-view 2D data. Classify the contents into threat / benign for volumes in excess of 100cc."
- Improved user interface: "Present 2D data to the operator with image controls that allow the OSARP to be applied with an average decision time of 4s"

Whole body Imaging

- Improved reconstruction algorithm: "Generate 3D image of a person from multiple walk-by images. Eliminate motion artifacts form moving arms and legs"
- Improved detection algorithm: "Identify molded threats that are concealed behind clothing and contoured to the human form"
- Improved user interface: "Present concealed threat data to the operator with image controls that allow threat/non-threat identification with an average decision time of 4s"

22. Appendix: Meeting Minutes

22.1 Harry Martz Minutes

Micheal Silovich-NEU

Long range fundamental science

Next 10 yrs.; be a sense of a community.

A report to put forth our ideas on where the COE will be going, what are the curtting edge ideas to go forward and put rsources on these ideas.

Academic and industrial opportunities go after funding together than separate.

Suriyun Whitehead Booz Allen-DHS support

Mike S. says add collaboration to the Competition, …outreach bottom line VG

NEMA make it easy to share data to get better performance. Carl this is the goal for the standard formats…

Richard Bijjani asked is the conference about image recon or ATD or both algorithms?

MS All the above algorithms.

Homor Pien Harvard asked are the requirements well defined? SW answers yes they are.

MS let's start from scratch and create a clean approach

Ben Tsui we found out that more is needed to know about the up front image processor…it depends on what hou are looking for and the algorithms that are required to do it. The liquid problem is a clar example of this presence of liqs. vs. threat in liquid vs. non-threat.

Carl Crawford csuptwo

John Pearson Siemens By algorithms do you mean computational processing to improve screening? CC said yes and more.

The cost of predictive value is zero, Suriyun mentioned there may not be any now but there is the possibility…in this case the cost is very high.

There are two D's in this field Detection or Deterence, which is more important?

Kris Roe Asked are big companies left out of the Algo RFI? John Pearson form Siemens said the big companies need to make it easier for the small companies and universities to get involved…mentioned NEMA DICOS…

Sondre Scatter GE said that the small vs. big companies is misleading and that all should and are involved…

HEM: LLNL 3rd parties are those not in the business today not small vs. big…

Strategies and implementation issues came up…the devil is in the details…Carl said this is off the table Mike Lonza said that this is an issue and the vendor are concerned how the gov't plans to go forward.

Carl Smith Guardian: DO both medical and security. When they were working on a medical problem the medical standard diod not have all the data in their standard. What is sent to the monitor for the screener vs. what ATD needs is quite different. This needs to be in the standard.

VG17 Integrated and Fused bullets are the same thing…

VG20 Add Your obligation is to TALK…

Jason Martin Passenger Screening Program

Useful to show images (clutter, attenuation, threat not threats) to help define the problem.

Reduce the number of bins required by divestiture…the opposite of exempt liquid rule.

Ben Hsui Asked what is the sensitivity level? Is it at the level you want. JM: No we want more, there is room for improvement.

Ben Tsui what is the Strategy?

Matthew Merzbacher GE

Robert Nishikawa: IHE Integrated Hospital Enterprise DICOM does not necessarily work but IHE will make sure this happens.

MM: Said they do not do detection they decide it is not a threat.

David Schafer GE

Threat Object Insertion, TIP …

HEM: Future conference like this:

Define the problem find explosives in people and luggage

- What are the hoops to get certified?
  - Image not needed for CERT?
- What happens after you are certified.
  - FAT, SAT, overtime
  - OSARP

HEM: It is good to hear from the current EDS vendors, but what about the new comers like Smiths, Rapiscan RTT, Surescan, etc. Have 3rd parties talk as well…Of the check point talks no one currently in the field with carry-on (S-D or Rapiscan) gave a talk on TRX and AT…also no one from WBI or trace talked.

Ben Tsui wants you (Carl) to say statistical not iterative :o) Method is more than an algorithm…C. Bouman said he calls it model based image reconstruction.

Alex Kat.: Asked if there are partial volume issues with full CT? DS said yes and Carl added the aggregation issue. Jim Connolly said that this also has issues with artifact reduction as well.

Sondre Skatter GE

Ben Tsui Asked if one looks beyond detection to identification/classification. The recon image for each is quite different.

It was mentioned that you need training data, validation data and evaluation data…

Medical conf. (France) Where they have a contest to get data and get good results…

HEM: NIST grand challenge…for the grand challenge data what data do the community want, calibrations, threats, non-threats, etc…

Clem: For image recon need good characterization of the sensor…

HEM: To have open discussions you need people to talk for 30-50% time and allow time for discussions…

Richard Bijjani Reveal

Ricahrd was one of the first to say that the explosives are small and hard to find…separation of the IEDs into components then assembled elsewhere.

HEM For Carry-on would one lower threat amount and add all alarms below threat together to show a real threat assembled later.

Operator is sometimes the weak link…they do image processing very well…however they can become prejiduced.

Very good position statement at end of Richard's talk…

John Pearson Siemens

Human factors Improving Visual Performance…People can do a better job than human vision algorithms…how do we keep them at their peak performance?

Human factors aka Human Machine Inteface and Cognitive Engineering.

Points made:

- Targets and non-targets ARE SIMILAR
- Non-targets ARE NOT SIMILAR
- Targets are SCARCE

Measure clutter automatically and inform the operator with a border proportional to clutter…

Said there is a big difference between medical images and bags images…HEM: Yes good point, pathology may be more appropriate than the normal chest x-ray image data analysis.

DARPA is doing studies on how to speed up training.

MRI image quality using full matrix, GRAPPA and mSENSE… change in quality rating to JND…

SOME VERY INTERESTING IDEAS IN THIS TALK !

RSDT method to speed up human visualization…Split an image up into many little images and flash them to the humans changes the results for the better…

Break out sessions…

Algos session

David Gerts: INL: One idea was that the future system should be able to adjust energy to scan different size bags…do not limit ourselves to the current hardware technology.

Ron Kikinis: What is the algorithm objective? Is it long term or near term.

Robert Nish. You want someone to team up with people who know the problem.

David Castanon: There was little discussion on the gaps more on what is being done today. Internship at the vendors and the national labs…

CC Vendor: Can you use the help of industry?

Jim C, L3 You have to remember the time lien of a grad student is longer than a product cycle. Yes If the gov't pays for the university internship at vendor sites.

Mike Silovich: ID gaps and then say what number of fellowships are required.

Jim C, L3: Said his biggest gap is segmentation. They believe the key to their success is image segmentation.

HEM note: Should lay out a flow diagram and then list gaps in ach area in the process flow.

Gerts: Brought up the Baysian priors issue of threats and non-threats.

Ron K. Can you clear objects as opposed to detect bombs…

Day Two – Friday, April 24, 2009

Matthew Clark DHS COE lead

W. Clem Karl BU for David Schafer Algorithms

A good summary overview

John Beaty two models

1. Academia and vendors work with NDAs
2. Work with LLNL
3. Work LLNL, Vendor and academia

Discussions of attending conferences and advertising…perhaps…this will happen if you start to do longer term R&D…

Michael Ell. Said that someone like ALERT should keep track of papers/reports and likes a database for this would be useful.

Create a set of standards especially object models and radiography models…start with object models to be the real world dictionary…

Richard's bag set of false alarm bags could be made available including data already acquired and could be run through new scanners…they are DHS bags and they have been scanned at Tyndall on Medical CT, CT-80 and some AT maybe…

Sondre Scatter Automatic Algorithms

Gaps

- Need truth images
- Standardization of the image formats as output rom sensors
- 3rd parties would need to embed grad students
- CT segmentation could be done w/o getting into SSI…

Richard said that what industry says is a problem, is a vulnerability and thus is classified

David Castonon plug and play into a challenge problem…how do hyou intergrate the different R&D advances as the vendors current do this…

Ted Grant – Transitional Research S&T

Need to transition technologies in 3-5 yrs. Ted's management reports to Jim Tuttle.

Need automatic threat detection at airports in the next few years. The TRXs are on their way out. The stimulus package will be replaced with FY09 funds. WBI's are also going to be deployed—looking automatic clearing algorithms to replace the humans. The benchmark is to do as well as people are doing now.

TSA pays ~$2B per yr. for TSOs at airports.

Richard Bijjani – Emerging technologies

Ho w do you bring new technologies into the field?

Laid out a nice strategy that included an exit strategy.

Matthew Clark Perhaps it could be like an SBIR model…phase 1&2 academia and phase 3 industry.

Try a venture capitalist model…academia talk about ideas on what they are working on…

Kris Roe: Vendors want to have a say in this process. IDed 3-4 key areas…could be conferences or workshops in special areas.

Msuptwo: Industry as COTR, an overview role. Also mentioned reliability and encryption of the data sets and their transfer…

Mike Lonzaro, L3 What and how?

Kris Roe Dou's talk what more longer term R&D and less of the spiral development. Enticement is the TSA buys.

David Isaacson – RPI An example of an emerging technology

A mathematician…

Proposed an EM imaging system…high risk R&D…

John Pearson – Siemens Surveillance and Human Factors

Just notable differences—JND

Bob Nishikawa – Univ. of Chicago: Discussed the prevalence report. Radiologists ignored 70% of the CAD marked regions…not sure

why…radiologists do not like new technologies you need to prove that the new technology works…

If you reduce false positives and the prevalence is low then it likes you are doing nothing. The use of prevalence did not seem to help the radiologists.

The DHS problem with a false negative…the penalty is a lot of false positive

Overall A GREAT Workshop…

Grant is combining models, recon, segmentation.

Patrick la Riviere: Said that having the big play box may not work, believes that small groups with industry is better. Simulations may be the best place to start and then with the real data need to work more closely with vendors. May be able to help

CC Asked for a list of references from all attendees.

Carl Smith: Appreciates the help working with vendors. Hardware is deployed for quite sometime and be able to make current data out there better…

Erik: Has worked with industry and knows what it takes to educate students. Educating PHD students is not a way to transfer technology. Student internships are very useful.

John Beaty: The dialogue has been the most valuable portion of this meeting. The sharing of information has been so valuable. Likes the idea of the play ground with some clear guideleines, no contracts no NDAs a free for all academic ideas and students. NDA stifles communicates between academics and the flowering of ideas are stifiled…nable real academic discussions on the problems.

Tim White INL: Would like to have access to a library of images for researchers. Likes the play ground idea. Simulating the data is problematic, the Zeff and u's are hard to model the data is in the noise…have done MCNP modeling but it takes a really long time…data is the most valuable. A test bed CT scanner w/o all the bells and whistles that can be used to get calibratrin data and data on what ever you want…HEM This is Tyndall. CC: Harry Martz CT company at LLNL.

Homer P. Can have good and poor simulators. We have modeled the Siemens CT medical scanners. These models have been used to design new CT scanners and they have been used to devlop recon and data reduction algos. CC: Should fund a modeling of the CT systems.

Ge Wang: Have a positive impression tat the medical work Ge does will have applications to the DHS problem area. Key issues funding and partnerships. Get more than just the attenuation coefficient and add the refractive/diffractive components as well.

SW Thanks for coming. I learned a lot. It is clear that academia needs to better understand how to work together. The idea of a playground is a great place to start.

Laura Palmer: Works closely with the COE. Doug and Laura's agenda is to develop a basic R&D plan forward. Need to look into the vendor, academic and government partnerships.

MS: How do we inspire the next generation of young people…find the explosive in the suitcase, like US first robotic competitions for High schools…can we do this for DHS? We have created the beginning of a think tank. Meet everything 3-4 months and really become a community…to do this we need to meet regularly talk and build things together.

Think about the follow on workshop in mid August.

22.2 Mariah Nóbrega and Amy Lehrmitt Minutes

DHS Objectives – Suriyun Whitehead

CC: Not everyone knows about the RFI/BAA.

RB: Could we specify between image reconstruction and threat detection algorithms?

SW: Well they do have some complimentarity and overlap, or tradeoff.

EM: They are directly related.

SW: We'd like to gather as much information as possible in image reconstruction. And thus narrow down data in threat detection.

CC: What about the people behind the threat? What I'm asking is, is there a real threat right now?

SW: Right now, the checkpoint is definitely a focus.

GG: How much should we be concerned with sensitivity and specificity?

SW: We have a lot of this data. Threats change and the current equipment has been used for a while now. But this is not entirely about the technology. We must consider the systems and the human factors as well. We have to consider everything. Behavior detection, for example.

HP: How well-defined are our requirements from a checkpoint perspective? For example, chemicals?

SW: It's defining the state-of-the-art.

MS: Really, we're working with a clean slate approach.

BT: It's most important right now to understand the imaging process. More about the system needs to be said.

Workshop goals, deliverables, and process – Carl Crawford

JP: Are you defining algorithms as computer processing to improve screening? Is this the definition we want?

CC: For now, this is the definition. Overall, of course it's more general than that.

SW: So are there threats? We must be aware that even if there is just ONE threat, the impact of that threat could potentially be huge. Constraints are different between medical and travelling cargo and other objects.

CC: Yes, so which is more important: detection or deterrent? These are things we must keep in mind.

KR: I'd like more discussion on RFI. Does anyone have any advice?

JP: Big companies supply software infrastructure for small companies. Note that the RFI deadline is being extended.

MBS: This is a catalyst to put partnerships together. For now, assume that the government will find a way to get it funded.

SS: So in terms of big companies and little companies, we also have to remember that third parties could be big.

CC: People other than these can get into the process too. We don't have to assign them these adjectives.

HM: In terms of the third party, most of these people are not in business with us currently. So how do we attract them?

--: What expectations does the government have?

HM: Look at the reconstruction results. These are things that are certified by the government to be sold. Can they partner with academia on this?

CC: All of these are admissible. Not necessarily transportable.

--: The medical market is mature, but we are evolving. How does the ecosystem of the medical community look?

CC: Collaborations have been formed. More information is needed upon evolution in terms of hierarchy and stages.

CS: A medical reader only uses parts of the information gathered.

BT: There is also a difference to be noted between reconstruction algorithms (which are mainly mathematical) and reconstruction method (which combines the algorithm with more things).

Overview – Jason Martin

CC: Who pays the vendor?

JM: PSP.

SW: But to be clear, the process is S&T has R&D objective, TSL certifies, and TSA buys it.

CC: Are you networked today?

JM: Some are, most are standalone.

CC: So it would be better to be networked.

AH: Where are we on the pendulum?

JM: Back and forth.

ML: Do you see any opportunities without improving technology?

KR: Would you open up equipment on STP to allow vendor communication rather then just authorized communication?

JM: Yes.

ME: How many scanners?

JM: 2325 by 2014.

GG: But it's not that many.

ME: But they're scanning every 2-5 seconds.

CC: Hundreds of millions of incidents.

JM: We're also looking at not just us but foreign governments, CBP…

GG: Is there a data storage aspect?

JM: There are privacy concerns.

SW: We do studies in laps/airports to see the prevalence rates. But it's too much data to handle. But we will be making data sets available for researchers.

JM: Whole body imaging has mid to high 90%. So convenience is a factor.

SW: There was a regular v whole body imaging choice, and people opted for the faster line.

Conversation about CAPS

ML: Is there a different algorithm to run on people?

CC: It's in lace in Israel. But there's a FA rate that's higher and goes slower.

ME: CBP using stress detectors to detect drugs/currency.

HM: Ethnic groups have higher cancer rates, is that accounted for?

HP: For cardiovascular disease, yes.

AH: Is reduction in cost important?

JM: It's not the most important thing, but it's a consideration. In the beginning, we weren't under FAR but now we are.

AH: Are your staff costs larger than equipment?

JM: Not for me, but I don't pay for TSOS. I have about twenty on staff.

BT: What is your sensitivity?

JM: There is room for improvement.

CC: Specificity for checked baggage is at 80%.

BT: Other modalities used in BC: where are they in baggage screening? Also, how do you deal with radiation dose?

DI: Are there whole body imagers with ionizing radioation?

OAK: Yes, in Phoenix.

Overview – Matthew Merzbacher

MBS: We should take advantage of synergy between corporate health care and GE.

MM: If people come to us, we can establish these partnerships.

SW: IHE (Integrated Hospital Enterprises) is part of DiCoast (sp?)

--: We must also differentiate screening (typically when asymptomatic) from diagnostic (asking the "what is it?" question)

--: The point of screening is to get rid of people without problems from the picture.

--: Why would all this information (eg, age) be included?

--: It's a way to exclude and trim parameters.

MM: Security can help medicine here.

CC: What are the problems?

MM: We don't have the details currently. Typically, they are fieldability issues.

MBS: What modality?

MM: Millimeter wave.

MBS: Not nearfield imaging?

MM: No.

MBS: What frequency?

--: 94 gigahertz, passive.

MBS: Are you looking at edges? Or metallic content?

MM: Mainly separability. Edges, distribution of pixels, etc.

MBS: I wonder if you can see it well enough with millimeter wave.

CC: Does GE need help?

MM: Always. We need to knock down the false positives and percentages.

D: How do you present the images?

BT: Is this dual energy?

MM: We're not there yet. It's single. We're using density. We're wanting to work on false positives at this time.

--: You haven't implemented dual energy. Why?

MM: Detection algorithm uses a scanner that was mono-energy.

--: It is computing?

MM: It's cost. It's coming though.

Reconstruction – David Schafer

--It's a geometric approximation of the real object. Basically, if you took cone beam data and ignored the cone beam. The sliced plane in tilted to approximate the data. It's fast but approximate, so there are inherent errors.

CC: Is this sufficient for images?

DS: They're certified.

--: What exactly makes a certified scanner?

DS: There are standards for the automatic detection part of check baggage. These standards include determination of certain explosives, false alarm rates, and throughput. It's a human-out-of-the-loop device. There are thresholds for all those things that you have to pass to pass the test. You don't even need an imaging system for that. You have to be able to give the operator something. The image has to highlight the real threat.

RM: Lower than medical?

DS: Yes. Doses are lower. Objects are bigger. Typically, millimeter in all dimensions would be common. The image here is a nylon phantom.

DS: Objects are not well-known ahead of time, unlike those in the human body. Scatter rejection algorithms will benefit.

--: Backscatter is 2-D?

DS: Yes, this is 2-D.

--: This is active. Don't know the areas of opportunities for reconstruction.

DS: The target problem is cost and volume of data. Threats change with time and could be smaller than detection size. When detecting and connecting things together, algorithms may not present them as separate objects.

--: We need wider boundaries on parts of the same object.

Automatic Threat Detection – Sondre Skatter

CC: What are special cases?

SS: Spectral configuration that the algorithm misses. Like a blindspot.

CC: So you have to know what the machine is doing?

BT: You need to have sample data. With TSA, you have that standard object for a ROC curve.

CC: Some exist and some do not.

SS: It's very resource-intensive.

CC: Is it better to fix algorithms and have better construction or get better detection?

BT: Detection and identification. There are several levels.

CC: This is binary. It's threat versus no threat.

BT: Resolution is better for identification. It just depends on what you want to do.

HM: From optimization, it's useful to understand the certification test.

CC: So third parties couldn't play in the physical knowledge area?

SS: It would be hard.

DS: It seems you would have to be in that box WITH a vendor.

BT: Method has an algorithm. If you want improvement, you need knowledge of the sensor.

MBS: With model-based reconstruction, you know the background model.

--: I disagree. You model would accurately predict.

--: Model is anything to help you predict the behavior. It doesn't have to be so sophisticated. Simple ones can give plenty of sophisticated information. Incorporation of the model can use iterative algorithms or not.

BY: But what kind of model?

CC: There is the need to satisfy the customer.

MBS: The military does this a lot. Medical too. Can we come up with specimen training to compare? Can we create a "gold standard" to create a valid comparison for benchmarking?

MM: It's expensive and rare.

CC: DHS has this is mind and has data sets in process.

EM: That would be very good. It would create a reference point.

CK: Formed image chips were available, but not great. Later they released raw phase images, which made a huge difference. The challenge is it's not enough. You need good characterization of the sensor.

Emerging Technology – Richard Bijjani

CC: Do x-rays detect explosives?

Are these images typical?

--: The point is, you need data, problems, and money.

Surveillance and Human Factors – John Pearson

SS: So threats don't happen often enough to be able to detect them?

JW: If you don't find it often, you often don't find it.

MM: Is clutter index for the whole bag?

JP: Yes.

MM: Did you track this over time?

JP: We haven't looked at that. It's still preliminary/

CC: How do you get better operators from the clutter algorithm?

DAC: Is J&D primarily 2-D?

JP: It's 2-D static and 2-D video.

CC wants presentations by next Wednesday.

Reconstruction – Clem Karl

CC: The limitation is the different modalities.

CK: Discussion was mainly on CT reconstruction. We didn't really mention millimeter wave.

MBS: Multisensor or joint inversion would be a fundamental strategy. One sensor can't do it all.

CK: Well, as I said, we focused on CT, but there are certainly possibilities there.

MBS: The more a priori information, the better.

--: Physics-based inversion is becoming a larger issue.

CC: If automatic threat detection mimics what a human does, you should still optimize for human display.

MM: And emphasize distinctions the human can't detect.

CK: It's not clear when you're designing the scanner what will be best.

JW: You wouldn't present raw numbers to the human. It would be something he could process.

CC: Your system model—the vendors have to participate. Are they willing?

CK: There's a middle path. DOD had the same problem.

MBS: There were journal publications showing progress.

CK: DOD put out channel projects. The government created the target.

--: They've also not done well with data release and support.

KR: Often, time/market pressure is the problem with vendor relations.

JB: We have two models: 1) contractual model of where things work – a non disclosure agreement, etc. 2) best final outcomes provided. This is more fruitful. It shows what their model can provide to commercial industry.

BT: In the beginning stage, system modeling helps. In the second, you're going to do that in real life. And in the third, you have the company you want to work with.

CB: Great specificity is missing here. What can be used? Is there potential for scatter to differentiate materials?

--: You can use coherent scattering.

SS: You can have a separate sensor.

CC: Conferences are typically recommended. Would you recommend, for example, IEEE meetings?

CK: They're good if there's money in it. The other thing is research. You need a broader base of involvement.

--: It's great to have a central suppository. A database. Always send the link.

--: The technology for that is RSS.

--: ALERT should be at the center of this. With some filter.

MBS: Do national labs have simulations of these scenarios for the underpinnings of a playground?

HM: We don't have object models, but we have radiographic models.

MBS: This could be a vehicle for working together. Create these simulations to get this valuable artificial data.

MC: There's a difference between a playground or forum and something that would cost money. Do we have that? If not, we do. You can have a workgroup go in there and play around. The money thing is a different question.

DAC: I don't like the idea of simulation. In my experience, they don't get used.

CK: It's more controlled.

DAC: What would you change?

CK: With a challenge scenario, get some data sets, and share the data sets, not the simulation.

--: What about the model?

CK: Absolutely.

--: Could we have model and image standards?

HM: Simulations only bring you so far, but then you get to the real data.

CK: I wouldn't stop at simulation either.

CB: This would allow play with new sets of geometry.

CK: It's a process, not an end result. There's a dialogue. You get feedback and do a second round.

--: I'd like some short-term wins. Most benefit would be a two-prong approach.

MM: They could even be small problems.

--: Like dropping the false alarm rate.

JB: The long-term goal is research. Right now, you need to the dialogue.

RB: We have bags we scan for finding false alarms.

--: Is there a well-known CT for reference?

Automated threat detection and fusion – Sondre Skatter

RN: DOD database is a well-defined scene. This is different. Targets aren't well-defined. You need expertise and understanding of how the image is acquired and what is acquired.

--: I still recommend sensing targets for shape.

SS: You don't want to be too biased.

RB: Real problem is you have to share your vulnerability with academia. And this is highly classified.

DAC: 1) Almost no data is released without authorization. 2) Almost no vendor releases data.

RB: With regionization, the challenge is how do we get them that data?

JB: Fundamental science is the density-z problem.

Classification discussion

--: If you want it, you have to figure out a way to release it. There is a forum that will do that.

SS: Stream of commerce is the biggest problem. It's less sensitive.

MBS: The gaps are 1) technical (wishlists of what we'd like) and 2) logistical (how do we play together without compromising security?).

CC: I expected more about technical gaps. We want examples of what can help to get funding.

--: There was segmentation.

CC: What is the return on that project?

--: Reducing the false positive rate by a percentage.

CC: Could metric come up?

--: There would have to be work done. And industry involvement to find examples of segmentation problems.

DAC: The grand challenge is targeting technologies.

TG: Problems are the need for automated detection. TRX is on the way out. It's being replaced with AT machines. The other problem is whole body imagers. What we want is automatic clearing of nonthreats.

JW: What is the benchmark for a clear? Are threats going to get through?

TG: Benchmark is the same level as humans now.

JW: Same or different kinds of errors?

TG: First off, do no harm. The hardware may not be purchased for at least five years.

MBS: If you gave us the interface, is this valuable?

TG: Absolutely. But I'm not able to do that. We need to dovetail these things. I'm focused too short-term. Hopefully ALERT can support this.

MBS: Developing data sets could be a deliverable. Can you support that?

TG: Sure.

SW: I'm focused on the long-term. Which would be basic research.

MC: You're talking about access to expertise. It will provide access point for short-term needs.

MBS: Yes, it would serve both short and long term.

TG: There is no general outline. There is a shift going on right now from short to long term.

Emerging Technologies – Richard Bijjani

MC: So, an SBIR model?

RB: Phase two becomes industry.

MC: That's usually phase three.

KR: Vendors like being involved when there's a problem. It guarantees research goes in the right direction.

MM: Industry is the tech advisor early in the process, and transitions into the procurer later on.

M-: The question is what and how.

LP: We addressed vendor point of view of short term, and academic technology for five years out. The interplay of how to get them to work together came out more then emerging technology.

KR: Were they any?

RB: What does this mean to academia?

CC: What are the incentives?

RB: Allowing high risk R&D. The incentive is procurement. That's the money.

Surveillance and Human Factors – John Pearson

RM: Is the J&D model extendable in this direction?

JP: It could be.

MM: Is it better to have screeners specialized in different things to divert them to specialists or otherwise?

JW: We don't have an answer with screeners. In radiology, there is a role for expertise. It's trickier in this realm. The most interesting task is finding some threat first.

CC: Can you clear a portion of a bag? EDS is looking for detection, not automatic clearing.

JP: Then you could apply that to the reader so they can only look at the questionable part.

MBS: If you don't trust the machine, you're not going to use it.

JP: Currently, data is lacking.

MBS: We need data sets for these algorithms.

M-: What's better with a human in the loop? Greater detection or lower false alarm?

--: That depends on your second system.

--: Well, assume it's the human.

--: The first one then.

M-: Industry has moved to lower pd and lower false alarm. It gets rid of the need for humans.

CC: Automated threat detection costs $x/yr. If the system is better, you save money.

BT: There are two tiers: screens, which has bad specificity, and secondary, which is more expensive. Is this worth it?

CC: Whole body imaging is another emerging technology.

Panel Discussion: David Castañón

MBS: I couldn't agree more about the sandbox.

CC: How big? The point of this workshop is to make the sandbox smaller.

DAC: It would be a different model that would help people. For example, to bring a thz imager in.

CC: More meat on the definition of the playground.

DAC: Not enough time right now. We'll discuss this later.

Panel Discussion: Mike Lanzaro

Time frame: 1 -> 10 -> 15 yrs

Roadmap difficult to build without going into more details on problem technologies.

DHS/S&T are facilitators in roadmap to align industry and academia.

CC: What do you mean "if we were all aligned"?

ML: We had feedback that trace was viable but when we had something to go on, there was no interest.

JC: We had this happen where someone wanted something and then when we came back six months later, they didn't mention it again.

CC: But the point is that S&T wants transformational. They want to know what you can do.

JC: But we want to know shorter term. Eg, is the most immediate need to take off shoes? What about more long-term, concrete examples?

DG: I hope the roadmap narrows the scope.

JC: Certification standards. Standards 1, 2, and 3 in Europe.

The level of standards was very clear. Eg, "I need to stop doing shoes by…"

Panel Discussion: Michael Ellenbogan

ME: We have people tell us that TSI is interested; it's their job to be interested. If there's no mandate to do it, there's not enough interest. Follow the mandates. Follow the money. Roadmap: bad guys have a roadmap too and the two don't track. The roadmap is only valid until a 45 degree attack.

More people, more quickly, more securely: everyone has different opinions about which is most important.

Shocked we don't know whether 90/20 or 40/1 is better.

If you've seen one airport, you've seen one airport. There are 429 airports; 32 layouts.

Database of capabilities

MBS: DHS might have fewer lanes than there are CT machines but the hospitals aren't direct funding agents.

CC: How do you figure out where the 5% is?

ME: It's hard. [example of NQR] You need to evaluate the sensors. It can't fry the electronics.

KR: To find out the 5%, talk to us and hear the lessons learned.

CC: Are you willing to talk about the problems with scanners?

ME: We can't talk about what it can't do. We talk about challenges facing the industry.

Discussion Panel: Harry Martz

--: Quality testing is done with humans in the loop.

SW: System to system technology is definitely a strong focus to DHS. We have datasets for whole body imaging on a variety of systems at Sandia.

Closing Comments

KR: This has been very valuable. We have many similar technologies and problems. And we partner with third parties and academia and would be happy to partner with new relations.

BT: How do we participate in this industry with industrial partners? We primarily image humans and are interested in full body scanning if applicable.

GG: We'd love to pull all this into one algorithm. Seems more possible in the medical field.

PLR: Still dubious of playground model. Individual academies working with individual companies would make more progress on the imaging front. We're just reluctant to reveal that information, in my experience. There's room to work on simulation at first. It would help if there were some real parameters.

CC: Could you provide a bibliography?

PLR: Yes.

CS: Short term focus is how to get information that you want out of sensors. Management of data is something ALERT and the government can have a role in.

CC: Could you bypass to work directly with academia?

CS: We work with both research and vendors.

EM: The playground is good for grad studies. May migrate ideas into industry. Would require collaboration or creative exchanges. Educating phd students is not the way to do this tech transfer.

JB: Dialogue has been valuable. The playground: I believe in it. It should be a general implementation description. No contract. Page needs open dialogue with general intellectual discussion. This will help all vendors and get the most important thing: students.

TW: We should have a library of data to show off the problem. The playground is a great concept but simulating data is a problem. Have a testbed that is well-characterized can generate real data with simulated threats.

HP: 1) Playground: You can build a good or bad simulator. Ours is a good CT scanner. 2) It takes time to get used to new domains.

SW: The questions are: how do we work together? How do we get the data? Etc. The idea of the playground is a great place to start. Siemens is building a simulation.

LP: 1) We want to develop a structure for ~5 years in the future. These workshops help. 2) Academia-industry-government collaboration needs more insight.

MBS: Another question: How do we inspire the next generation to be engaged in this field? An idea is a video game like a stimulant. Can DHS sponsor competitions that would inspire students? That's another adjunct of our playground. Here, we've put together a think tank. We should meet every three to four months and become a community to share ideas and build things together. We will write up this report for follow up.

23. Appendix: Presentation Slides

The slides from the presentations are attached according to the following table.[14]

Session/Talk	Speaker	Notes
DHS Objectives for Workshop	Suriyun Whitehead	
Workshop goals, deliverables and process	Carl Crawford	
Overview of Integrated Check Point Algorithms: Issues of today and tomorrow	Matthew Merzbacher	
Reconstruction: State of the Art and Issues	David Schafer	
Automated threat detection and fusion: State of the Art and Issues	Sondre Skatter	
Emerging technologies: State of the Art and Issues	Richard Bijjani	
Surveillance and human factors: State of the Art and Issues	John Pearson	Overview and breakout summaries combined.
Instructions for breakout sessions	Carl Crawford	
Reconstruction: Gap analysis and technology roadmaps	David Schafer	
Automated threat detection and fusion: Gap analysis and technology roadmap	Sondre Skatter	
Emerging technologies: Gap analysis and technology roadmap	Richard Bijjani	
Surveillance and human factors: Gap analysis and technology roadmap	John Pearson	Overview and breakout summaries combined.

[14] Michael Silevitch, Jason Martin, Daniel Kopans and Jeremy Wolfe also gave presentations that were not directly relevant to the final report.

Recommendations for Research Roadmap	David Castañón	
	Carey Rappaport	
	Michael Ellenbogan	
	Harry Martz	
	Michael Lanzaro	

The slides can also be found at: ftp://ftp.censsis.neu.edu/ADSA/

23.1 Suriyun Whitehead Presentation Slides

DHS Objectives

Algorithm Detection for Security Applications Workshop

Suriyun Whitehead

Explosives Division
Science and Technology
Department of Homeland Security

April 3rd, 2009

Homeland Security

1

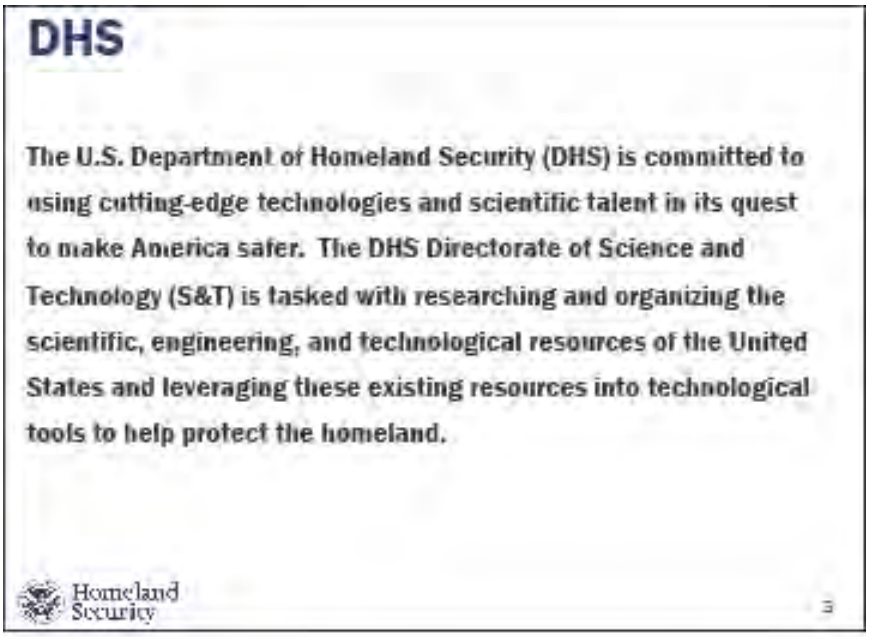
Attendees

- Northeastern University / DHS Explosives Center of Excellence
- Security Screening Equipment Vendors
- Algorithm Researchers in Academia and adjacent domains.
- DHS S&T, TSA, TSL

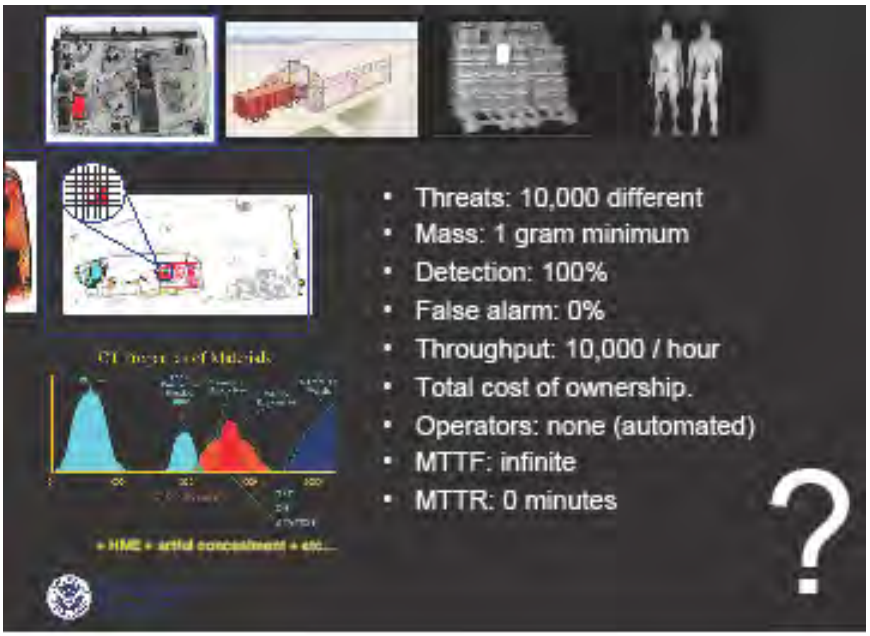
- RFI

Homeland Security

3


DHS
The U.S. Department of Homeland Security (DHS) is committed to using cutting-edge technologies and scientific talent in its quest to make America safer. The DHS Directorate of Science and Technology (S&T) is tasked with researching and organizing the scientific, engineering, and technological resources of the United States and leveraging these existing resources into technological tools to help protect the homeland.
Homeland Security
3

TSA
sets transportation security policy.
establishes the threat list.
sets the system requirements.
establishes the qualification and certification criteria.
acquires, deploys, maintains and decommissions detection systems.
S&T / EXD
sponsors basic research and technology development.
develops enabling technology.
engages in systems studies.
provides recommendations
transitions technology to meet TSA-expressed needs.
Homeland Security
4


• Threats: 10,000 different
• Mass: 1 gram minimum
• Detection: 100%
• False alarm: 0%
• Throughput: 10,000 / hour
• Total cost of ownership.
• Operators: none (automated)
• MTTF: infinite
• MTTR: 0 minutes
?

Does DHS have the "best" / most effective systems in place in order to meet present and upcoming security screening challenges?
What is the best value to the government?
Competition. Innovation. Outreach.
Homeland Security
6

Goals

1. Forum for experts.
2. Introduce the challenge of the security application.
3. Determine detailed criteria to enable meaningful 3rd party contribution.
4. Develop information sufficient for future acquisition.
5. Share examples of independent and creative algorithm development.

Homeland Security

7

Partnership

- Educating Government helps to develop informed requirements and evaluation and acquisition criteria by making available the scientific basis when weighing practical, political, economic and operational concerns.
- Educating Industry and maintaining a viable and robust market space helps to ensure availability of systems, committed vendors, and production capacity to meet Government requirements.

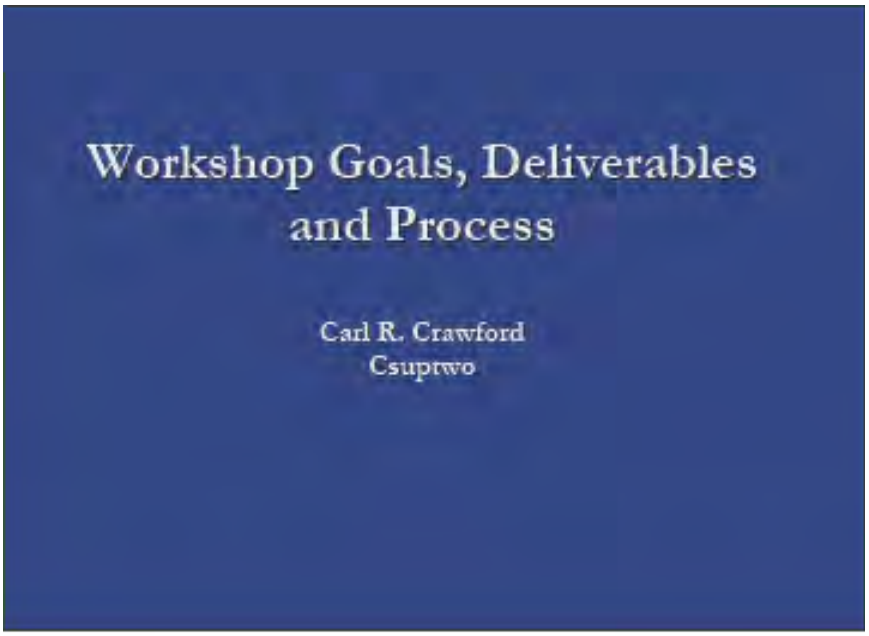
Homeland Security

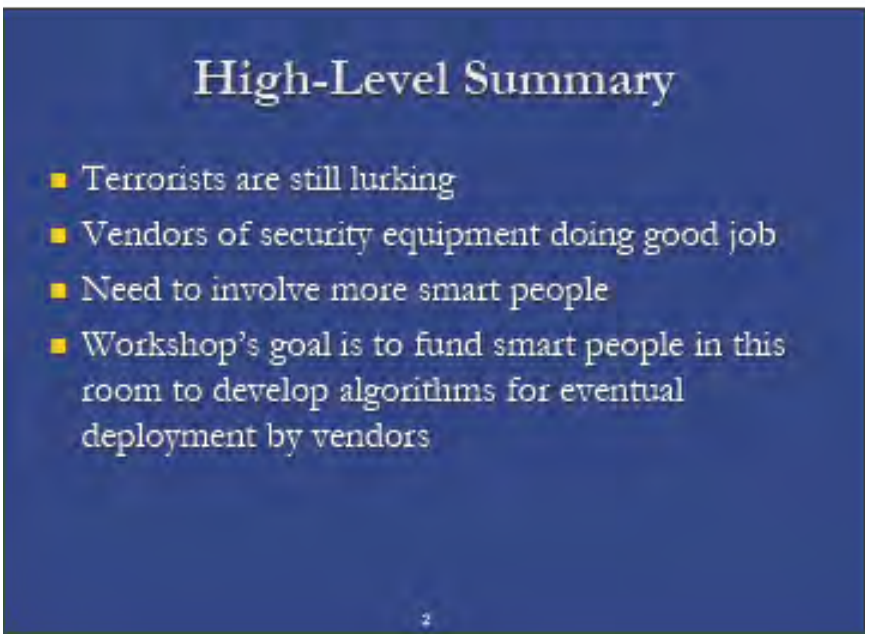
8

1. Create a forum for experts in image processing whatever the application to gather together to exchange technical perspectives on the potential for and challenges surrounding algorithm development and application.
2. The gathering is designed to introduce the challenge of the security application and to assess how independent algorithm development activities might be applied to that application.
3. Determine the necessary and sufficient detailed criteria that an independent 3rd party algorithm developer would need from a hardware developer to be able to develop the most discriminating image of the target.
4. Develop for the government information that is explicit and sufficient enough for its future acquisition on algorithm development.
5. Share some of the creative applications of algorithm development in a non-security application with participants as examples of independent and creative algorithm development.

9

23.2 Carl Crawford Presentation 1 Slides





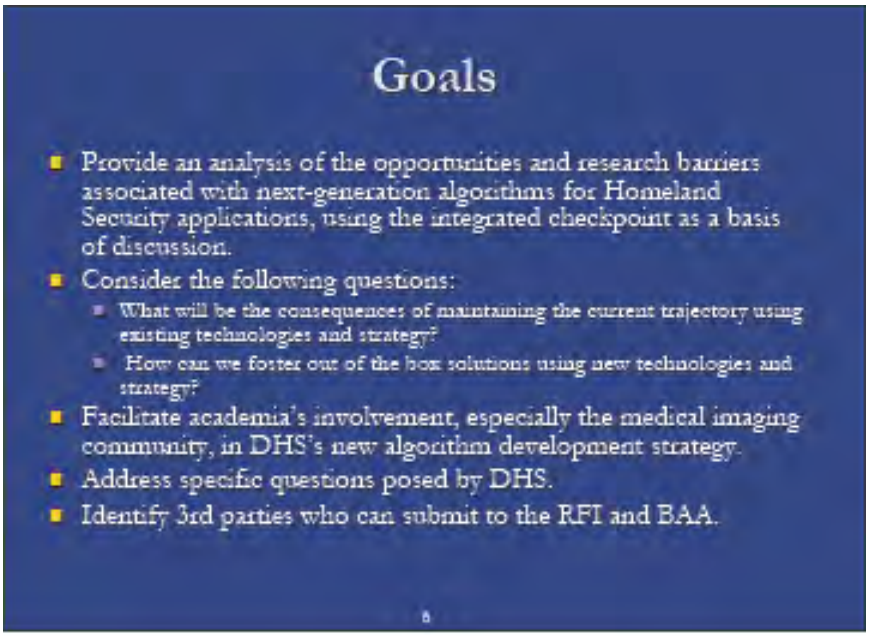
Am I a Terrorist?

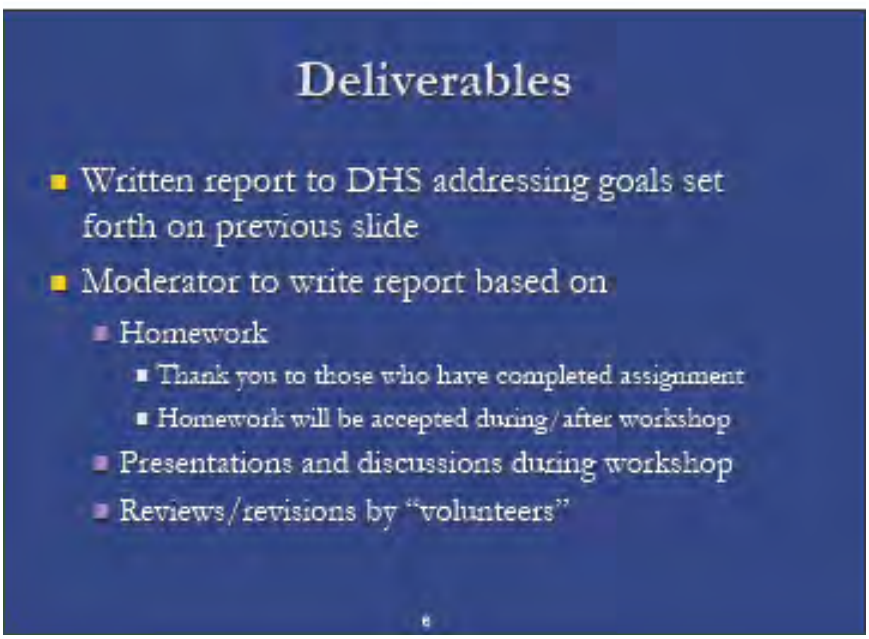
3

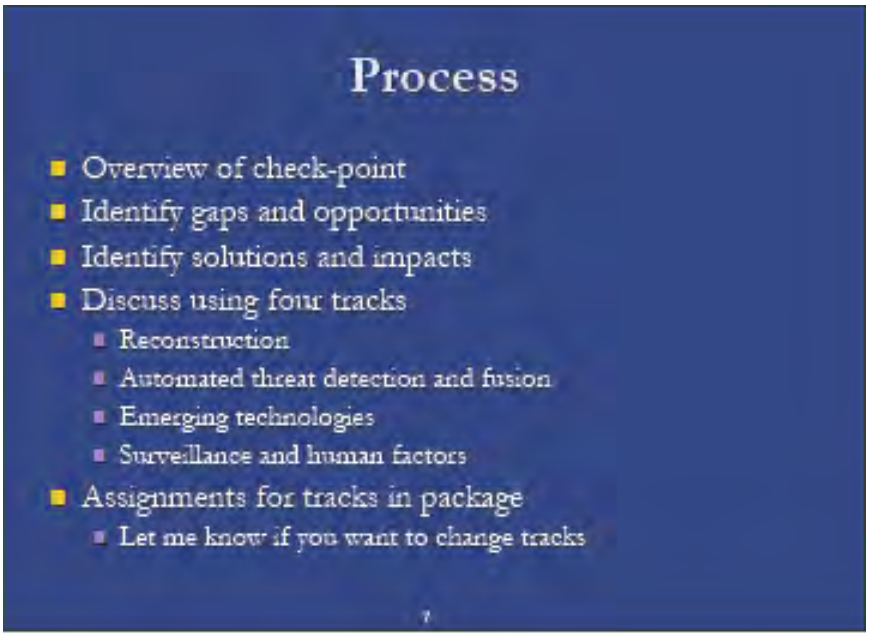
Workshop Definition

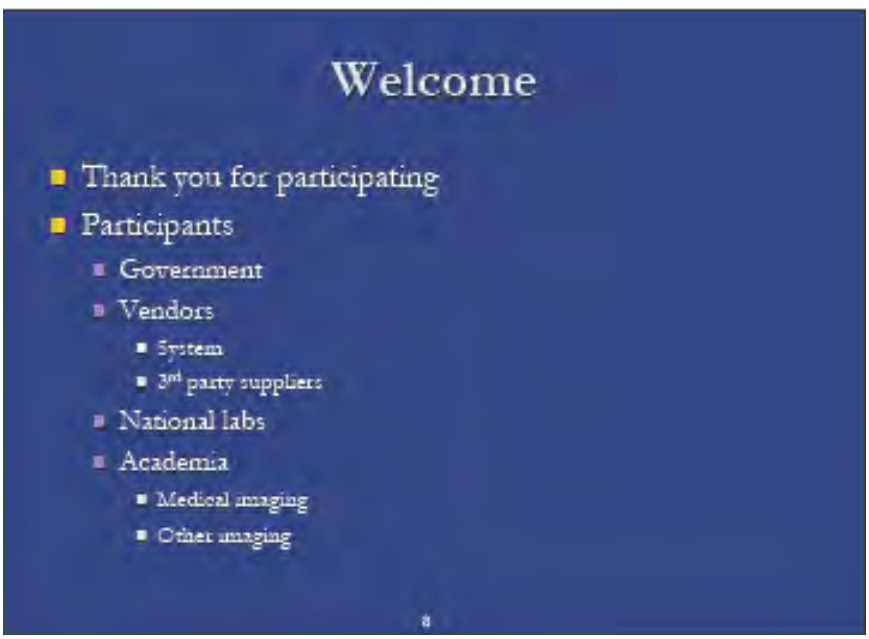
- Not a conference
  - Serial presentation and discussion
- Discussion permitted and required at all times by all participants
  - Parallel presentation/discussion
- Attendance limited to allow discussion
  - Sorry that we were not able to accommodate all interested parties
  - Lay foundation for DHS to involve broader audience for funding

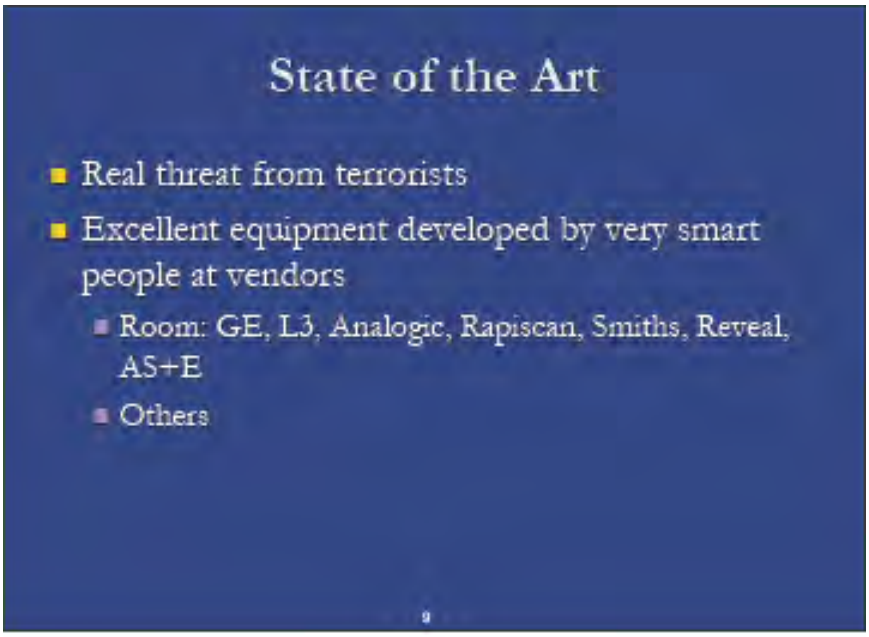
4

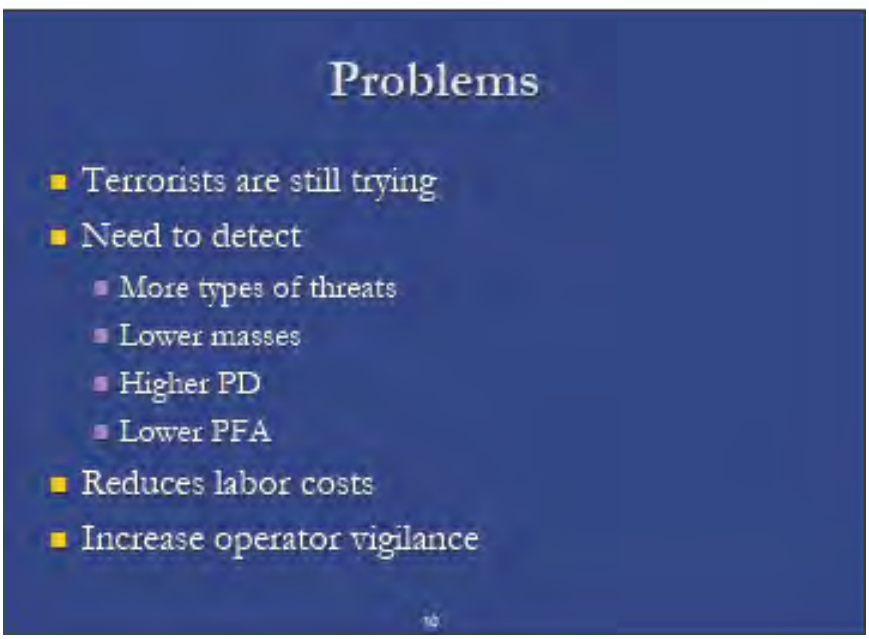

Goals
Provide an analysis of the opportunities and research barriers associated with next-generation algorithms for Homeland Security applications, using the integrated checkpoint as a basis of discussion.
Consider the following questions:
What will be the consequences of maintaining the current trajectory using existing technologies and strategy?
How can we foster out of the box solutions using new technologies and strategy?
Facilitate academia's involvement, especially the medical imaging community, in DHS's new algorithm development strategy.
Address specific questions posed by DHS.
Identify 3rd parties who can submit to the RFI and BAA.
5

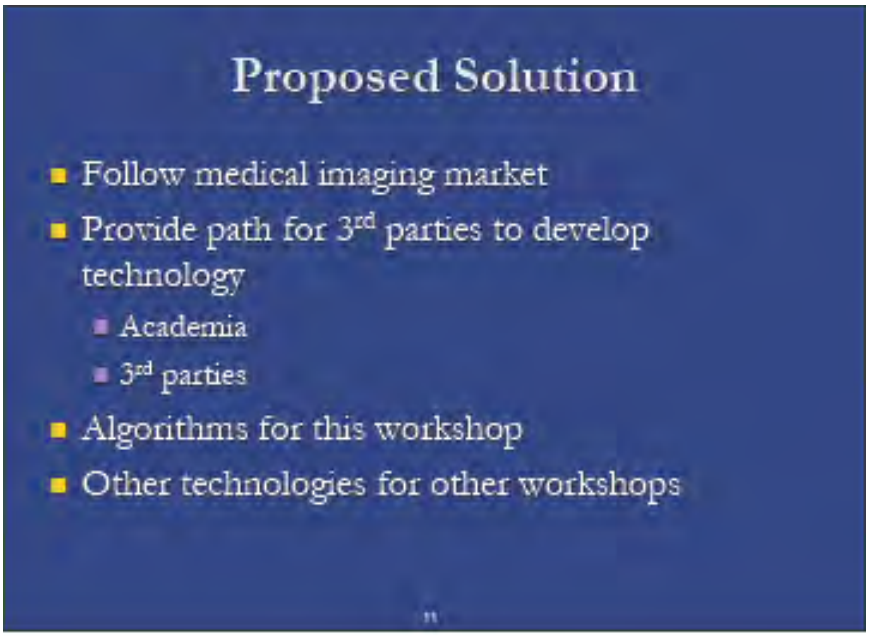

Deliverables
Written report to DHS addressing goals set forth on previous slide
Moderator to write report based on
Homework
Thank you to those who have completed assignment
Homework will be accepted during/after workshop
Presentations and discussions during workshop
Reviews/revisions by "volunteers"
6

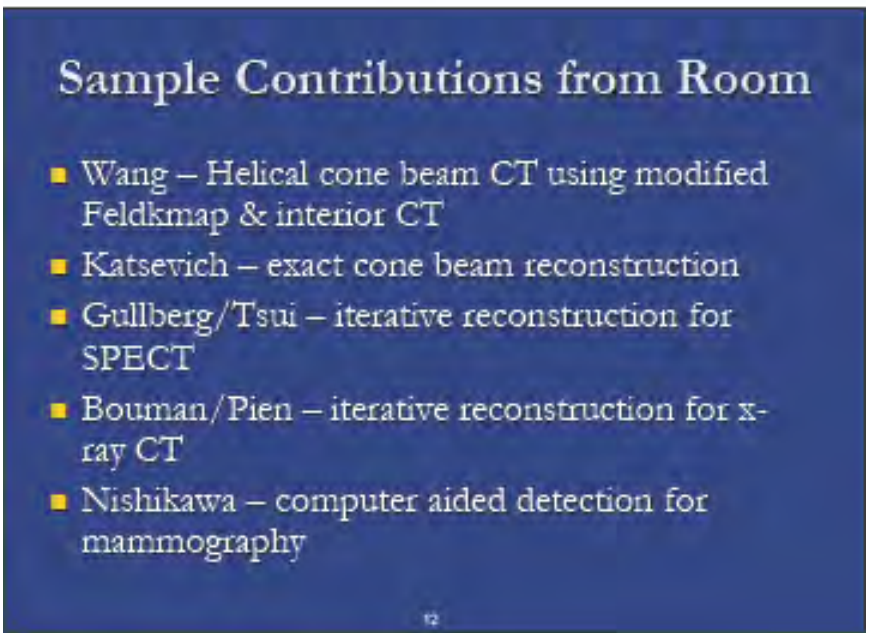

Process
Overview of check-point
Identify gaps and opportunities
Identify solutions and impacts
Discuss using four tracks
Reconstruction
Automated threat detection and fusion
Emerging technologies
Surveillance and human factors
Assignments for tracks in package
Let me know if you want to change tracks
7

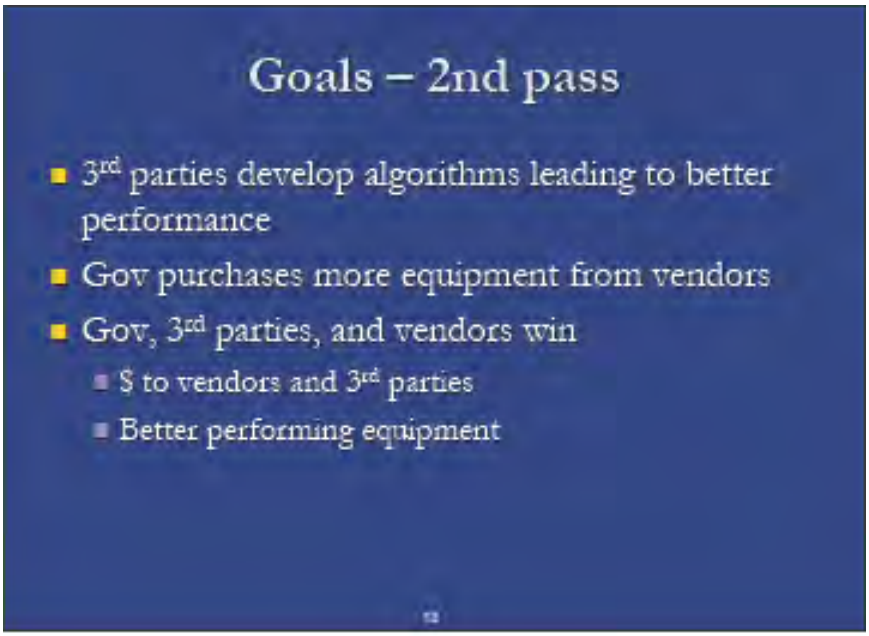

Welcome
Thank you for participating
Participants
Government
Vendors
System
3rd party suppliers
National labs
Academia
Medical imaging
Other imaging
8

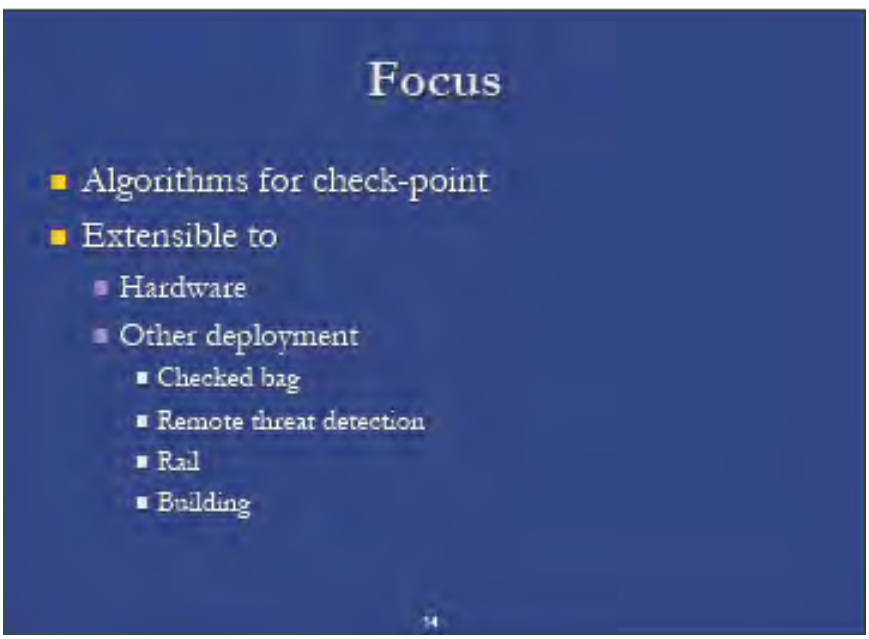

State of the Art
Real threat from terrorists
Excellent equipment developed by very smart people at vendors
Room: GE, L3, Analogic, Rapiscan, Smiths, Reveal, AS+E
Others
9

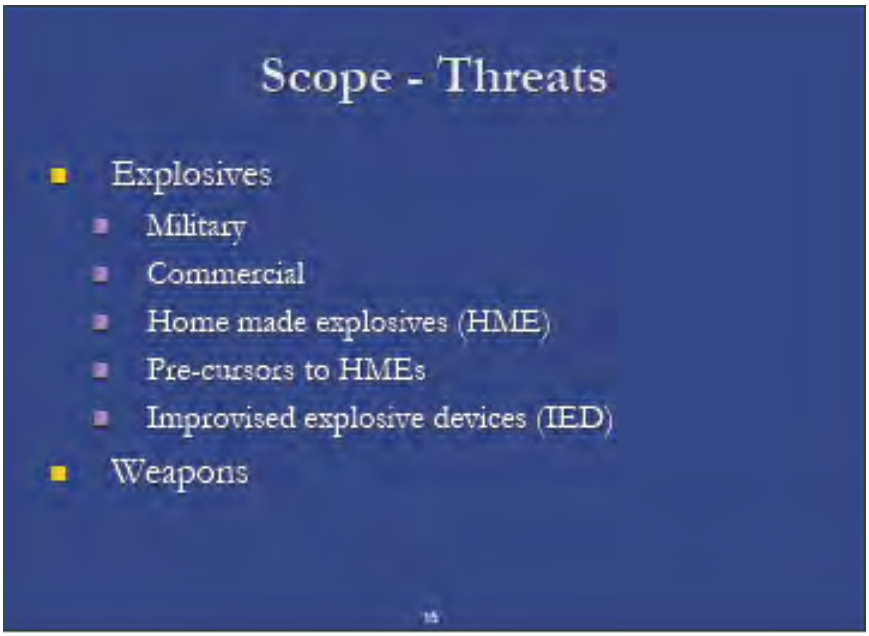

Problems
Terrorists are still trying
Need to detect
More types of threats
Lower masses
Higher PD
Lower PFA
Reduces labor costs
Increase operator vigilance
10

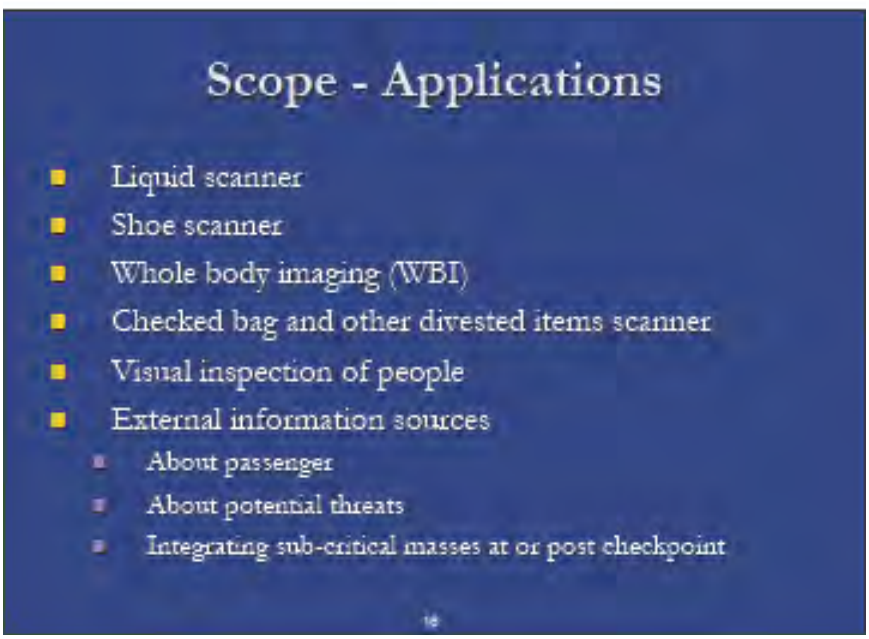

Proposed Solution
Follow medical imaging market
Provide path for 3rd parties to develop technology
Academia
3rd parties
Algorithms for this workshop
Other technologies for other workshops
11

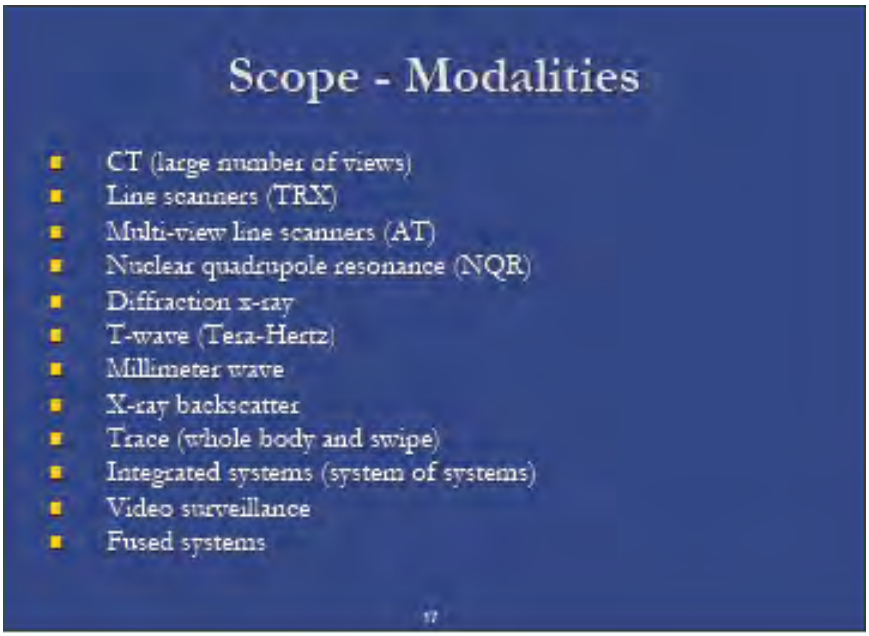

Sample Contributions from Room
Wang – Helical cone beam CT using modified Feldkmap & interior CT
Katsevich – exact cone beam reconstruction
Gullberg/Tsui – iterative reconstruction for SPECT
Bouman/Pien – iterative reconstruction for x-ray CT
Nishikawa – computer aided detection for mammography
12

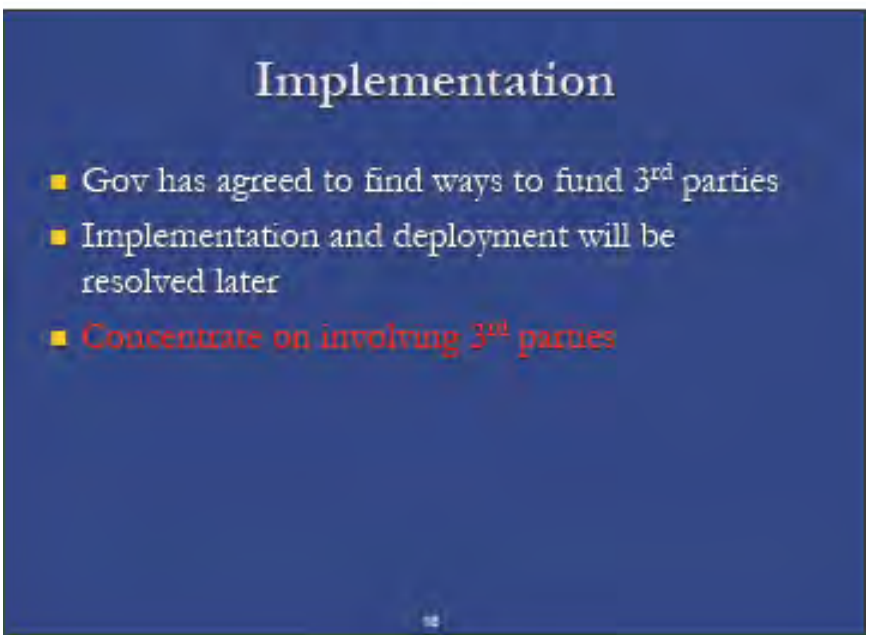

Goals – 2nd pass
3rd parties develop algorithms leading to better performance
Gov purchases more equipment from vendors
Gov, 3rd parties, and vendors win
$ to vendors and 3rd parties
Better performing equipment

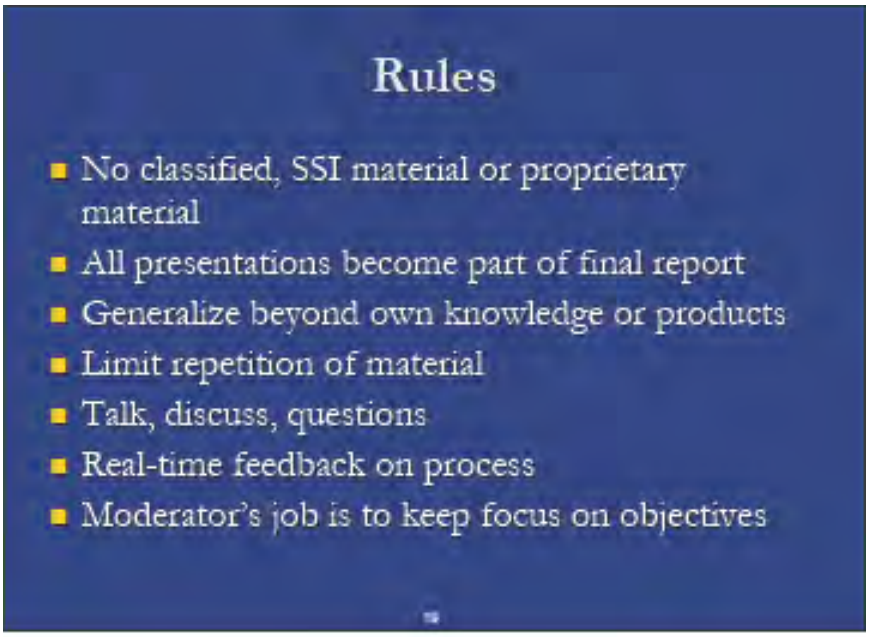

Focus
Algorithms for check-point
Extensible to
Hardware
Other deployment
Checked bag
Remote threat detection
Rail
Building

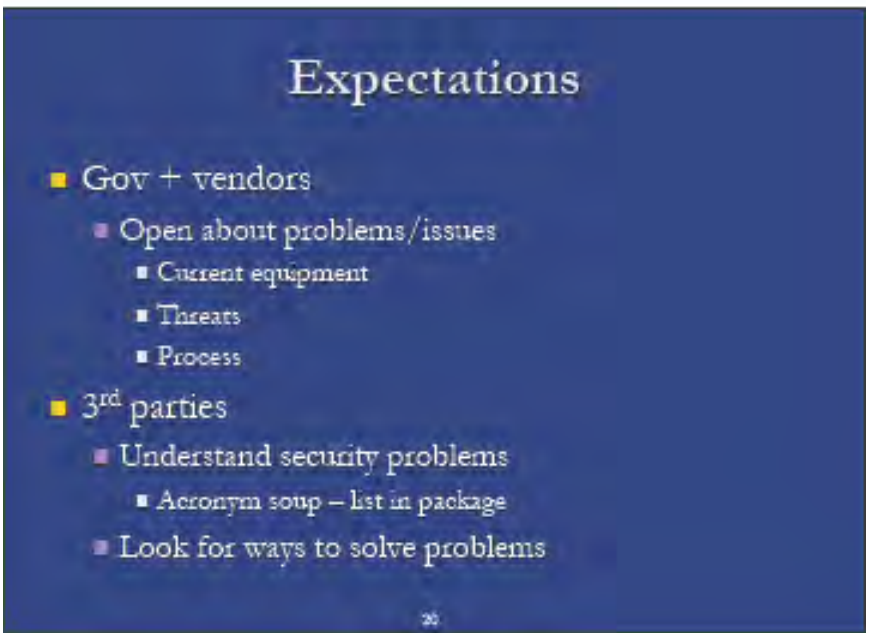

Scope - Threats
Explosives
Military
Commercial
Home made explosives (HME)
Pre-cursors to HMEs
Improvised explosive devices (IED)
Weapons

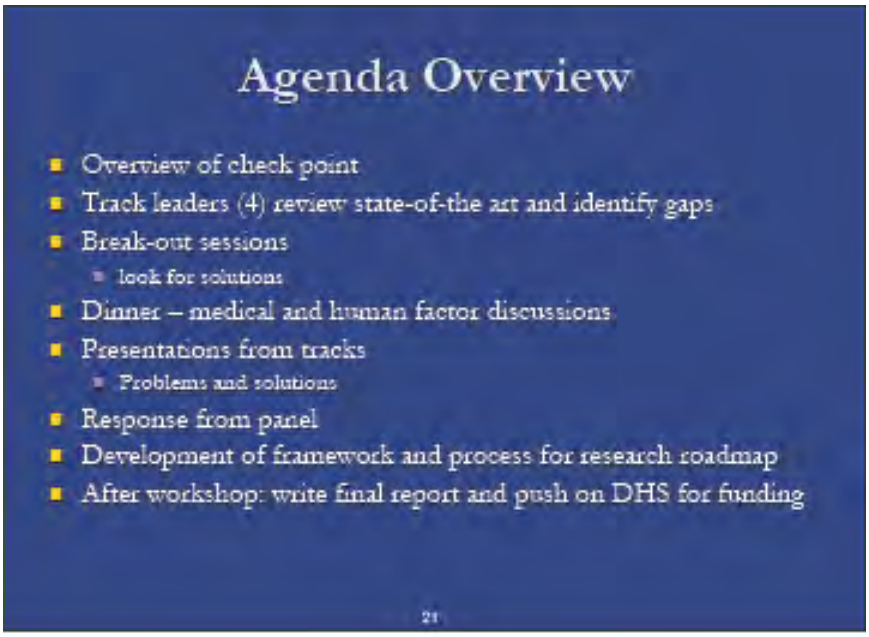

Scope - Applications
Liquid scanner
Shoe scanner
Whole body imaging (WBI)
Checked bag and other divested items scanner
Visual inspection of people
External information sources
About passenger
About potential threats
Integrating sub-critical masses at or post checkpoint

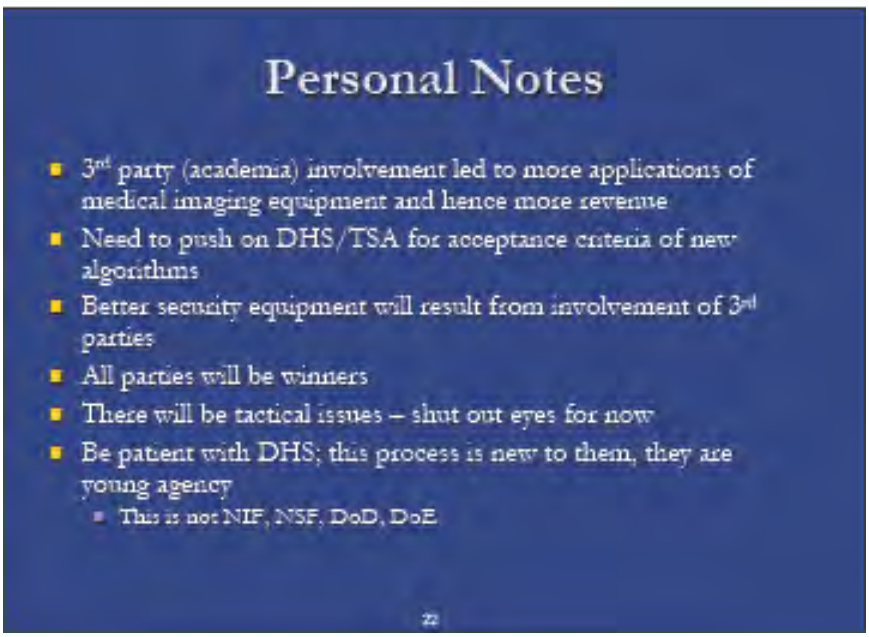

Scope - Modalities
CT (large number of views)
Line scanners (TRX)
Multi-view line scanners (AT)
Nuclear quadrupole resonance (NQR)
Diffraction x-ray
T-wave (Tera-Hertz)
Millimeter wave
X-ray backscatter
Trace (whole body and swipe)
Integrated systems (system of systems)
Video surveillance
Fused systems


Implementation
Gov has agreed to find ways to fund 3rd parties
Implementation and deployment will be resolved later
Concentrate on involving 3rd parties

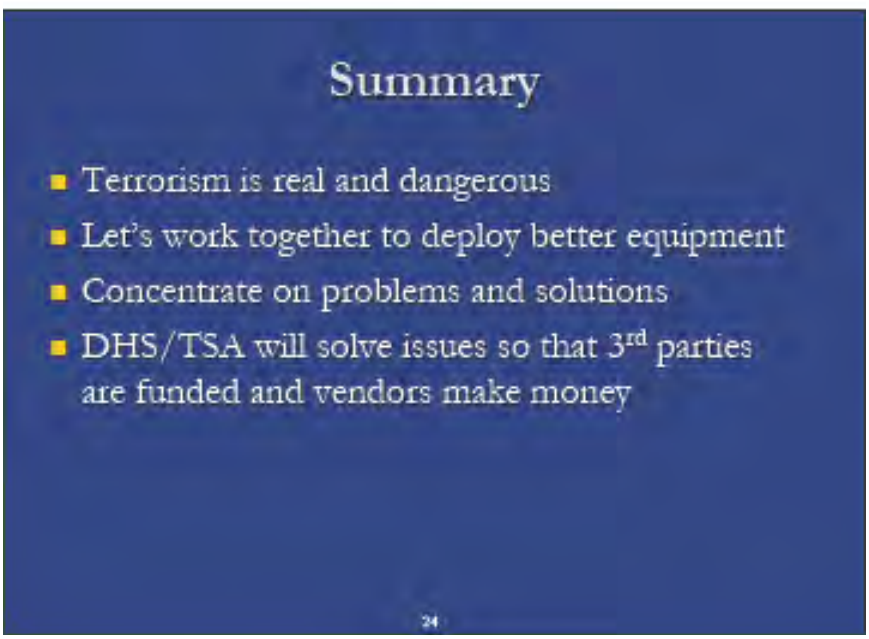

Rules
No classified, SSI material or proprietary material
All presentations become part of final report
Generalize beyond own knowledge or products
Limit repetition of material
Talk, discuss, questions
Real-time feedback on process
Moderator's job is to keep focus on objectives


Expectations
Gov + vendors
Open about problems/issues
Current equipment
Threats
Process
3rd parties
Understand security problems
Acronym soup – list in package
Look for ways to solve problems

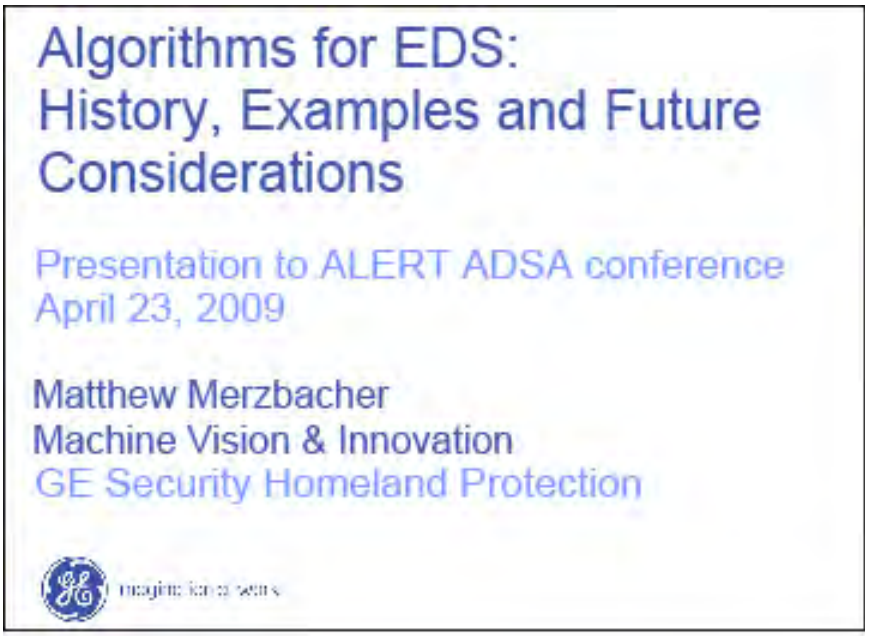

Agenda Overview
Overview of check point
Track leaders (4) review state-of-the art and identify gaps
Break-out sessions
look for solutions
Dinner – medical and human factor discussions
Presentations from tracks
Problems and solutions
Response from panel
Development of framework and process for research roadmap
After workshop: write final report and push on DHS for funding
21

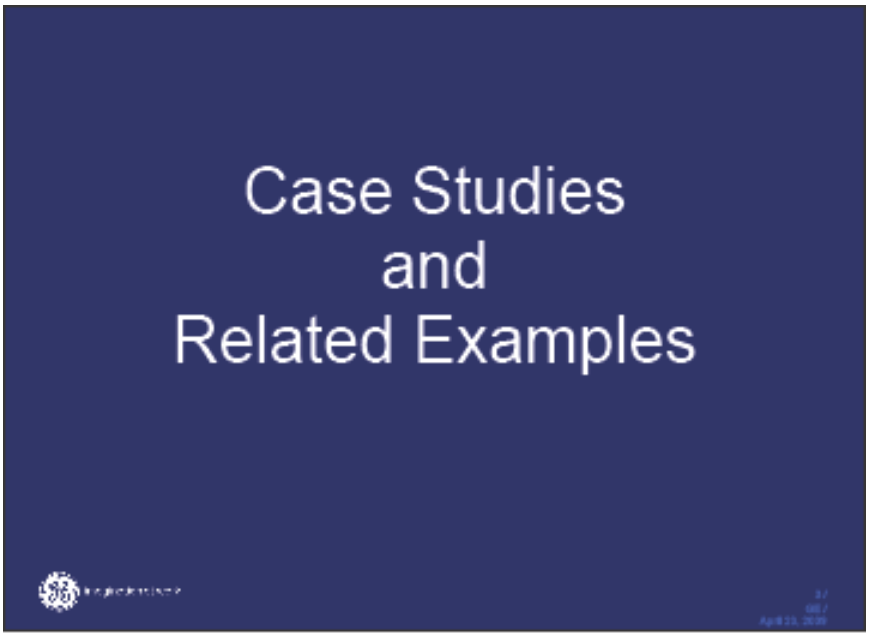

Personal Notes
3rd party (academia) involvement led to more applications of medical imaging equipment and hence more revenue
Need to push on DHS/TSA for acceptance criteria of new algorithms
Better security equipment will result from involvement of 3rd parties
All parties will be winners
There will be tactical issues – shut out eyes for now
Be patient with DHS; this process is new to them, they are young agency
This is not NIF, NSF, DoD, DoE
22

Logistics
Mariah Nóbrega, NEU
Thank you for setting of logistics
Ask her for help
Wifi available
Locals, stay for dinner – working session
Introductions via handout
23


Summary
Terrorism is real and dangerous
Let's work together to deploy better equipment
Concentrate on problems and solutions
DHS/TSA will solve issues so that 3rd parties are funded and vendors make money
24

23.3 Matthew Merzbacher Presentation Slides




Case Studies
and
Related Examples

Case Study:
DICOM & Health Care Imaging

Case Study: DICOM for Health Care

History:

- > 1983: Standards committee first formed
- > Customers not satisfied with proprietary OEM formats
- > DICOM presented as alternative
- > 1990: Six participants in first reported demo at RSNA
- > 1993: Most recent version of standard (3.0) released
- > Pushed by vendors and by customers tired of supporting proprietary formats

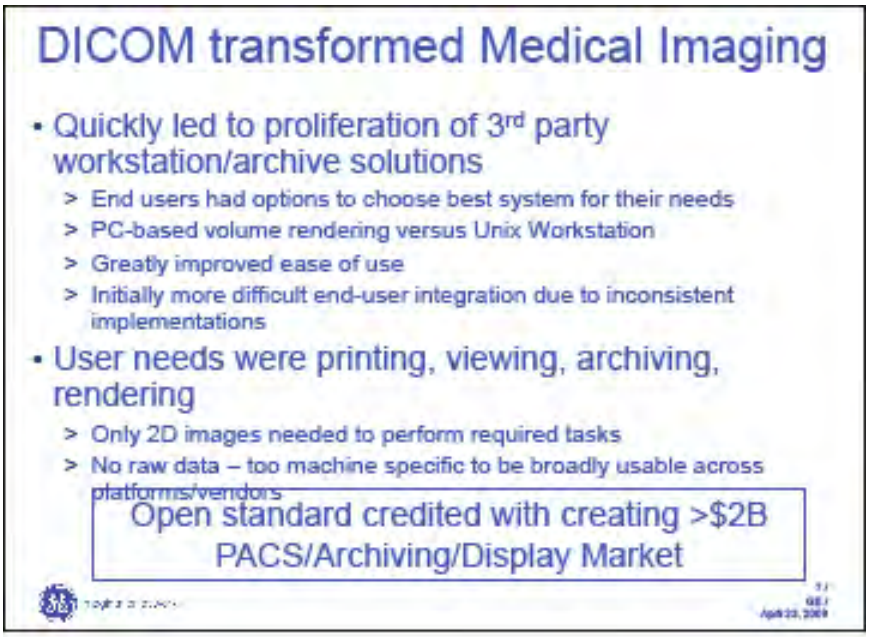
Case Study: DICOM for Health Care

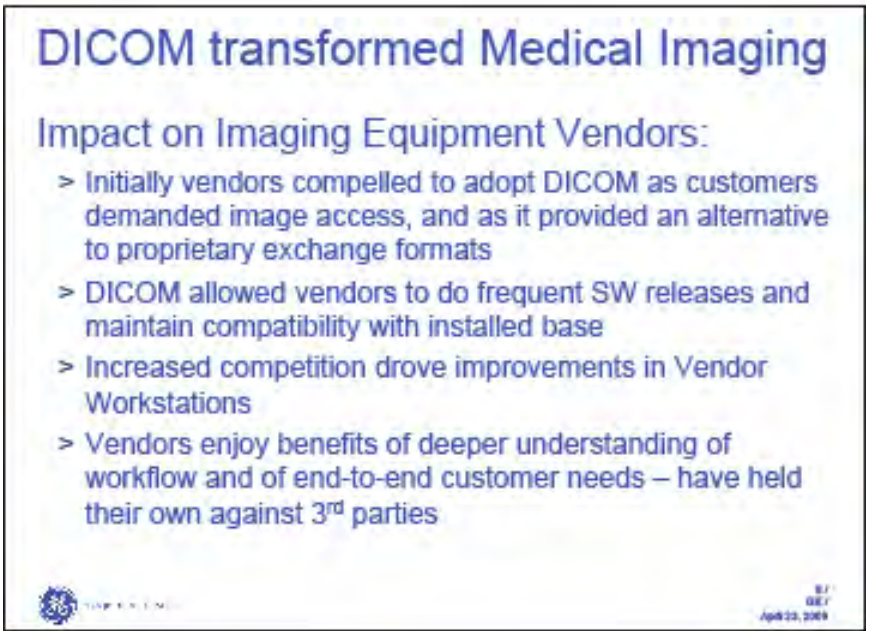
Current standard supports:

- > All medical imaging modalities (CT, MR, etc.)
- > All peripherals (printers, workstations, archive systems)

Who Benefits?

• Hospitals, clinics, imaging centers, specialists	• Ensure all systems work together
• Manufacturers of imaging equipment and information systems	• Ensures that every imaging facility is a potential customer
• Manufacturers of peripheral equipment	• Ensures that products work with all current or future imaging modalities, regardless of vendor.


DICOM transformed Medical Imaging
• Quickly led to proliferation of 3rd party workstation/archive solutions
> End users had options to choose best system for their needs
> PC-based volume rendering versus Unix Workstation
> Greatly improved ease of use
> Initially more difficult end-user integration due to inconsistent implementations
• User needs were printing, viewing, archiving, rendering
> Only 2D images needed to perform required tasks
> No raw data – too machine specific to be broadly usable across platforms/vendors
Open standard credited with creating >$2B PACS/Archiving/Display Market


DICOM transformed Medical Imaging
Impact on Imaging Equipment Vendors:
> Initially vendors compelled to adopt DICOM as customers demanded image access, and as it provided an alternative to proprietary exchange formats
> DICOM allowed vendors to do frequent SW releases and maintain compatibility with installed base
> Increased competition drove improvements in Vendor Workstations
> Vendors enjoy benefits of deeper understanding of workflow and of end-to-end customer needs – have held their own against 3rd parties

Case Study: DICOM for Health Care

Lessons Learned:

> Information model must be extensible – accommodate future modality features and workflows

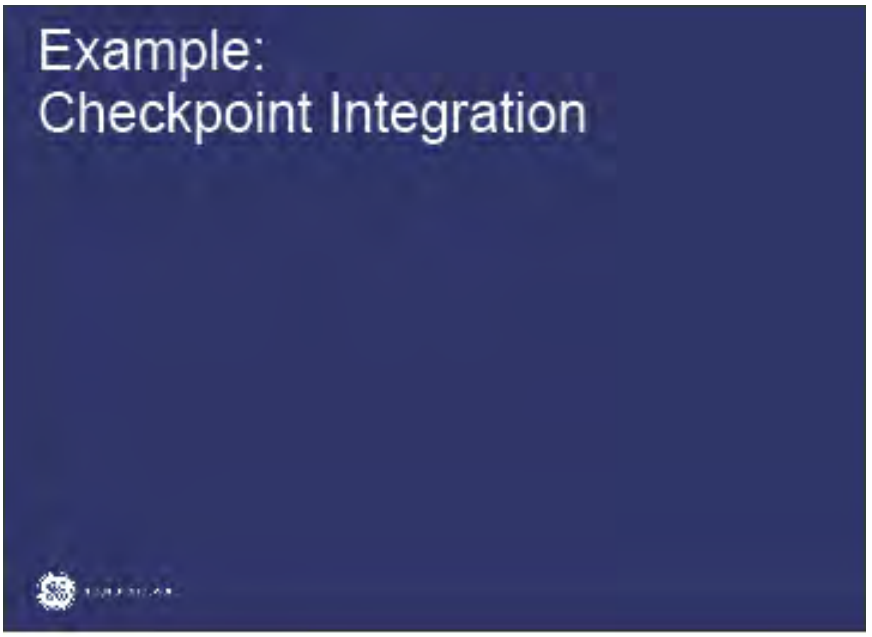
> Data element types must be strictly defined and enforced – otherwise development of performance optimized parsers very difficult

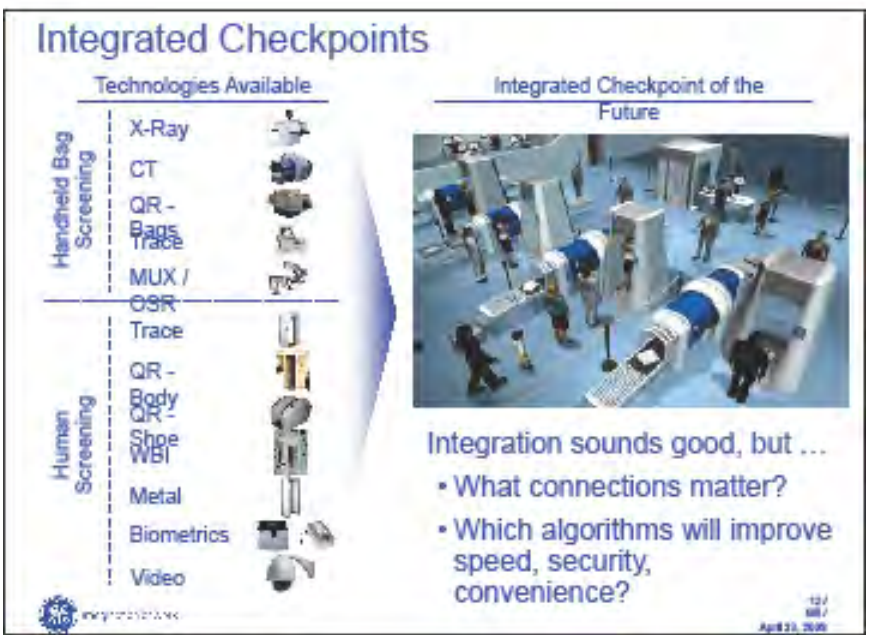
> Service/workflow definition must be separated from transmission protocol definition

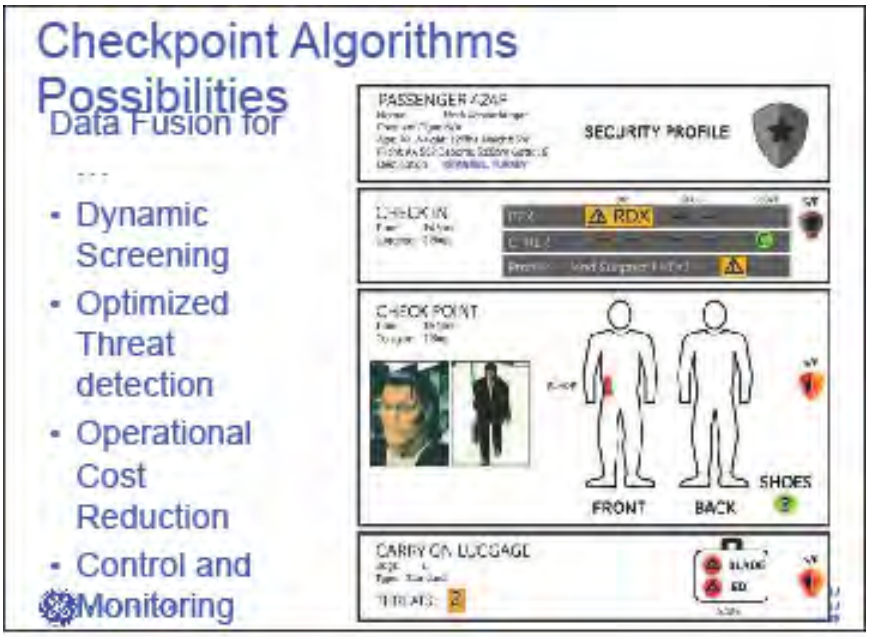
Conclusion: DICOM Case Study

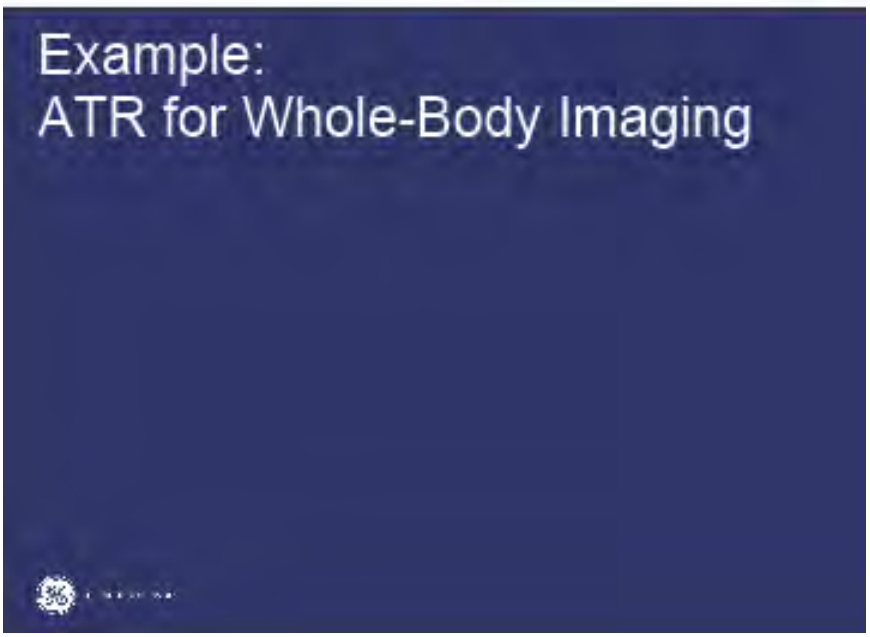
Success Depends on Four "process" pillars in priority order:

1. The users of the interoperability and the implementors (vendors) need to work together to ensure that requirements are clearly understood before technical standards discussions happen.
2. Users need to be engaged in a collective manner to reduce the commercial infighting. Firm predefined schedules are key to prevent the discussions from dragging on.
3. The standards specifications are the golden reference, not any reference SW (which may have bugs or not be faithful to standard)
4. The standards adoption need to be driven by the users, through their organization of testing sessions and demonstrations to engage the buyers and implementers.


Example:
Checkpoint Integration


Integrated Checkpoints
Technologies Available
Handheld Bag Screening
X-Ray
CT
QR - Bags
Trace
MUX / OSR
Human Screening
Trace
QR - Body
QR - Shoe
WBI
Metal
Biometrics
Video
Integrated Checkpoint of the Future
Integration sounds good, but …
• What connections matter?
• Which algorithms will improve speed, security, convenience?


Checkpoint Algorithms Possibilities
Data Fusion for
- Dynamic Screening
- Optimized Threat detection
- Operational Cost Reduction
- Control and Monitoring
SECURITY PROFILE
RDX
CHECK POINT
FRONT
BACK
SHOES
CARRY ON LUGGAGE

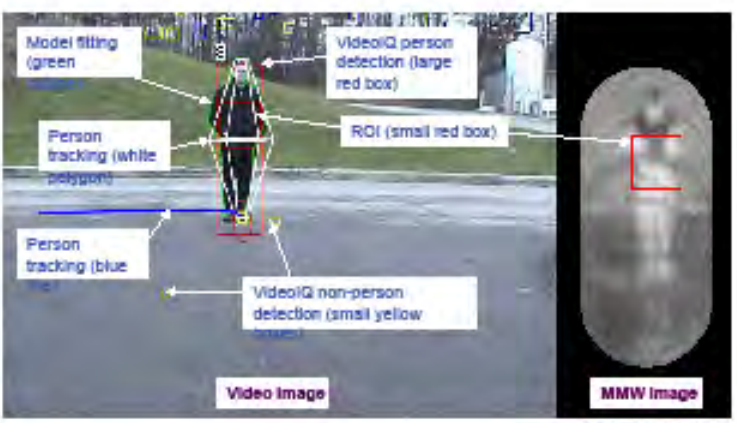

Example:
ATR for Whole-Body Imaging

Example: WBI ATR Research

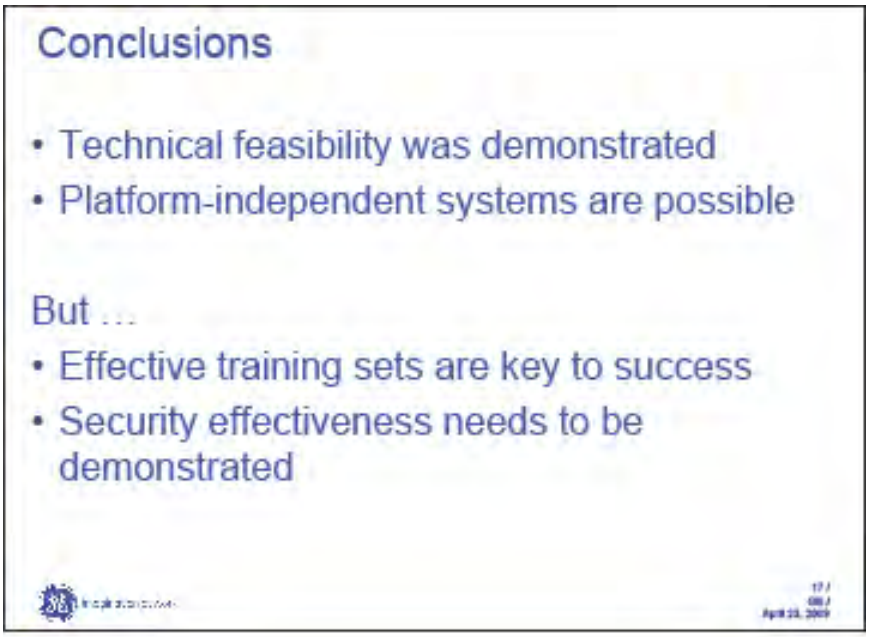
Highlights:

- Platform-independent automated detection of concealed threats
- Training system; Support Vector Machine implements ATR
- No proprietary interfaces or custom data fields – video out or screen capture
- Lab results: FPR=1.4%, TPR = 95%

Example: WBI ATR Research



imagination at work


Conclusions
• Technical feasibility was demonstrated
• Platform-independent systems are possible
But …
• Effective training sets are key to success
• Security effectiveness needs to be demonstrated

Example:
EDS Image Conversion

TSWG Imaging Study Project

Objective

Determine effect of resolution on detection, using a variety of explosive (traditional and new threats) and benign materials

Collaborative effort

- Funded by DHS through TSWG
- Test plan jointly from GE HLP and LLNL
- Explosives handling and data collection at Tyndall AFB by AFRL personnel
- Image Reconstruction and downsampling at GE GRC
- Detection/FA and Analysis at GE HLP, GE GRC
- Long-term data archiving at LLNL

Data Flows Through Interfaces

Data Collected at Tyndall on Lightspeed CT scanner

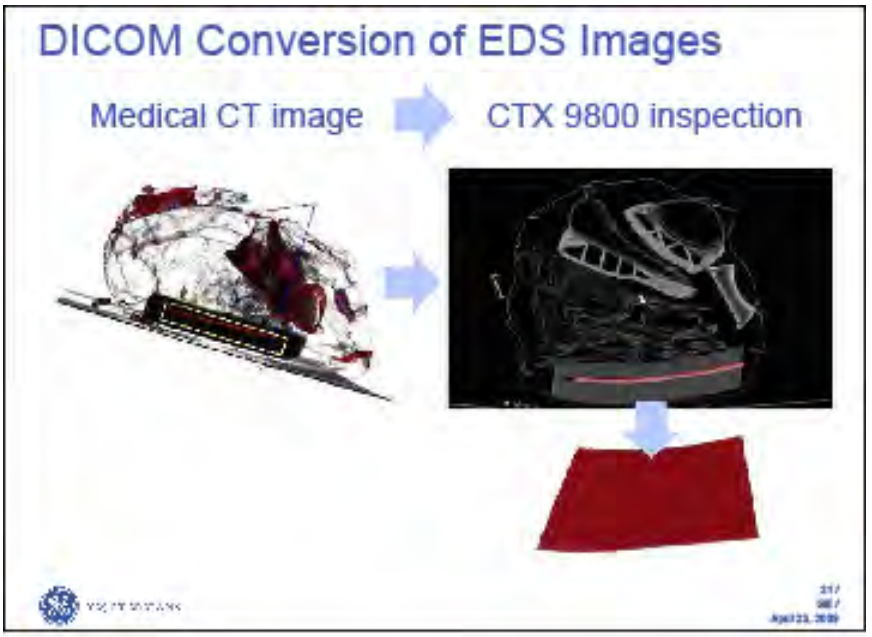
Data Energy Image Reconstruction at GE GRC

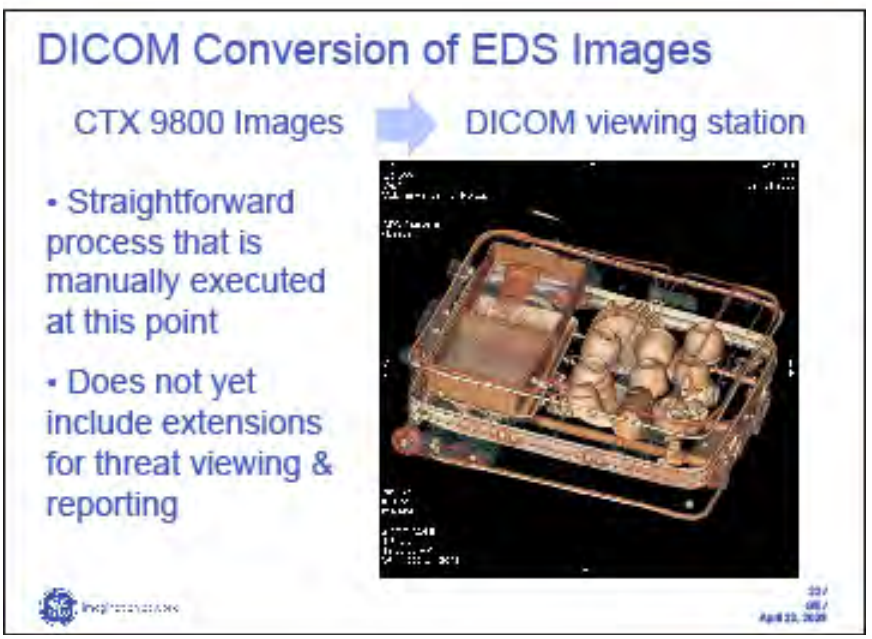
Detection/FA & Analysis at GE HLP and LLNL

~2700 bags collected (8.1TB total)

Data include:

- Raw (2 energies)
- CT & Z_{eff}
- Decompositions and Downsamplings


DICOM Conversion of EDS Images
Medical CT image
CTX 9800 inspection

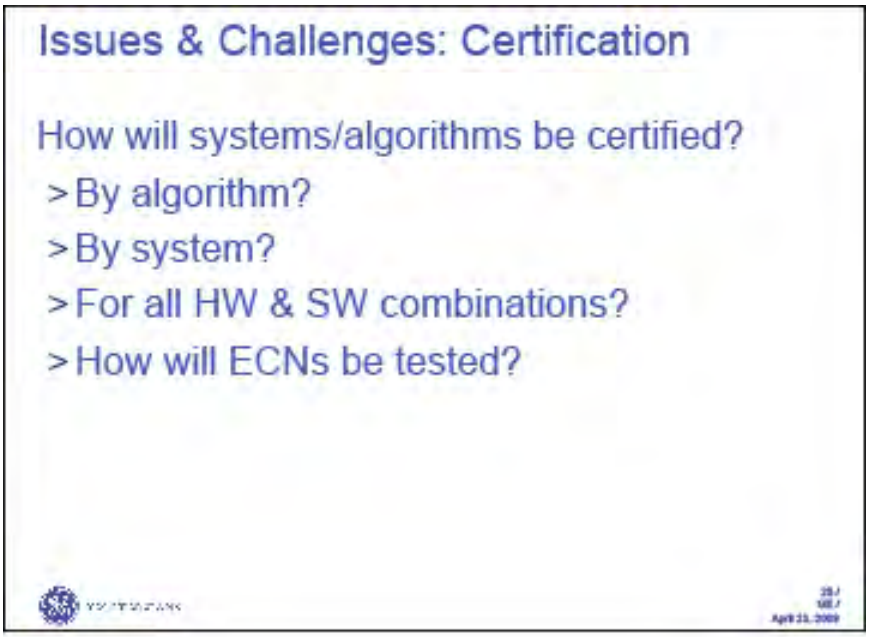

DICOM Conversion of EDS Images
CTX 9800 Images
DICOM viewing station
• Straightforward process that is manually executed at this point
• Does not yet include extensions for threat viewing & reporting

Issues & Challenges: System Integration

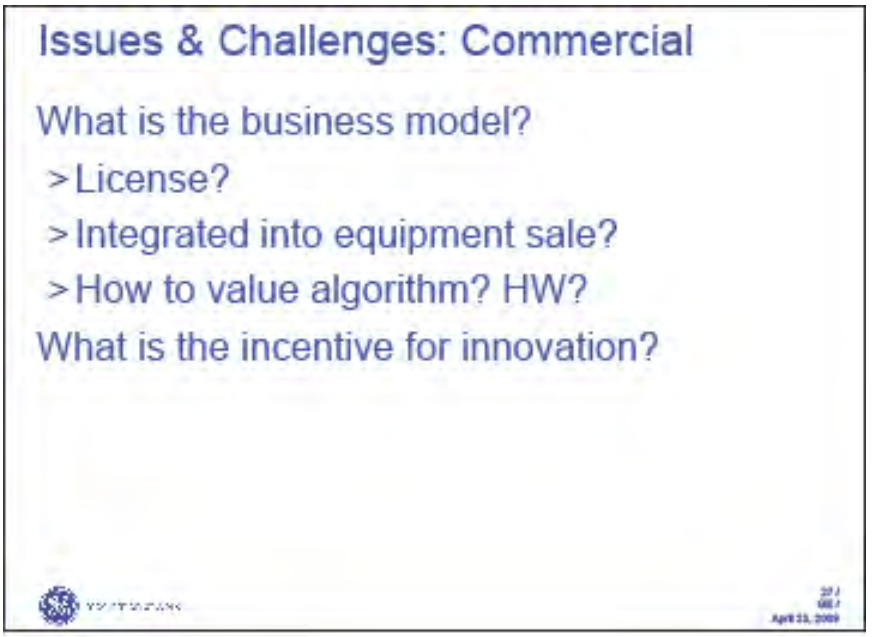
Who owns system integration?
- > Government?
- > Equipment manufacturer?
- > 3rd party integrator?

What are the implications for:
- > Warranty?
- > Performance?
- > Service?
  - – *Who fixes it when it breaks? More to the point … Who decides what is broken?*

What is the configuration management approach?


Issues & Challenges: Certification
How will systems/algorithms be certified?
>By algorithm?
>By system?
>For all HW & SW combinations?
>How will ECNs be tested?

Issues & Challenges: Technical
Interfaces
>Which is best?
>What are the interface "losses?"
Compatibility
>How to accommodate variety of acquisition modes?
>What about installed base?
Detection & FAR
>What is the performance benefit?


Issues & Challenges: Commercial
What is the business model?
>License?
>Integrated into equipment sale?
>How to value algorithm? HW?
What is the incentive for innovation?

Observations

Pros and Cons

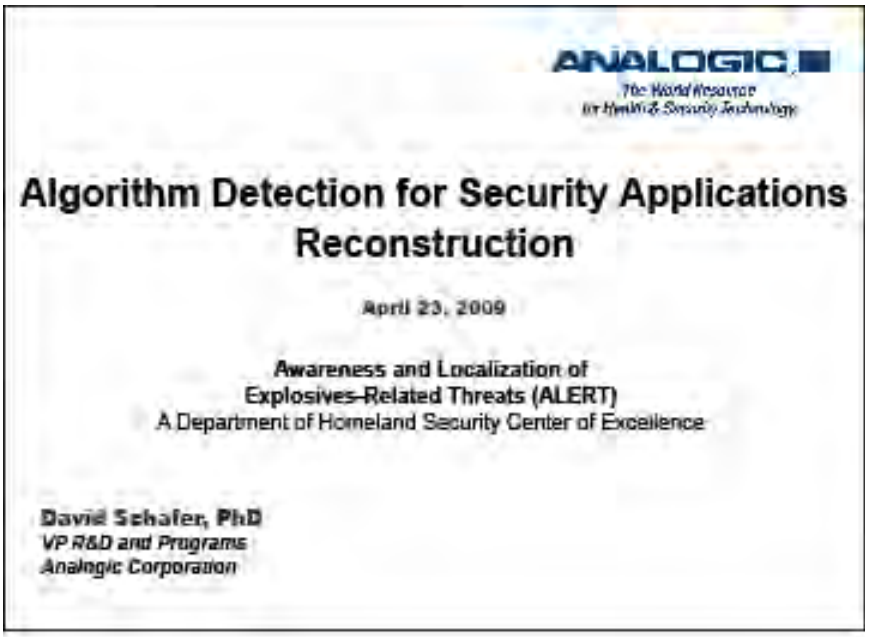
Intended Benefits	Possible Risks
• Best algorithms from all the smartest people	• Standardization across platforms may lose optimization; interfaces, proprietary know-how
• Specialized algorithms optimized for special cases	• May create turmoil – industry, config mgmt & certification
• Rapid. Fleet-wide unpdates	

Observations

- EDS is not medical … automated detection is not the same as clinical radiology; nor is EDS market the same size as the health care diagnostics market
- Certification is "all" about corner cases – requires optimization with detailed knowledge of HW/FW/SW and interactions of these.
- Current systems meet current requirements; new requirements always drive innovation.
- Impact of algorithm development is function of technology maturity … newer applications *might* see more benefit.

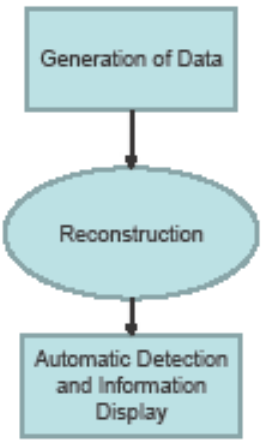
Thank You

23.4 David Schafer Presentation 1 Slides



Overview - Reconstruction

- Expanded definition of reconstruction
  - Image Enhancement
  - Data Fusion
- Examples and Opportunities - Baggage
  - CT
    - Single Energy
    - Dual/Multiple Energy
    - Limited View CT
    - Stationary CT
  - Multi-View
  - Backscatter
  - X-ray Backscatter for Personnel
  - Millimeter Wave for Personnel
  - Radiation Detection and Location



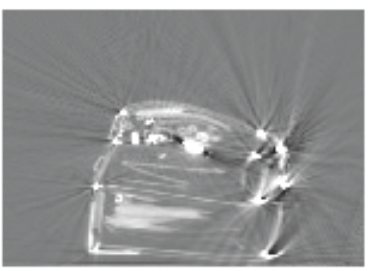
Reconstruction

- Processing of data to create an image
  - Correction for system variations
    - Detector gain, Source variations, Temperature, Position, etc
  - Conversion of corrected data to viewable image
    - CT, Multi-View, Direction Calculation,
- Expand to include
  - Modification of data for machine interpretation
    - Dual or Multi-Energy Decomposition
    - Other Image Processing steps
  - Modification of data for operator
    - Threat object insertion
    - Image Enhancements

Examples – Helical Cone Beam CT artifacts

- Issues
  - Cone Beam Artifacts
  - Scatter Artifacts
  - Beam Hardening
  - Photon Starvation
  - Metal Artifacts
  - Multiple Source Artifacts
- Opportunities
  - Exact Algorithms
  - Iterative reconstructions
  - Targeted reconstructions for specific threats

Cone beam artifacts



Cone Artifacts after NSR

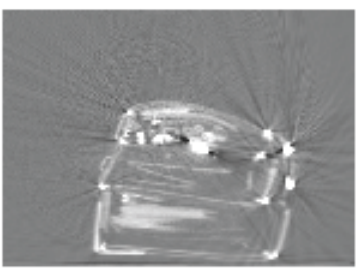


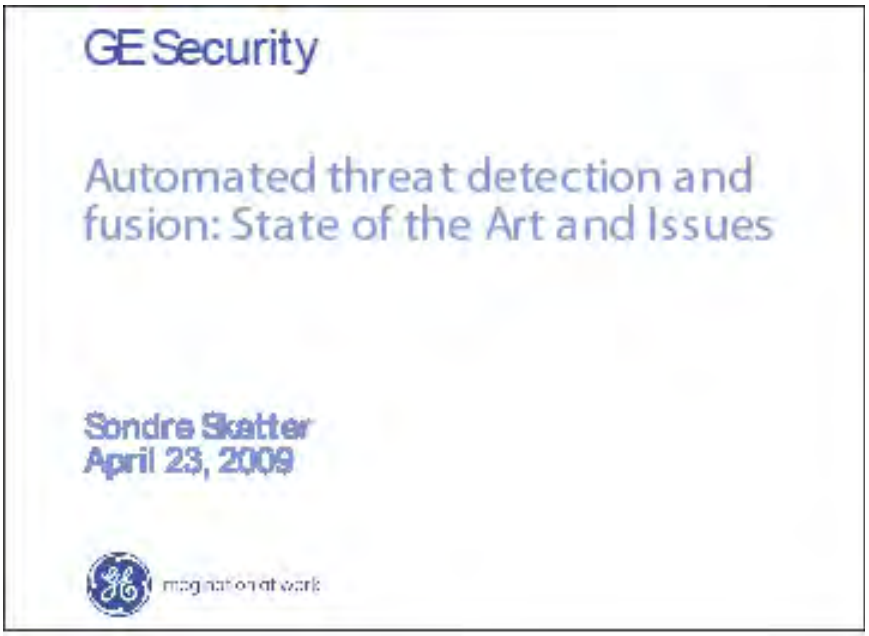
Image after some artifact reduction

•Typical Current System – Helical cone beam approximations such as NSR
•Opportunity – New reconstruction algorithms based on 3D data (eg. Feldkamp) or exact algorithms (eg. Katsevich)

Scatter

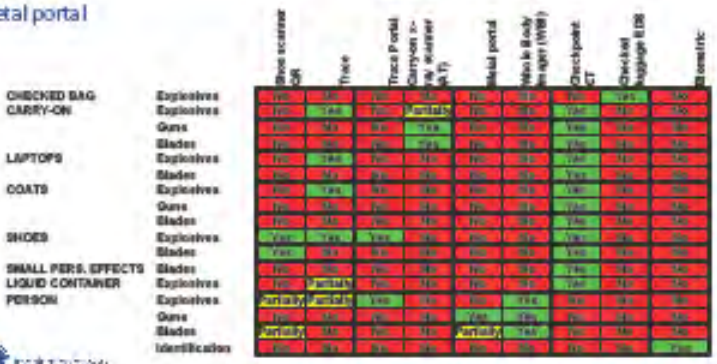
- Typical Current System – Mechanical scatter rejection, scatter detectors
- Opportunity – Improved design scatter rejection, improved scatter correction algorithms – Particularly for multi-source or stationary gantry geometries

23.5 Sondre Skatter Presentation 1 Slides



Modalities

- CT -> Carry-on or checked luggage
- X-ray multi-view (AT), dual energy
- X-Ray Diffraction
- Nuclear Quadrupole resonance (QR) (Shoes)
- Metal portal
- Trace (portal, or secondary)
- Whole Body Imager (mm wave, x-ray back scatter, THz)
- Biometric: Confirming identity
- Intelligence -> profile or scenario based
- Video ->



Algorithm types

- Tomographic Image reconstruction
- Detection
  - > Image segmentation
  - > Chemical identification -> Pattern matching
  - > Shape recognition (not allowable for explosive detection, but OK for weapons and prohibited items)
  - > Classifiers

Lots of algorithms…
Some domain specific, others cross-domain

Fusion Algorithms
- > Decision fusion
  - – Boolean (AND/OR)
  - – "Co-tuning" + Boolean
- > Ad-hoc
- > Evidence based (probability theory)
  - – Dempster-Schafer
  - – Possibility theory
  - – Bayesian
  - – …

Automatic Detection System

Requirements:

- Issue Alarm or Clear decision
- Minimum detection rate: $Pd >= Pd_{min}$
- While optimizing:
  - False positives rate: min(*Pfa*)
  - Throughput: max(*Throughput*)

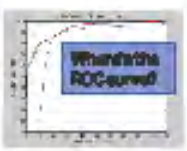
Managed by certification, and data collection assistance by the TSA/TSL

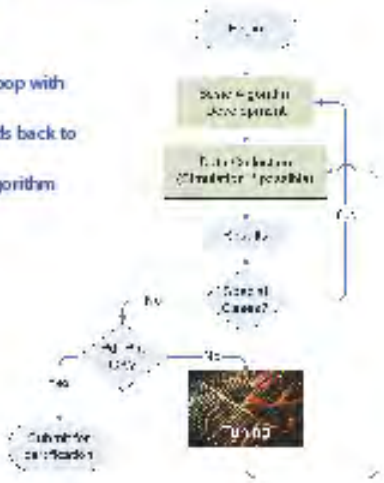
Automatic Detection System: Algorithm Development Cycle

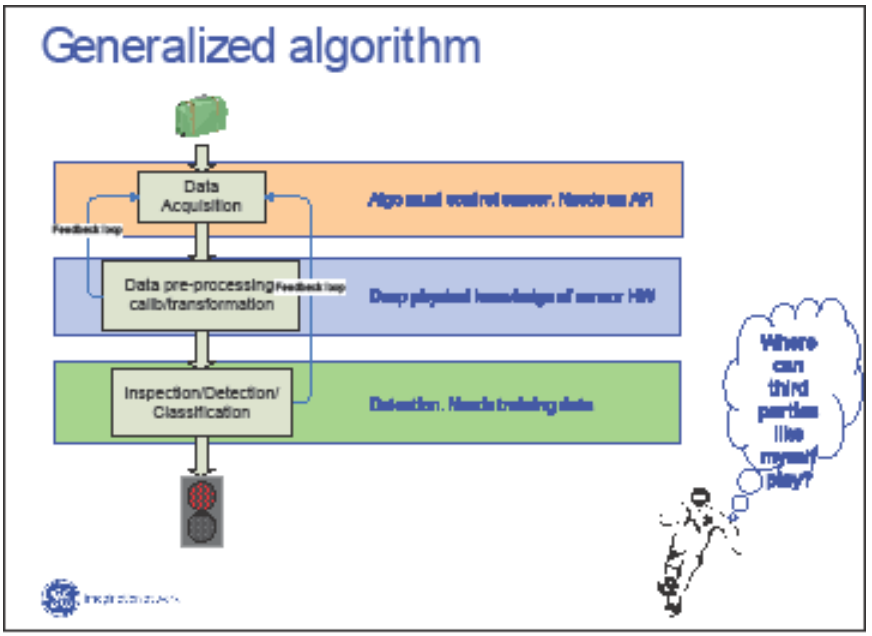
Algorithm development in a closed loop with regulator

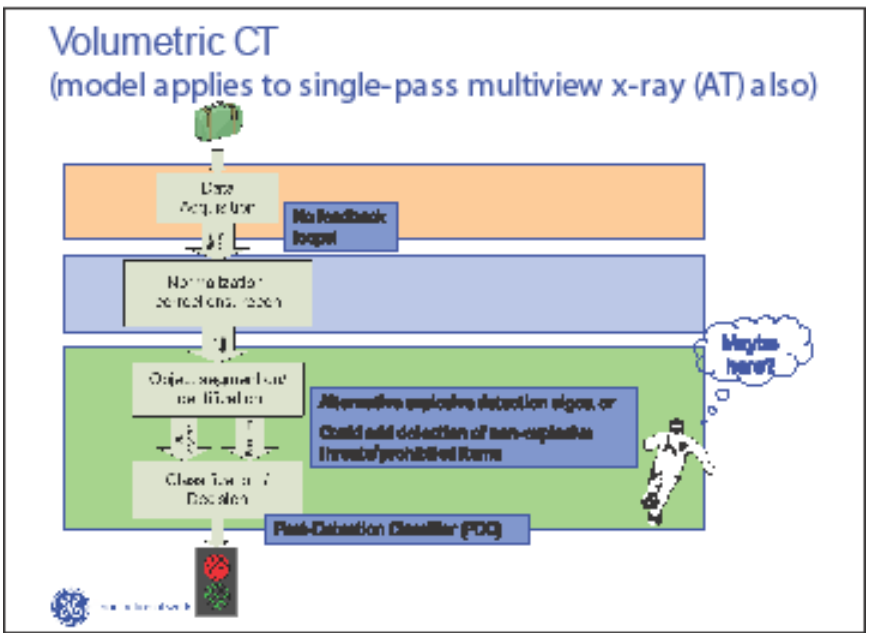
Special cases (missed detection) feeds back to basic algorithm development

Typically, a number of knobs that algorithm developer can tune






Generalized algorithm
Data Acquisition
Data pre-processing calib/transformation
Inspection/Detection/ Classification
Where can third parties like myself play?


Volumetric CT
(model applies to single-pass multiview x-ray (AT) also)
Maybe here?

Data pre-processing

- Most sensors would have some pre-processing
  - > Very dependent on underlying HW
  - > Calibrations often involved
- Examples:
  - > CT: After-glow correction, beam hardening, geometry, bad detectors, etc
  - > NQR: Corrections based on external fields,
  - > Video…
- Usually, the equipment manufacturer would own this domain
- Maybe not a good area for third-party algorithm developers?

Questions for Work-out sessions:

- **Bring an example of pre-processing step. Would this be suited for a 3rd party to improve upon?**
- **What would be the issues?**

Feedback loops: Inspection <-> data acquisition

- Usually implemented as a trade-off between throughput and Signal-to-noise ratio
- Makes algorithm playground more difficult, but reduces cost of ownership of sensor

Modality	Mechanism	Purpose
Sparse slicing CT	Slice request	Increase throughput, by only acquiring a minimum of needed CT data
Trace	Sampling length	Improve S2N
Whole Body Imager	Focus on area of interest	Optimize throughput vs signal quality
Video systems	Focus, zoom, sample rate responding to activity	Optimize the utility of limited HW resources (cameras) by using SW
NQR	Conditional, secondary scan sequence	Optimize throughput vs signal quality

Feedback loops: Inspection <-> data acquisition : Impact on 3rd party algorithm development

- To enable 3rd party algo development despite such feedback loops:
  - > Equipment manufacturer would need to publish an API that allows 3rd parties to control data acquisition
  - > This has already been done in other industries: Video a good example
  - > Alternatively, a generalized protocol/API provided by regulator
- Simulator is needed to "playback" various scenarios

Questions for Work-out sessions:

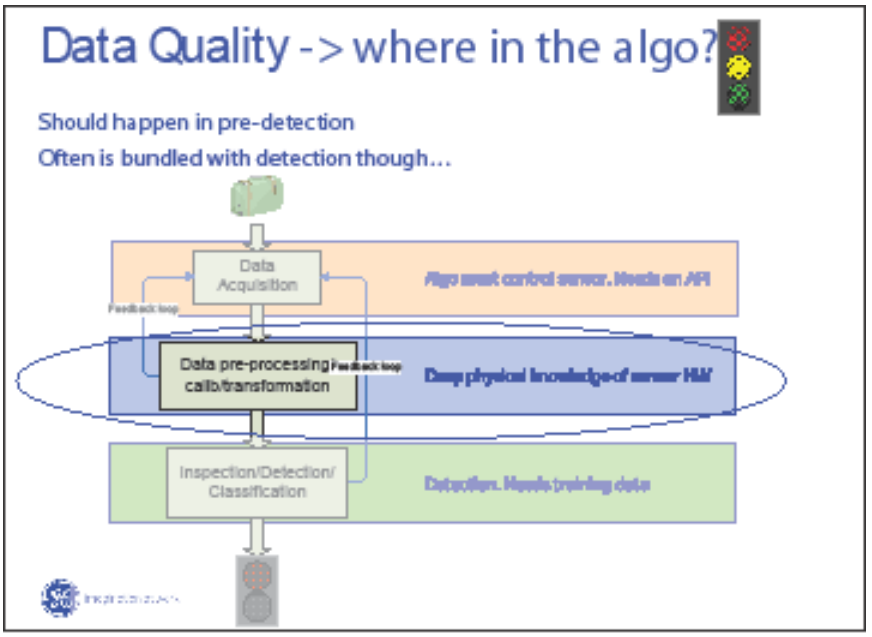
- **Are you aware of other feedback mechanisms between detection algorithms and data acquisition than those mentioned?**
- **Could a 3rd party developer make a meaningful contribution if an API was available to control the sensor?**

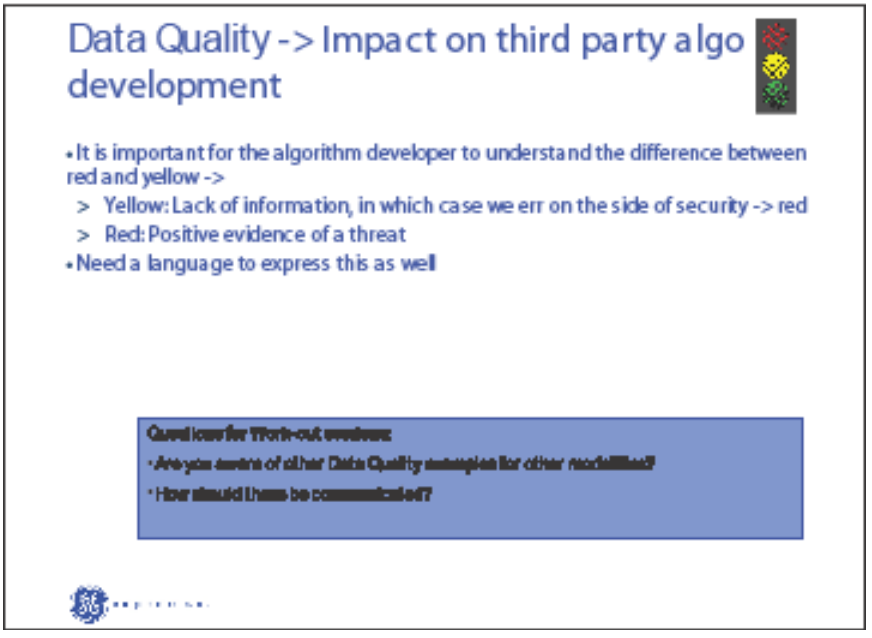
Data Quality -> A third output

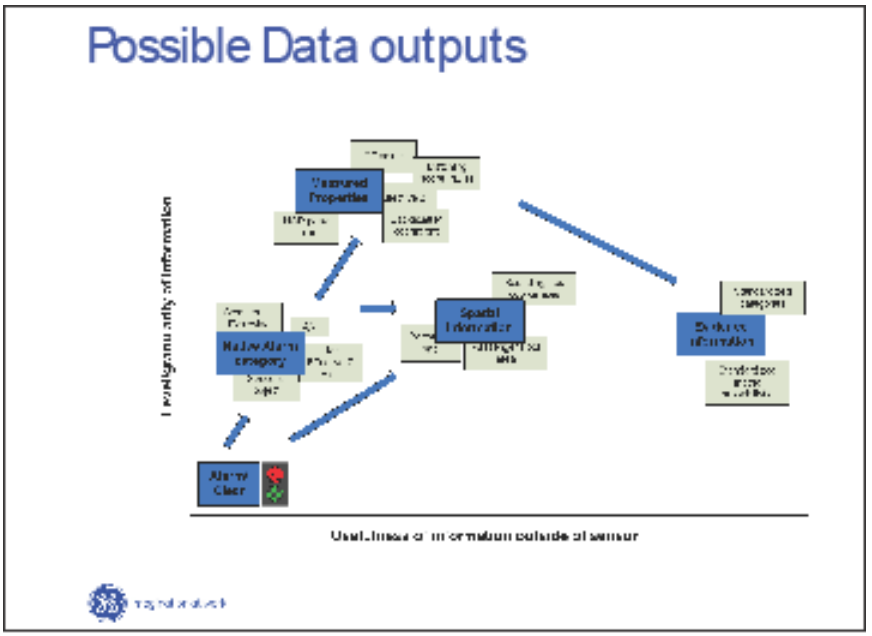
A "yellow" means that sensor has insufficient information. Obscuring elements

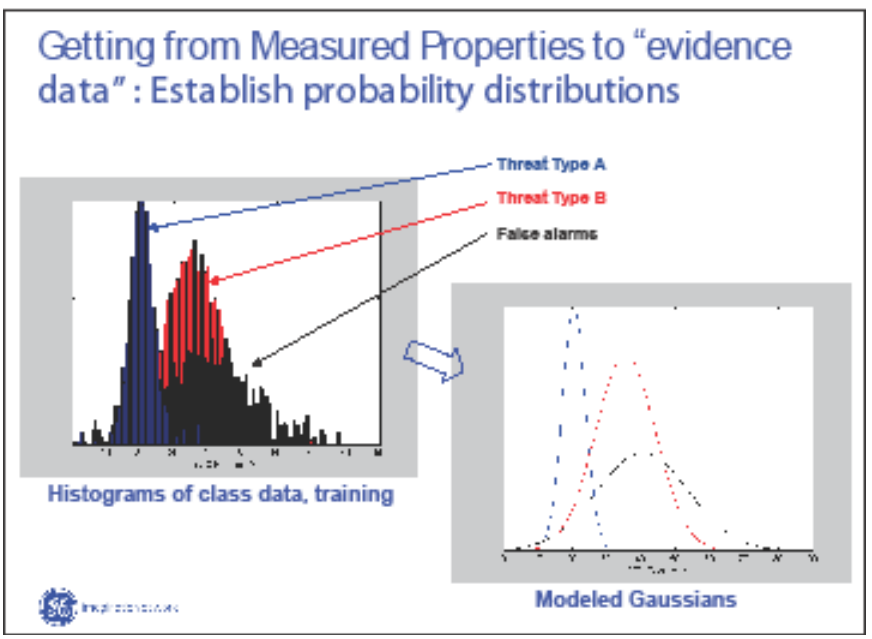
In practice, yellow is always lumped into red category since requirement is red/green

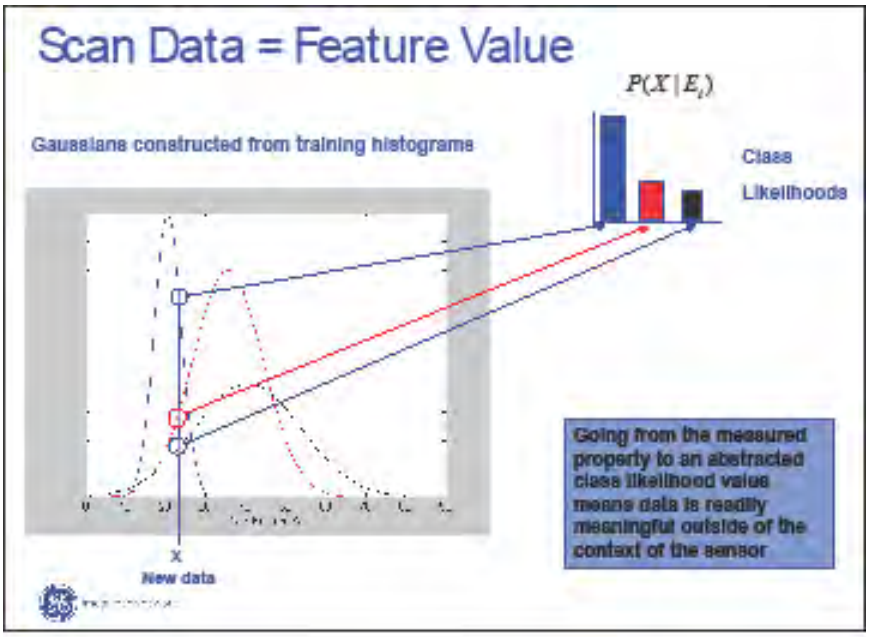
Modality	Mechanism	Impact
CT & X-Ray	Shield: insufficient x-ray penetration due to high-attenuation object	Low Signal-to-noise ratio, image artifacts
Fingerprint sensor	Dirty, or obscure sample	Unable to make a match
X-ray diffraction bag scanning	Dark Scan: insufficient x-ray penetration due to high-attenuation object	Insufficient signal to confirm or reject presence of threats
Video systems	Insufficient lighting	Unable to identify and classify objects
NQR	Ringing: interference of QR signal by metal objects	Masks possible explosive signature

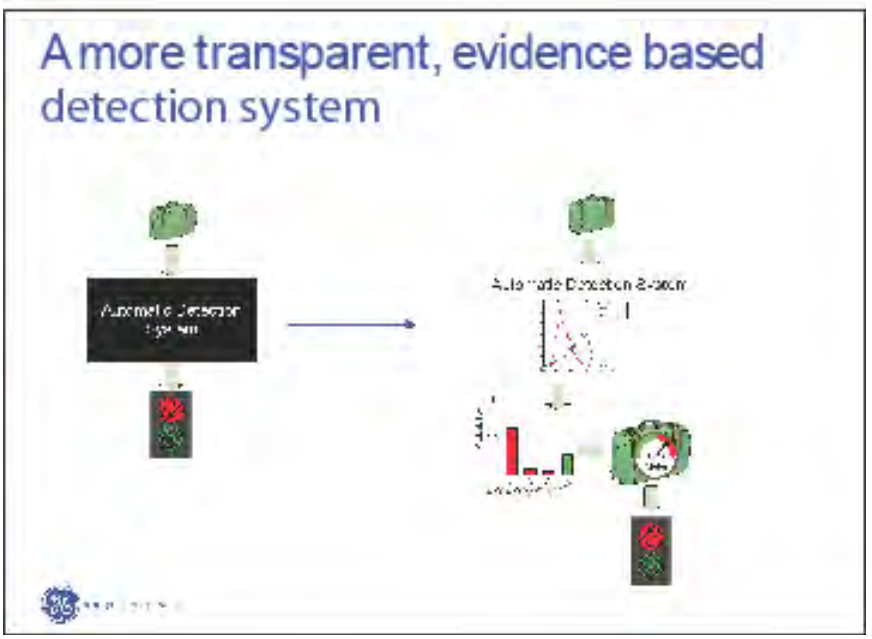

Data Quality -> where in the algo?
Should happen in pre-detection
Often is bundled with detection though…
Data Acquisition
Feedback loop
Data pre-processing calib/transformation
Feedback loop
Inspection/Detection/ Classification


Data Quality -> Impact on third party algo development
• It is important for the algorithm developer to understand the difference between red and yellow ->
> Yellow: Lack of information, in which case we err on the side of security -> red
> Red: Positive evidence of a threat
• Need a language to express this as well


Possible Data outputs


Getting from Measured Properties to "evidence data": Establish probability distributions
Threat Type A
Threat Type B
False alarms
Histograms of class data, training
Modeled Gaussians

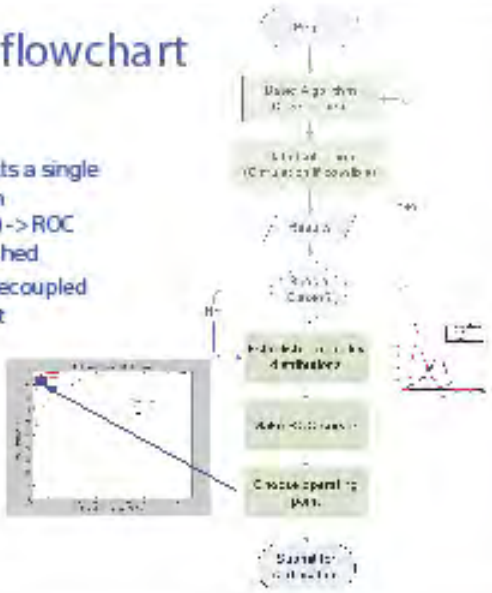

Scan Data = Feature Value
$P(X \mid E_i)$
Gaussians constructed from training histograms
Class
Likelihoods
Going from the measured property to an abstracted class likelihood value means data is readily meaningful outside of the context of the sensor
X
New data


A more transparent, evidence based detection system

Modified Algo flowchart

If Detection Algorithm outputs a single probability (aggregated from individual probability values) -> ROC curves can easily be established

Sensitivity tuning could be decoupled from algorithm development



ROC curve "lab"

Considerable effort could be dedicated to establishing ROC curves

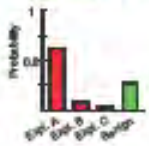
Would improve transparency

Adds flexibility for regulator

> Even possible to certify a range of operating points?

Data Fusion

- "Black box"-ness of detection system a major obstacle to data fusion
- Individual system performance must be fully understood before putting them together
  - > Would be much easier if systems spoke a "language of evidence":
    - – Shared quantitative threat units
    - – Shared threat categories



  - > Even non-sensor data can be fused within this framework
    - – Example: Passenger profiling, general threat level, intelligence
  - > Evidence language might be useful in a higher-level context: Command & Control at/across airports

Conclusion

Opportunities for algo development:

1) Detecting non-explosive threats on CT & x-ray line scanner

2) Need to re-partition the "black box" aspect of detection systems if
- > 3rd parties to contribute
- > For optimum data fusion

- A common risk-based language would be needed
- Might also affect the development-certification cycle
- Re-defining the playground…

23.6 Richard Bijjani Presentation 1 Slides

REVEAL

- At the Checkpoint
  - Divested Bags:
    - X-rays
    - XT
    - CT
    - DECT
    - EDT
    - Diffraction
  - Shoes
    - X-rays
    - THz
    - NQR
    - Trace
  - Liquid / Solids Scanners
    - X-rays
    - Microwave
    - Trace
  - People
    - Passive: mass detector, active THz, Thermal, IR
    - Active, backscatter x-ray
      - Perceived Privacy and Health issues
  - Behavior/Intelligence

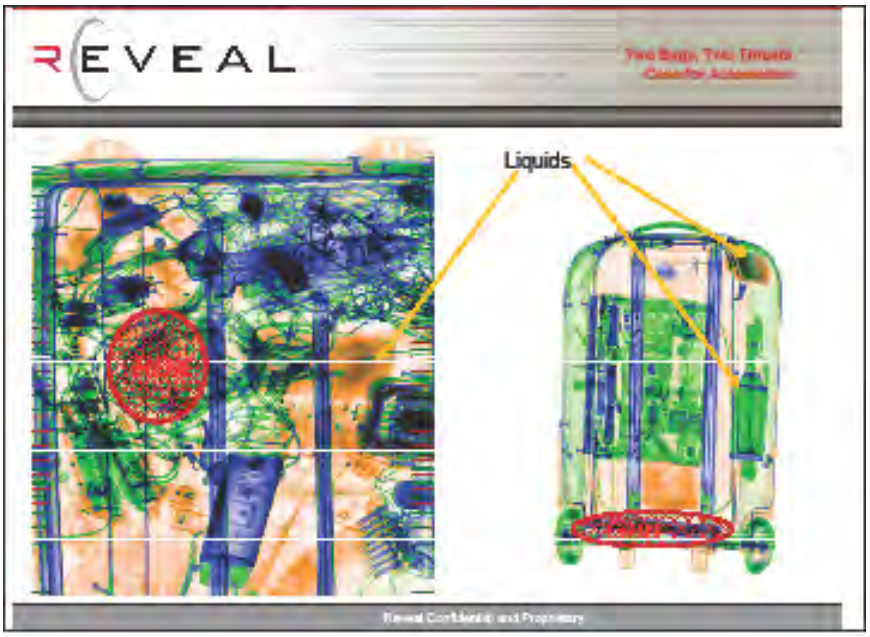
REVEAL

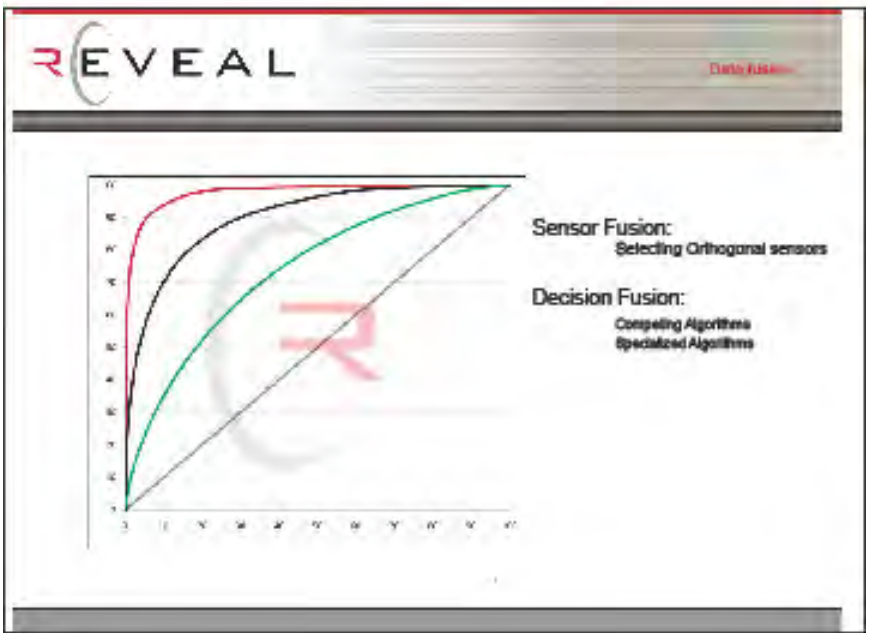
- Aviation Size Explosives hard to detect mainly because components could be assembled after security
  - IED's may be unassembled and Distributed between the multiple items the passenger carries and his/her body

Sensor Improvement
Selection of Orthogonal sensors
System/Information Fusion across modalities

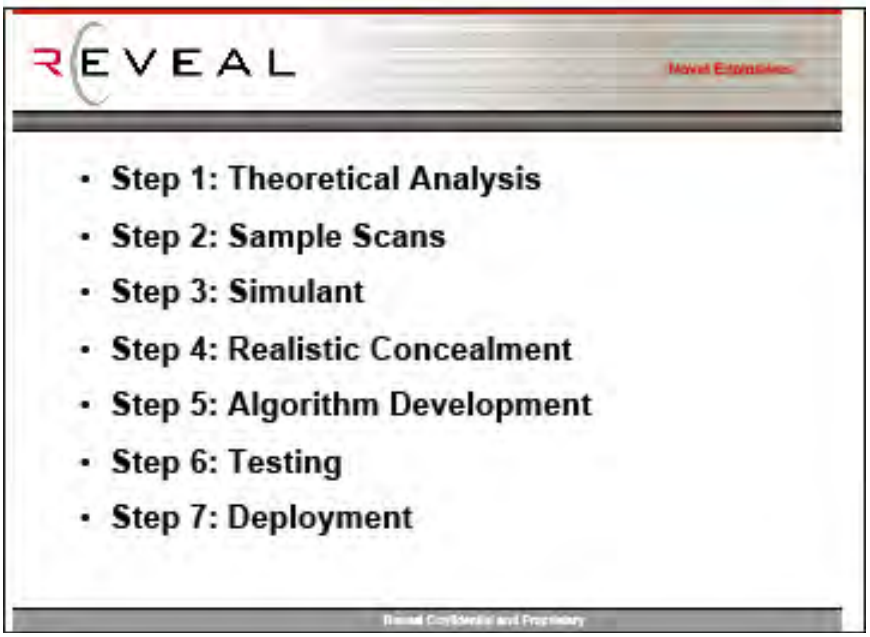
- Operator is sometimes the weak link

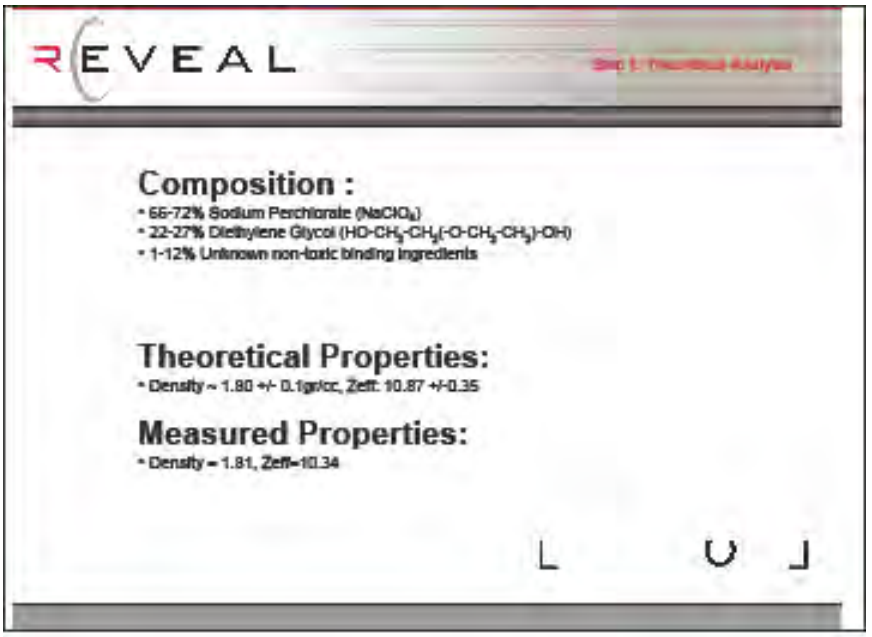
Automate
Train

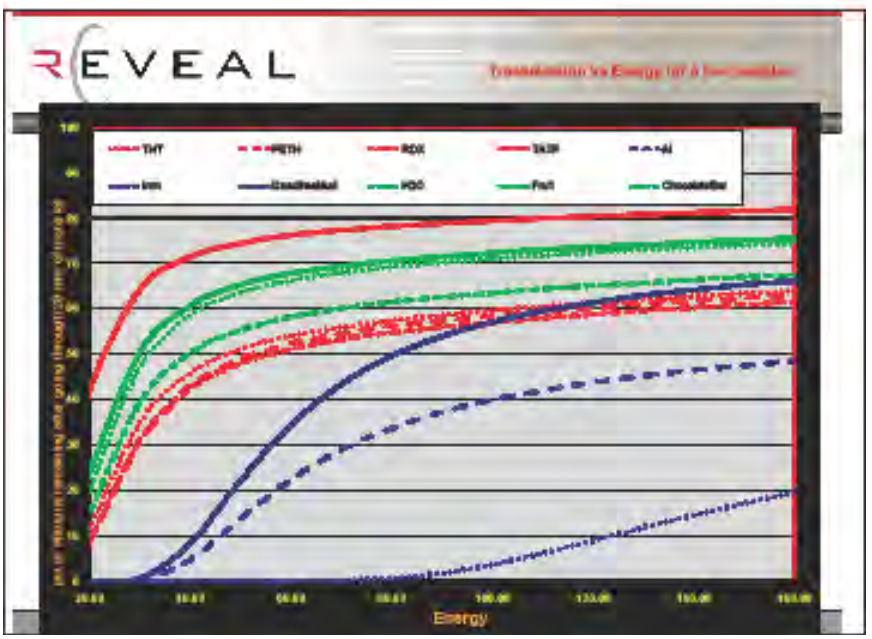

REVEAL
Liquids

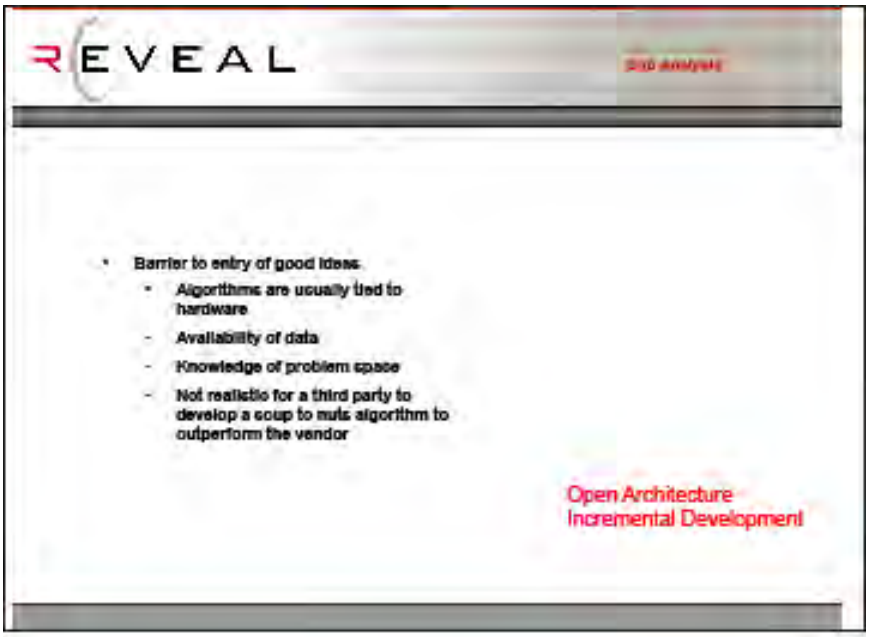

REVEAL
Sensor Fusion:
Selecting Orthogonal sensors
Decision Fusion:
Competing Algorithms
Specialized Algorithms

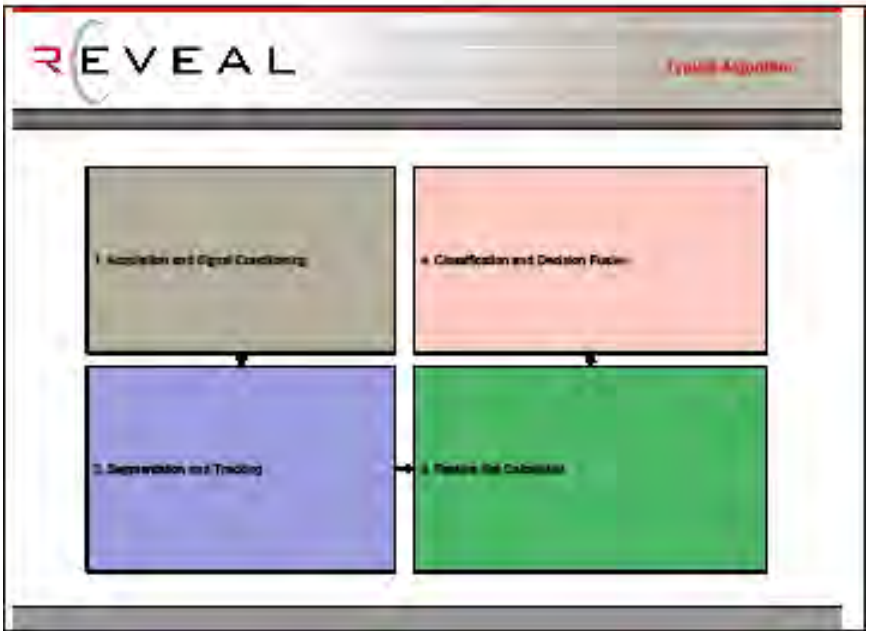
REVEAL


REVEAL
• Step 1: Theoretical Analysis
• Step 2: Sample Scans
• Step 3: Simulant
• Step 4: Realistic Concealment
• Step 5: Algorithm Development
• Step 6: Testing
• Step 7: Deployment


REVEAL
Composition :
• 66-72% Sodium Perchlorate ($NaClO_4$)
• 22-27% Diethylene Glycol ($HO-CH_2-CH_2(-O-CH_2-CH_2)-OH$)
• 1-12% Unknown non-toxic binding ingredients
Theoretical Properties:
• Density ~ 1.80 +/- 0.1g/cc, Zeff: 10.87 +/-0.35
Measured Properties:
• Density = 1.81, Zeff=10.34


REVEAL
TNT
RDX
Energy


REVEAL
Barrier to entry of good ideas
Algorithms are usually tied to hardware
Availability of data
Knowledge of problem space
Not realistic for a third party to develop a coup to nuts algorithm to outperform the vendor
Open Architecture
Incremental Development

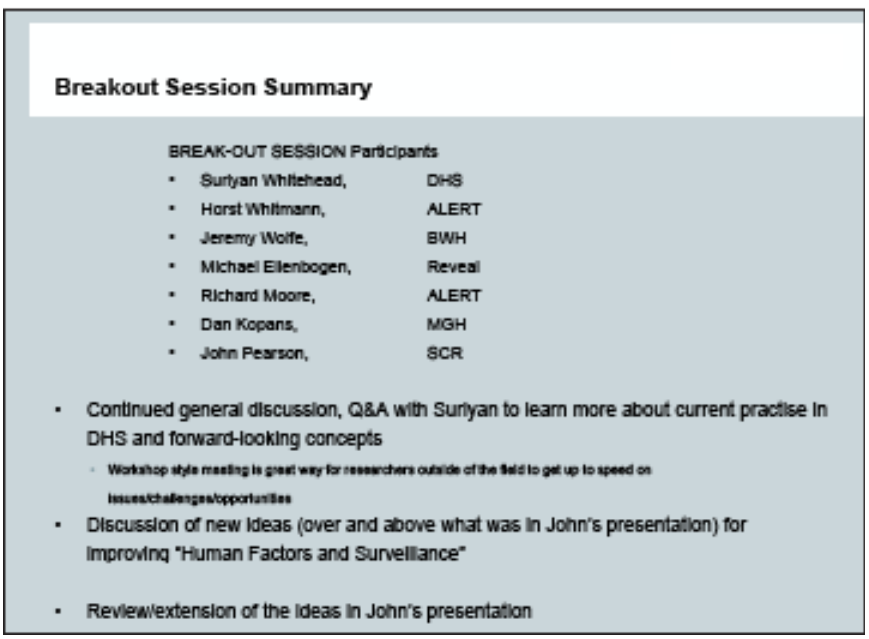

REVEAL

REVEAL
We the manufacturers have to start to acknowledge that we do not have all the answers.
"My sensor is the best out there"
"My sensor is the answer, can find everything"
We need the brain power out there. We may know more about the problem statement and the industry, but the imaging community is collectively smarter than any one of us
Reveal is eager to collaborate with the research community to give the best ideas the opportunity to flourish.

23.7 John Pearson Presentation 1 and 2 Slides

Table of Contents – Surveillance and Human Factors Topic

- Presentation following the Break-out Session on Day 2 2 → 18
- Presentation made on Day 1 19→ 46



Breakout Session Summary

BREAK-OUT SESSION Participants

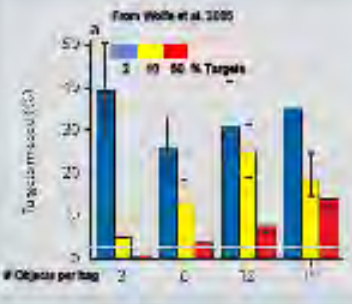
- Suriyan Whitehead, DHS
- Horst Whitmann, ALERT
- Jeremy Wolfe, BWH
- Michael Ellenbogen, Reveal
- Richard Moore, ALERT
- Dan Kopans, MGH
- John Pearson, SCR

- Continued general discussion, Q&A with Suriyan to learn more about current practise in DHS and forward-looking concepts
  - Workshop style meeting is great way for researchers outside of the field to get up to speed on issues/challenges/opportunities
- Discussion of new ideas (over and above what was in John's presentation) for improving "Human Factors and Surveillance"
- Review/extension of the ideas in John's presentation

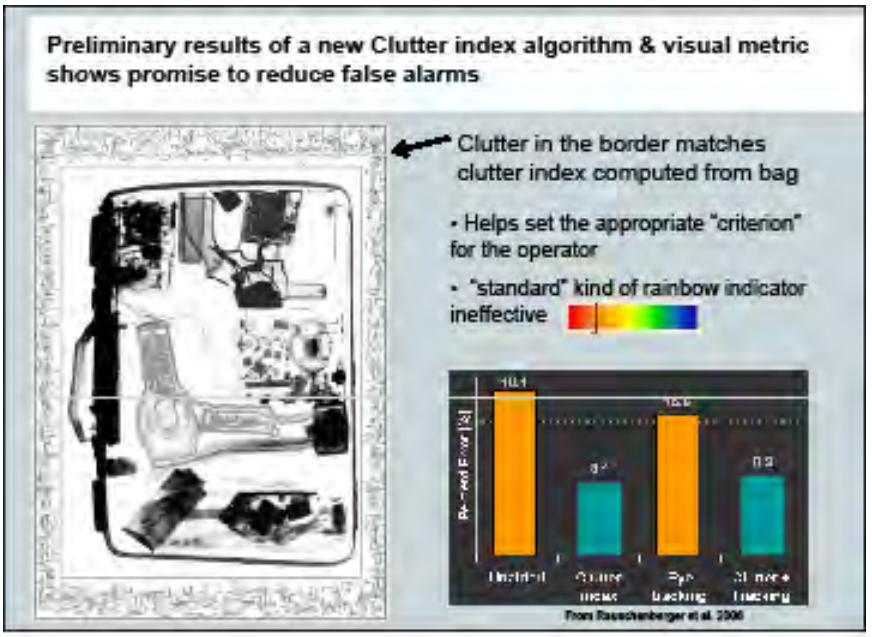
Summary / Highlights of Topics from Breakout Session

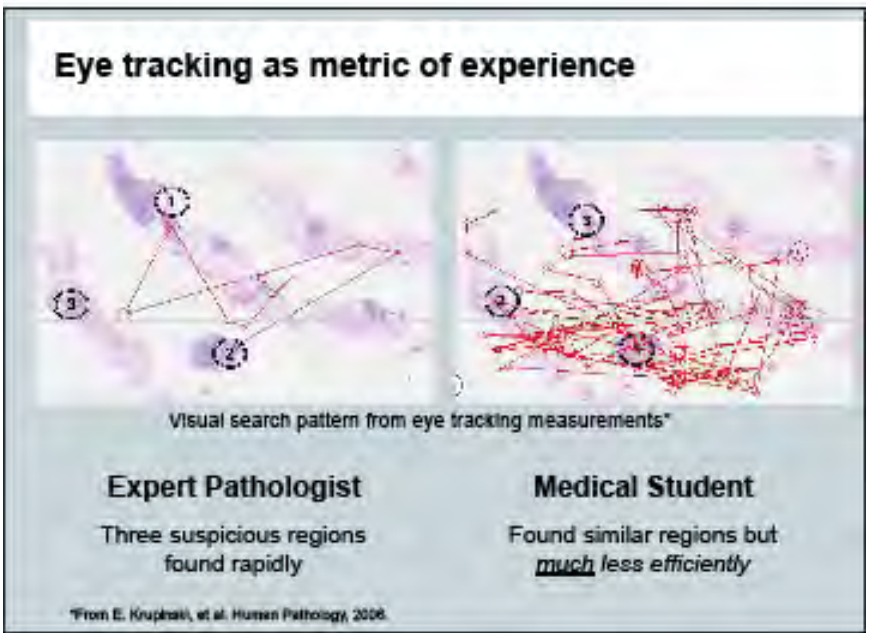
- Yes, there is much that "cognitive engineering" can bring to improve screening
  - Optimizing display and workflow to deal with low prevalence, clutter, etc
  - Eye tracking as monitor of experience and for training
- Computational Models of human vision is mature field with many applications
  - Optimizing reconstruction and image processing algorithms
  - Optimizing compression for remote reading applications
  - Must of course first be "tweaked" and validated for screening applications
  - Possibility of "low-hanging fruit" here – 1-2 years could produce a tool used by algorithm community that in a few minutes could perform the equivalent of a 30 subject perception study
- Video analytics have many possible applications as new requirements are defined by DHS
  - Tracking in dense crowds and behavior analysis are open "grand challenge" problems in computer vision, so don't expect quick hits, but there is much to leverage from DOD funded programs
  - Techniques like multi-camera image mosaicing with high-definition cameras could offer great improvement in situational awareness as tool to human tracking of suspicious individuals.

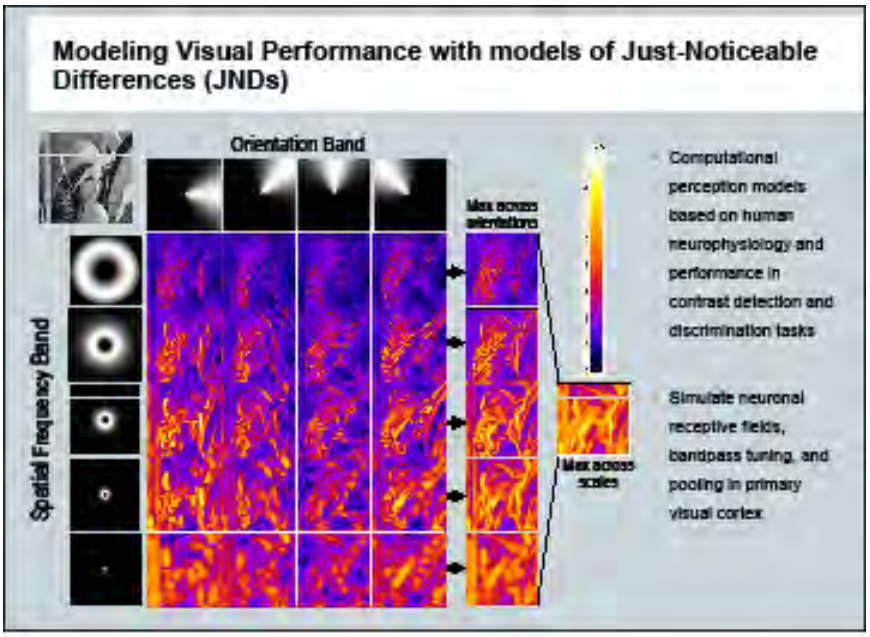
Challenge to maintain vigilance and search criterion – low target prevalence in highly cluttered images

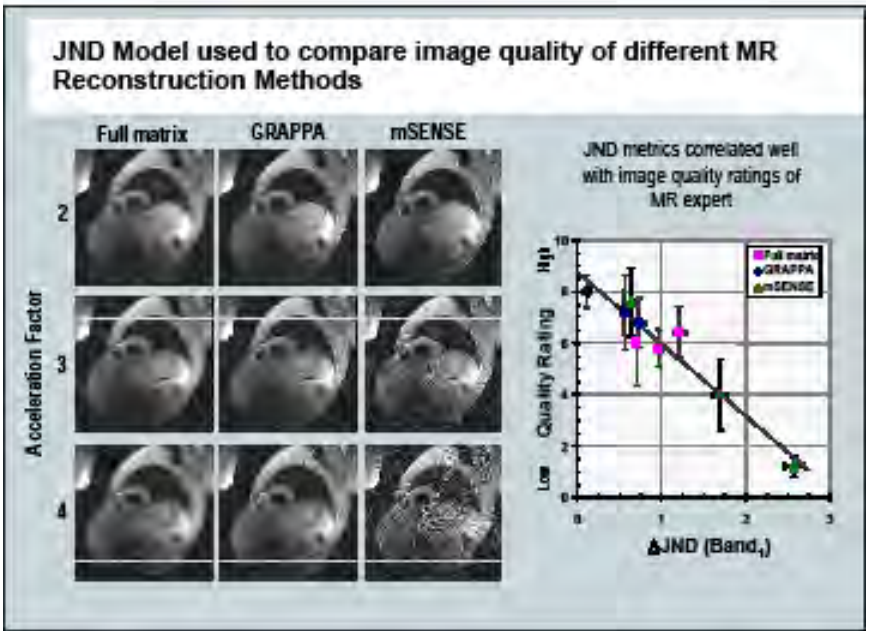


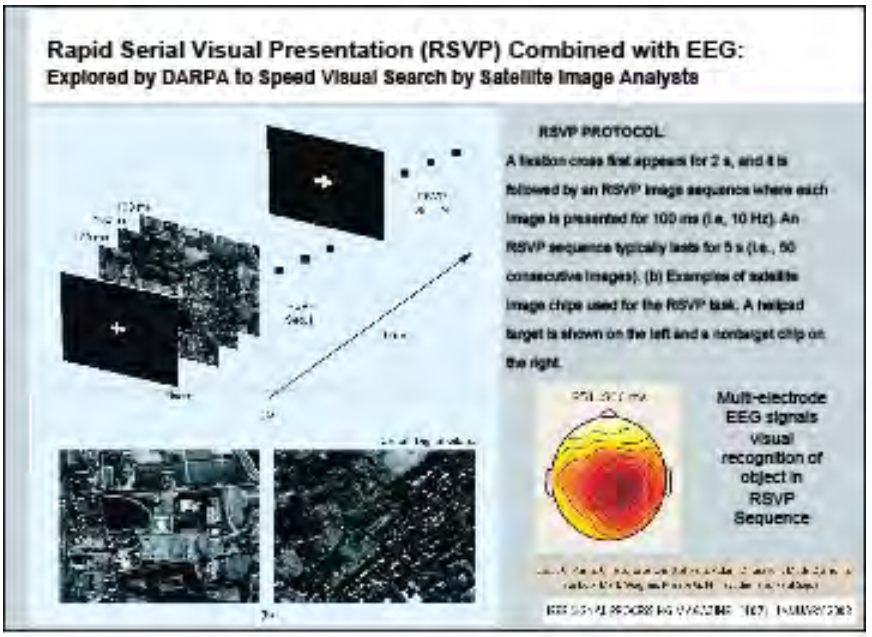
- Targets and Non-Targets ARE SIMILAR
- Non-Targets ARE NOT SIMILAR
- Targets are SCARCE


Preliminary results of a new Clutter index algorithm & visual metric shows promise to reduce false alarms
Clutter in the border matches clutter index computed from bag
• Helps set the appropriate "criterion" for the operator
• "standard" kind of rainbow indicator ineffective


Eye tracking as metric of experience
Visual search pattern from eye tracking measurements*
Expert Pathologist
Three suspicious regions found rapidly
Medical Student
Found similar regions but much less efficiently
*From E. Krupinski, et al. Human Pathology, 2006.


Modeling Visual Performance with models of Just-Noticeable Differences (JNDs)
Orientation Band
Spatial Frequency Band
Max across orientations
Max across scales
Computational perception models based on human neurophysiology and performance in contrast detection and discrimination tasks
Simulate neuronal receptive fields, bandpass tuning, and pooling in primary visual cortex


JND Model used to compare image quality of different MR Reconstruction Methods
Full matrix
GRAPPA
mSENSE
Acceleration Factor
2
3
4
JND metrics correlated well with image quality ratings of MR expert
Quality Rating
High
Low
ΔJND (Band,)


Rapid Serial Visual Presentation (RSVP) Combined with EEG:
Explored by DARPA to Speed Visual Search by Satellite Image Analysts
RSVP PROTOCOL
A fixation cross first appears for 2 s, and it is followed by an RSVP image sequence where each image is presented for 100 ms (i.e, 10 Hz). An RSVP sequence typically lasts for 5 s (i.e., 50 consecutive images). (b) Examples of satellite image chips used for the RSVP task. A helipad target is shown on the left and a nontarget chip on the right.
Multi-electrode EEG signals visual recognition of object in RSVP Sequence

Multi-camera fusion for enhanced surveillance:
Concepts from recently awarded DHS PBIED Project (ALERT)
"Video Loops"

Video Analytics Combined with Multi-camera Fusion for Enhanced HMI for Surveillance:

Concepts from recently awarded DHS PBIED Project (ALERT)

To reduce cognitive and manual workload on the operator, and to leverage other advantages of monitoring an observer's subtle behaviors via a non-invasive, free-viewing eye tracker, the operator's eye fixation patterns would be monitored. If any (new) pedestrians flagged explicitly by the automated pedestrian detection system is fixated or tracked for a critical period or through a critical distance across the screen, his/her flag would be cleared automatically or changed into an 'already inspected' flag. At any point, the operator could signal a target of interest by prolonging his gaze, or via voice command, or by making an appropriate manual response, directing the auto-zoom camera to hone in on the target and display the zoomed-in image region in form of a video "loupe." This loupe would simulate the structure of the visual field of humans. The eye tracker/loupe interface could furthermore be augmented by a multitude of other cognition/perception-inspired interaction concepts (e.g., pupil dilation response).

Tracking Results from DHS PBIED Project (2007)

(Play)

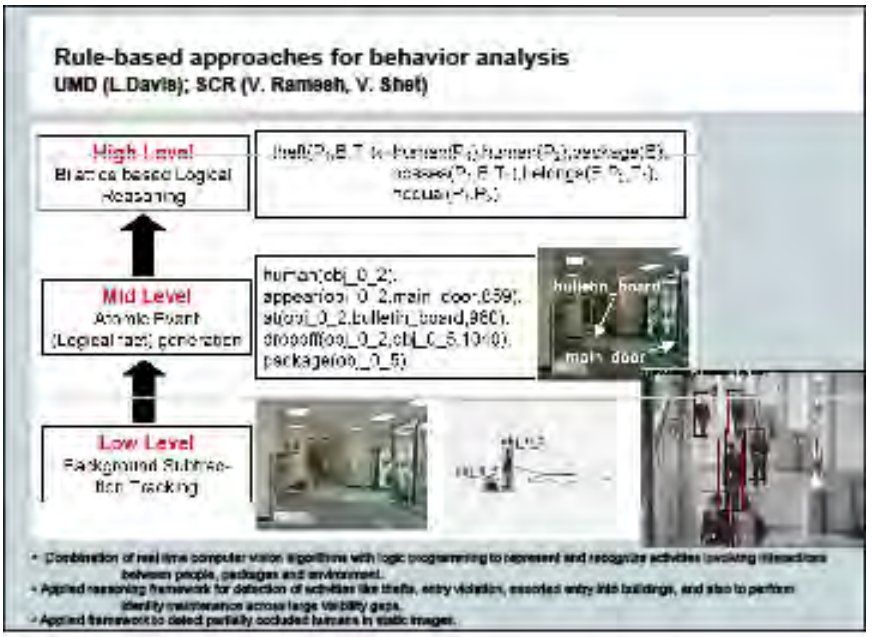
Legend for video:
- boxes appear on all tracked pedestrians
- green, yellow, or pink box indicates degree of occlusion of pedestrian tracked throughout entire sequence
- if pedestrian tracking is lost, box turns red shortly before tracking is lost

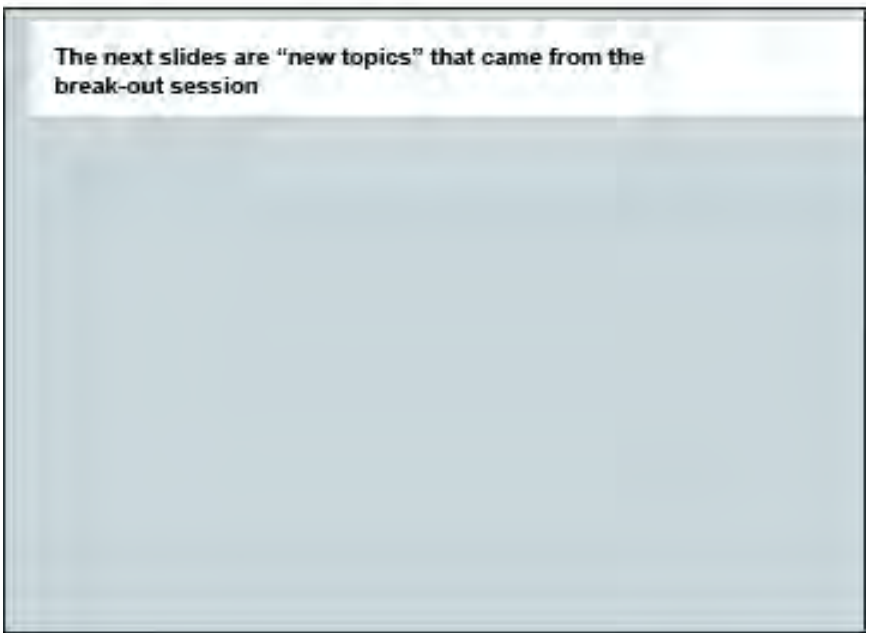
no occlusion

partial occlusion

severe occlusion

	No Occlusion	Partial Occlusion	Severe Occlusion	Speed
Mean-shift tracker (7-bits/channel)	95.8% (91/94)	86.5% (32/37)	69.23% (18/26)	~250 ms


Rule-based approaches for behavior analysis
UMD (L.Davis); SCR (V. Ramesh, V. Shet)
High Level
Mid Level
Low Level
Background Subtraction Tracking
bulletin_board
main_door
• Combination of real-time computer vision algorithms with logic programming to represent and recognize activities involving interactions between people, packages and environment.
• Applied reasoning framework for detection of activities like thefts, entry violation, escorted entry into buildings, and also to perform identity maintenance across large visibility gaps.
• Applied framework to detect partially occluded humans in static images.


The next slides are "new topics" that came from the break-out session

Remote Reading by the Baggage Screeners

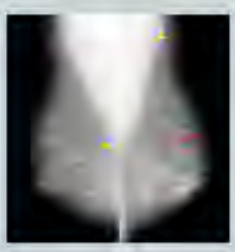
- Objective is to improve the operating environment of the screeners – less distraction, less pressure, better lighting, better ergonomics -> better visual performance
- Current practice is to stream the images to the screen (TSA requirement). They must stop the belt and generate a still image, but likely the decision was made while the image was moving, when the image is degraded (blur), especially when LCD monitors are used.
- This would enable the multiplexing of operators, providing more time to review difficult bags without the concern of slowing down the flow of bags.
- If lossy compression is required to fit the bandwidth between the scanners and the reading room, then the issue of the visual impact of artifacts should be studied/controlled as described in the lead presentation.
- Design of such a screening reading room, and the re-design of screening workflow, could benefit from a variety of human factors studies, human vision modeling, etc. Much can be learned from the experience gained from the design of digital radiology reading rooms – significant literature.

Image from RSNA website, showing a collaboration between Baltimore VA (Dr. Eliot Siegel) and GE Medical

During the breakout presentation, Carl came out with idea of using the threat detection algorithm used to designate areas of the bag needing human examination, i.e., the regions that with high-confidence do not contain threats are "masked-off" and the human does not need to examine them. This might be able to greatly reduce the number of screeners needed.

Interface Between Screener and Automatic Threat Detection

- If there are too many false positives, or if they typically point too "obvious" non-targets, they become ignored.
- Much can be learned from the experience of the medical community with computer aided diagnosis for screening applications, such as mammograms, with low target prevalence (2-5 per 1000).
- This is an interesting issue where fundamental data is deeply lacking. There is a data space defined by CAD ROC, Human ROC, & target prevalence. It is impossible to explore this space in the field (e.g. with radiologists or screeners). You need to test hypotheses in the lab and then deploy to the field. Some relevant work has been done
- We put this topic on the "back burner" until we could get Bob Nishikawa involved.
- Bob?



Horsch, K., Giger, M. L., & Metz, C. E. (2008). Prevalence scaling: applications to an intelligent workstation for the diagnosis of breast cancer. Acad Radiol, 15(11), 1446-1457.

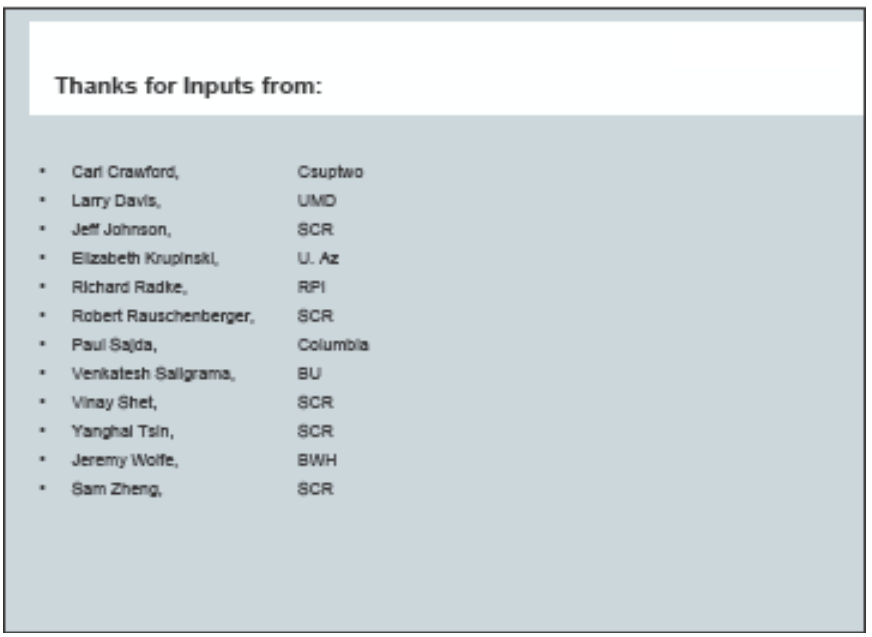
Improve the personal incentive schemes for screeners

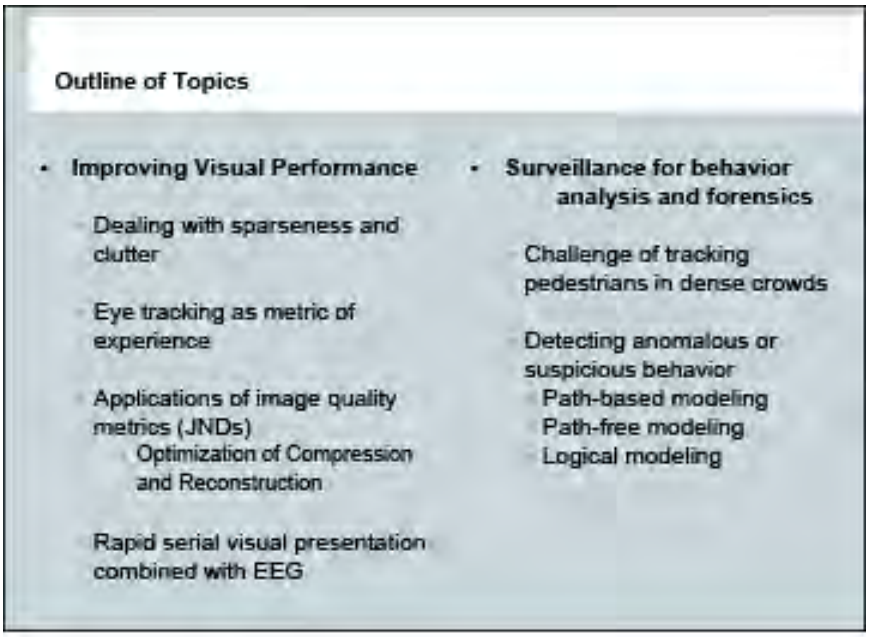
- Experience in Europe has shown that simple scoring of TIP (Threat Image Projection) is not enough. Perhaps making the TIP scores are part of a competitive game, its more useful.
- Red Team site visits are problematic as the "word gets out" to the screeners, etc....
- Combinations of money, promotion, peer and other recognition (pride), and RT reward systems can improve performance. But need careful, in-situ study.
- We need everyday and every week psudo-random stimuli to keep everyone on their toes, coupled to reward systems

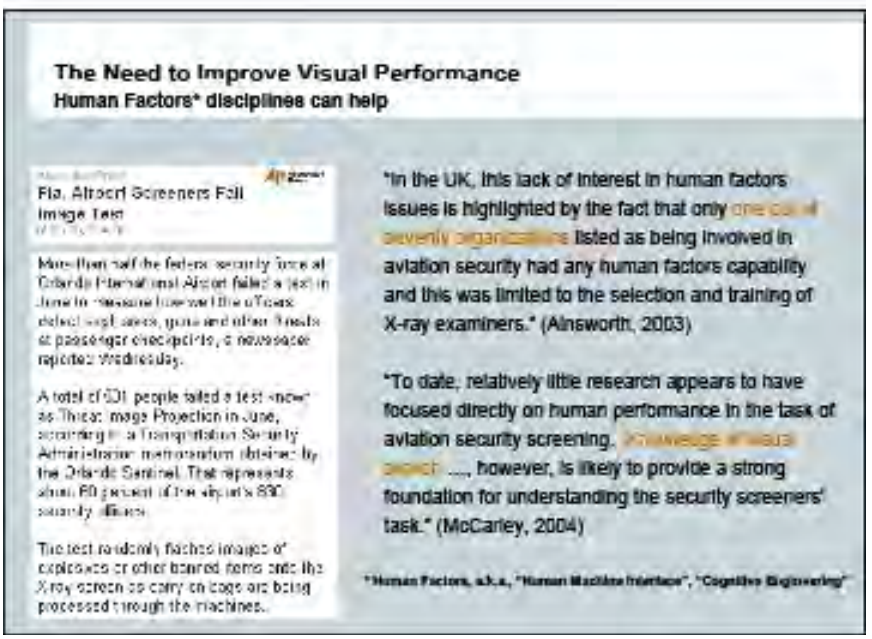
Other topics requiring further elaboration

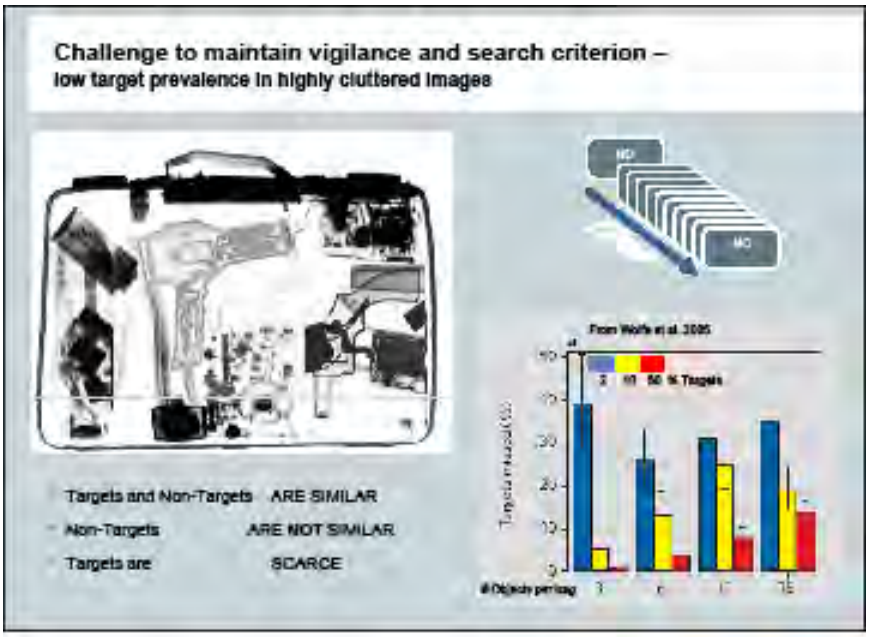
- "Machines better for explosive detection (organics), people better for detecting hard objects with shapes" – implications for workflow (Ellenbogen)
- Video analytics for keeping track of bag ownership to prevent the situation of a passenger picking up someone else's laptop, which can be very disruptive as the one passenger tries to get the attention or "run down" the other (Radke)

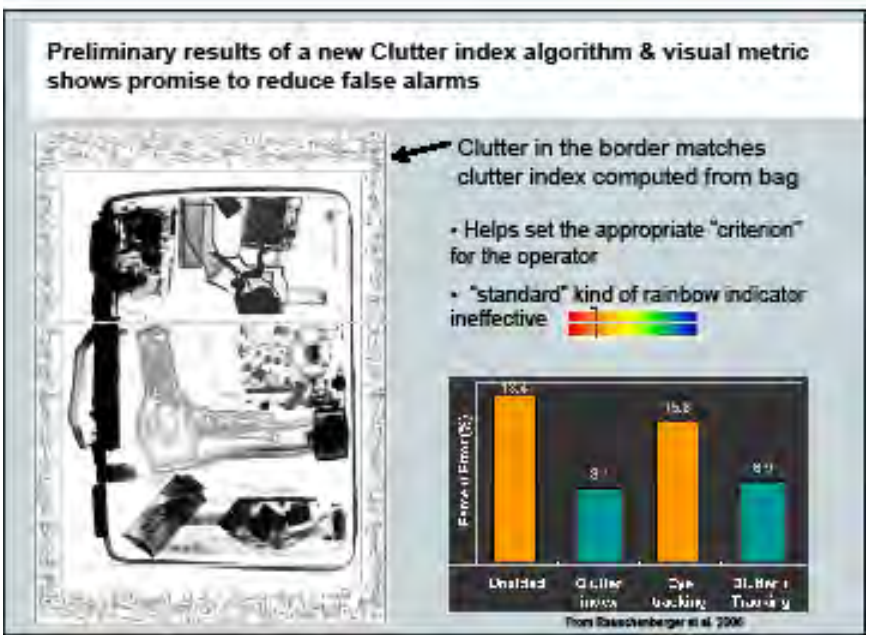
Surveillance and Human Factors:
Long-range Research Challenges &
Opportunities
John Pearson, PhD
Siemens Corporate Research
Princeton, NJ
For use of Department of Homeland Security and the ALERT Center only.

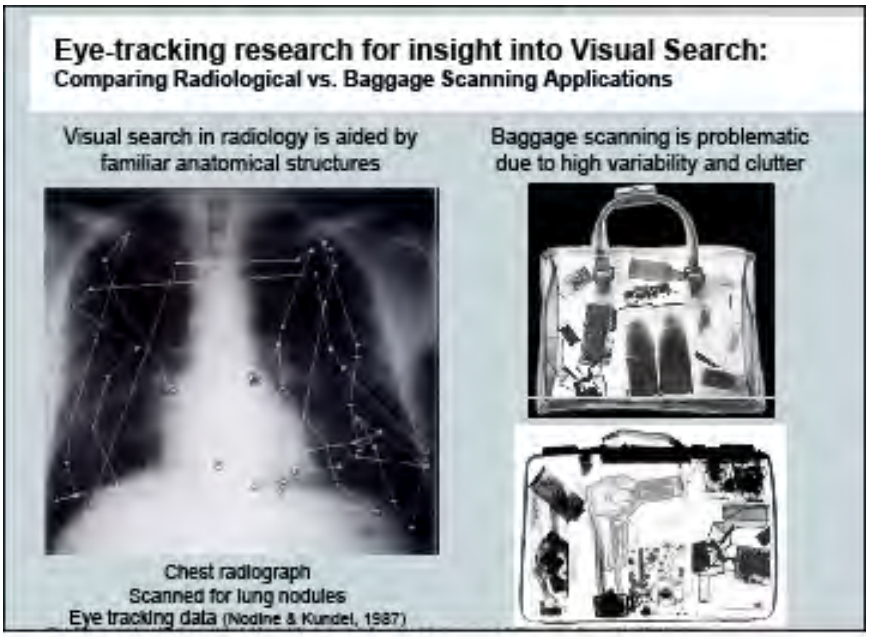

Thanks for Inputs from:
Carl Crawford, Csuptwo
Larry Davis, UMD
Jeff Johnson, SCR
Elizabeth Krupinski, U. Az
Richard Radke, RPI
Robert Rauschenberger, SCR
Paul Sajda, Columbia
Venkatesh Saligrama, BU
Vinay Shet, SCR
Yanghai Tsin, SCR
Jeremy Wolfe, BWH
Sam Zheng, SCR

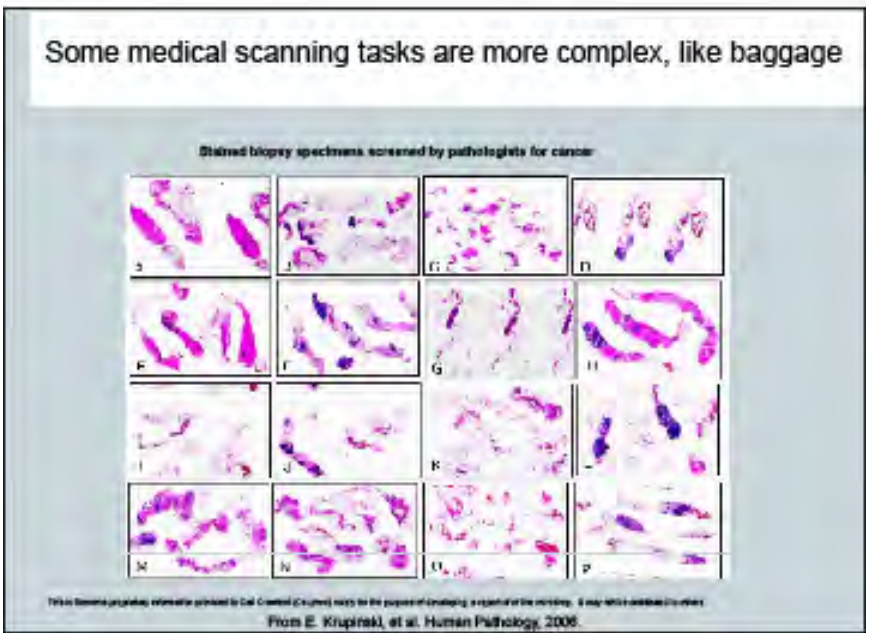

Outline of Topics
• Improving Visual Performance
Dealing with sparseness and clutter
Eye tracking as metric of experience
Applications of image quality metrics (JNDs)
Optimization of Compression and Reconstruction
Rapid serial visual presentation combined with EEG
• Surveillance for behavior analysis and forensics
Challenge of tracking pedestrians in dense crowds
Detecting anomalous or suspicious behavior
Path-based modeling
Path-free modeling
Logical modeling

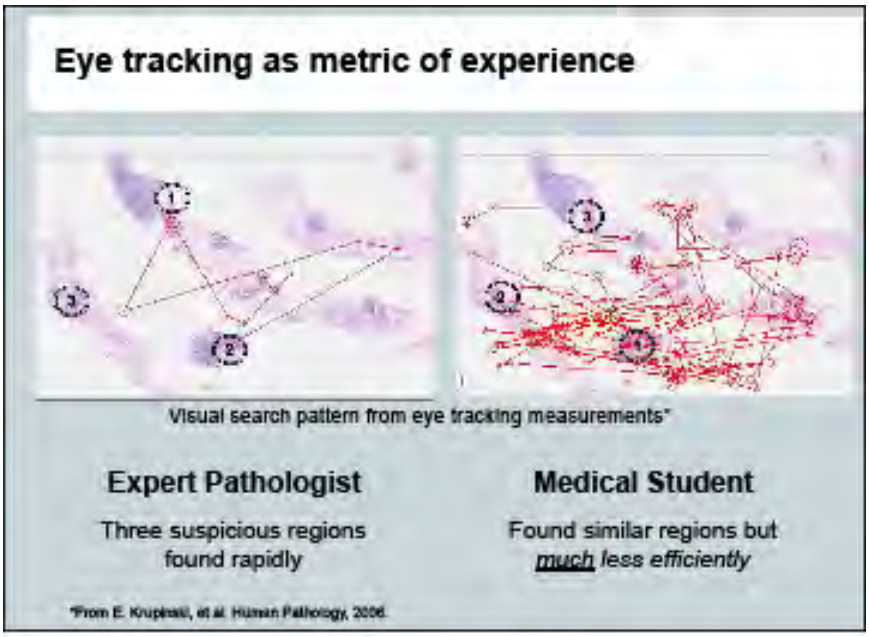

The Need to Improve Visual Performance
Human Factors* disciplines can help
Fla. Airport Screeners Fail Image Test
"In the UK, this lack of interest in human factors issues is highlighted by the fact that only one out of seventy organizations listed as being involved in aviation security had any human factors capability and this was limited to the selection and training of X-ray examiners." (Ainsworth, 2003)
"To date, relatively little research appears to have focused directly on human performance in the task of aviation security screening. ..., however, is likely to provide a strong foundation for understanding the security screeners' task." (McCarley, 2004)

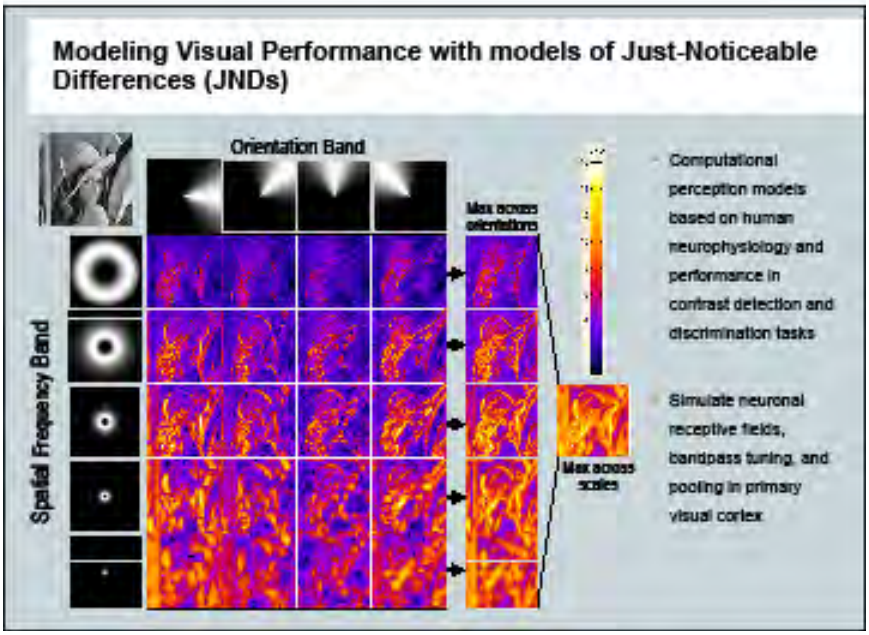

Challenge to maintain vigilance and search criterion –
low target prevalence in highly cluttered images
Targets and Non-Targets ARE SIMILAR
Non-Targets ARE NOT SIMILAR
Targets are SCARCE
From Wolfe et al. 2005
2 10 50 % Targets
Objects per bag

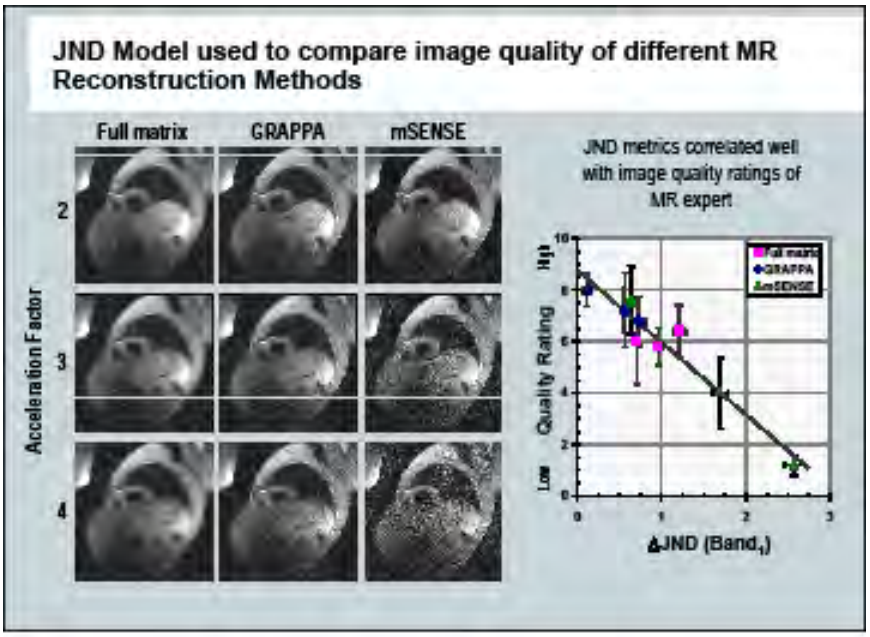

Preliminary results of a new Clutter index algorithm & visual metric
shows promise to reduce false alarms
Clutter in the border matches
clutter index computed from bag
• Helps set the appropriate "criterion"
for the operator
• "standard" kind of rainbow indicator
ineffective
Unaided
Eye tracking

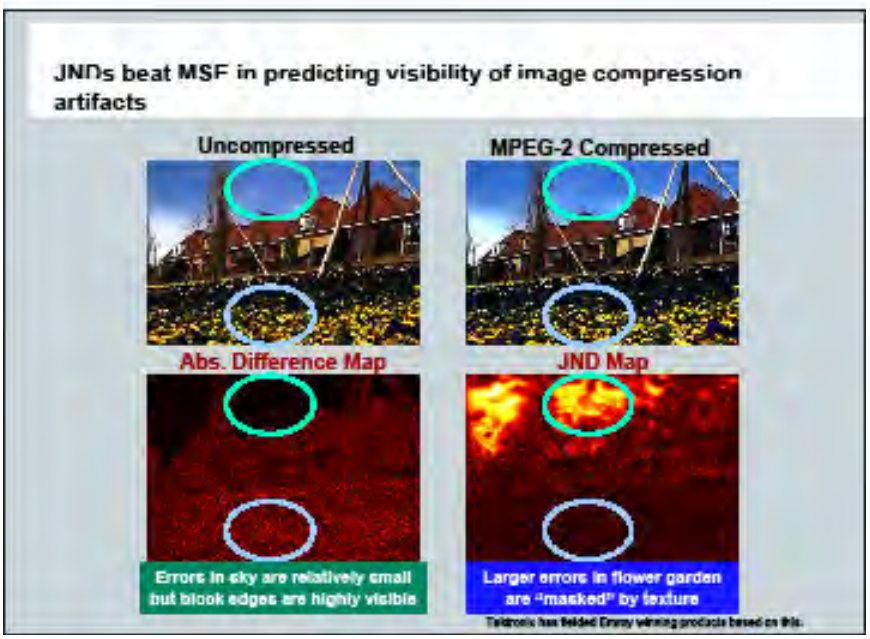

Eye-tracking research for insight into Visual Search:
Comparing Radiological vs. Baggage Scanning Applications
Visual search in radiology is aided by familiar anatomical structures
Baggage scanning is problematic due to high variability and clutter
Chest radiograph
Scanned for lung nodules
Eye tracking data (Nodine & Kundel, 1987)

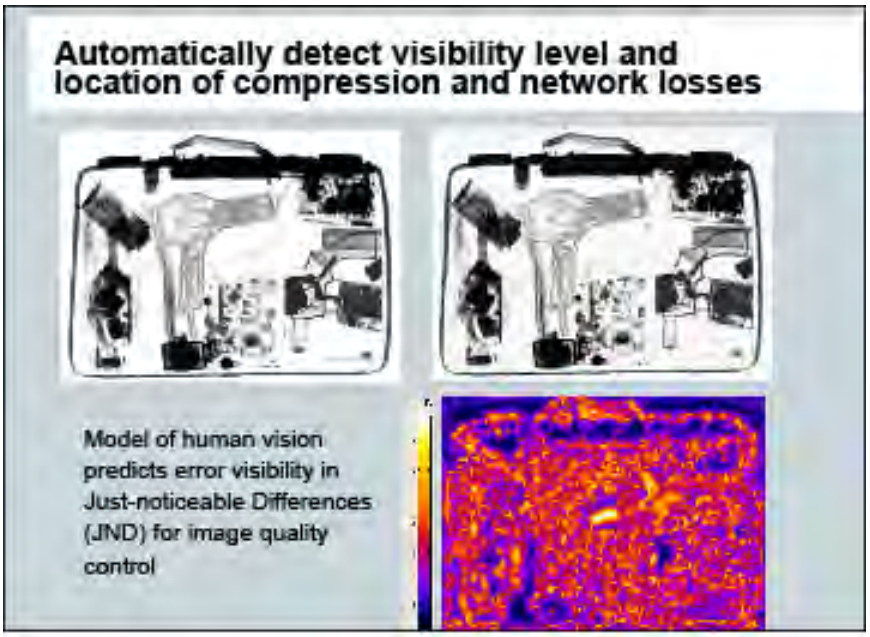

Some medical scanning tasks are more complex, like baggage
Stained biopsy specimens screened by pathologists for cancer
From E. Krupinski, et al. Human Pathology, 2006.

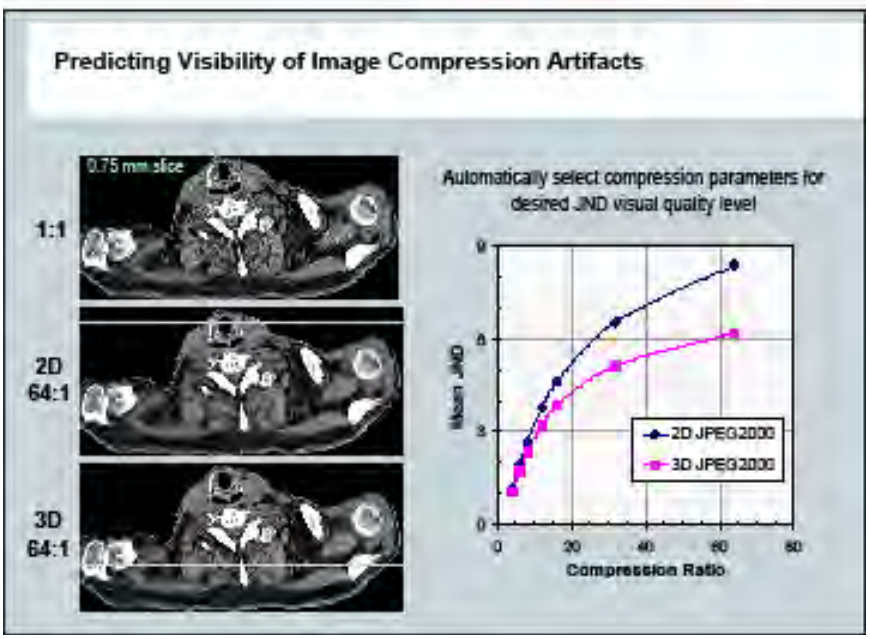

Eye tracking as metric of experience
Visual search pattern from eye tracking measurements*
Expert Pathologist
Three suspicious regions found rapidly
Medical Student
Found similar regions but much less efficiently
*From E. Krupinski, et al. Human Pathology, 2006.

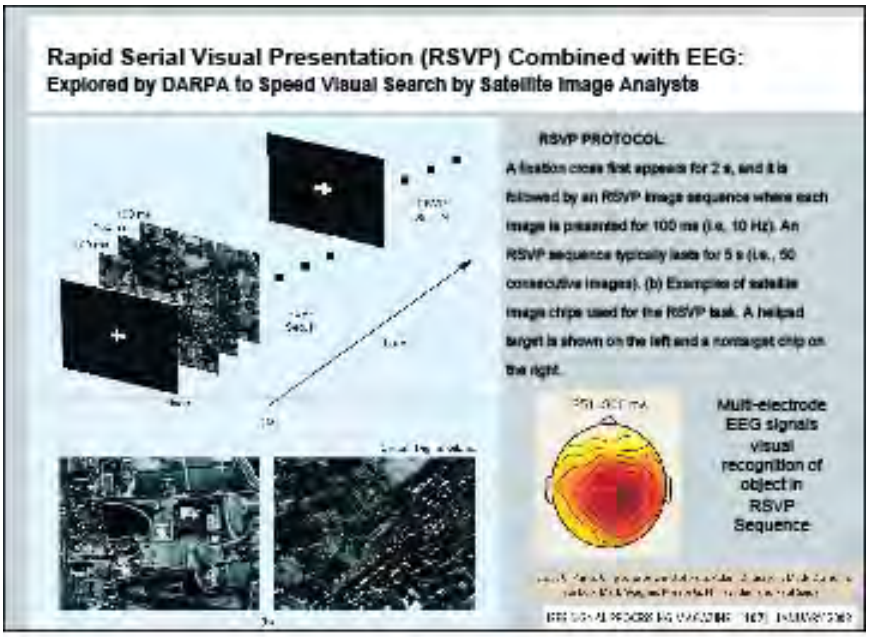

Modeling Visual Performance with models of Just-Noticeable Differences (JNDs)
Orientation Band
Spatial Frequency Band
Max across orientations
Max across scales
Computational perception models based on human neurophysiology and performance in contrast detection and discrimination tasks
Simulate neuronal receptive fields, bandpass tuning, and pooling in primary visual cortex

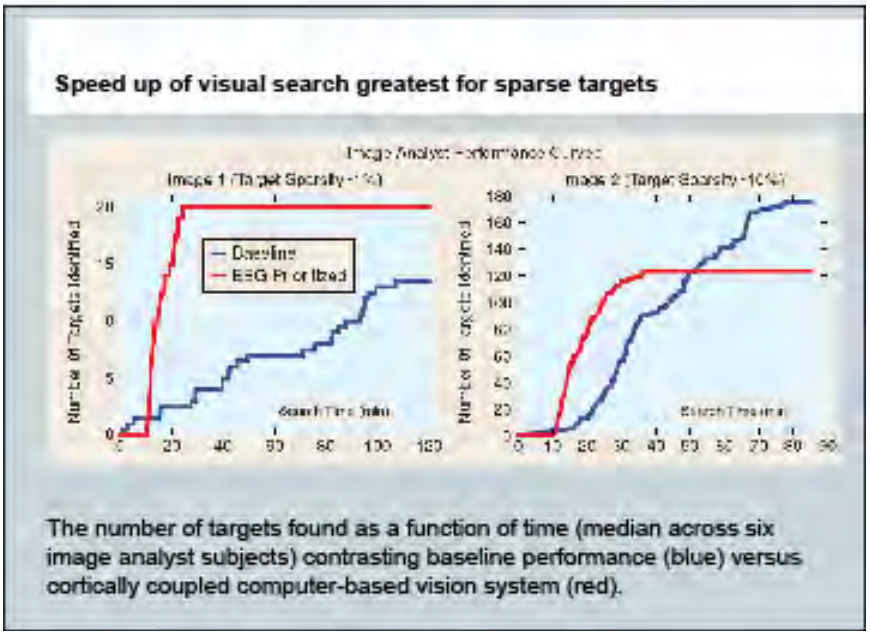

JND Model used to compare image quality of different MR Reconstruction Methods
Full matrix
GRAPPA
mSENSE
Acceleration Factor
2
3
4
JND metrics correlated well with image quality ratings of MR expert
Quality Rating
High
Low
ΔJND (Band,)


JNDs beat MSF in predicting visibility of image compression artifacts
Uncompressed
MPEG-2 Compressed
Abs. Difference Map
JND Map
Errors in sky are relatively small but blook edges are highly visible
Larger errors in flower garden are "masked" by texture


Automatically detect visibility level and location of compression and network losses
Model of human vision predicts error visibility in Just-noticeable Differences (JND) for image quality control


Predicting Visibility of Image Compression Artifacts
0.75 mm slice
1:1
2D 64:1
3D 64:1
Automatically select compression parameters for desired JND visual quality level
Mean JND
Compression Ratio
2D JPEG2000
3D JPEG2000


Rapid Serial Visual Presentation (RSVP) Combined with EEG:
Explored by DARPA to Speed Visual Search by Satellite Image Analysts
RSVP PROTOCOL
A fixation cross first appears for 2 s, and it is followed by an RSVP image sequence where each image is presented for 100 ms (i.e. 10 Hz). An RSVP sequence typically lasts for 5 s (i.e., 50 consecutive images). (b) Examples of satellite image chips used for the RSVP task. A helipad target is shown on the left and a nontarget chip on the right.
Multi-electrode EEG signals visual recognition of object in RSVP Sequence


Speed up of visual search greatest for sparse targets
Baseline
EEG Prioritized
The number of targets found as a function of time (median across six image analyst subjects) contrasting baseline performance (blue) versus cortically coupled computer-based vision system (red).

Outline

- Improving Visual Performance
  - Dealing with sparseness and clutter
  - Eye tracking as metric of experience
  - Applications of image discriminability metrics (JNDs)
    - Optimization of Compression and Reconstruction
  - Rapid serial visual presentation combined with EEG
- **Surveillance for behavior analysis and forensics**
  - Multi-camera fusion for enhanced surveillance
  - Challenge of tracking pedestrians in dense crowds
  - Detecting anomalous or suspicious behavior
    - Path-based modeling
    - Path-free modeling
    - Logical modeling

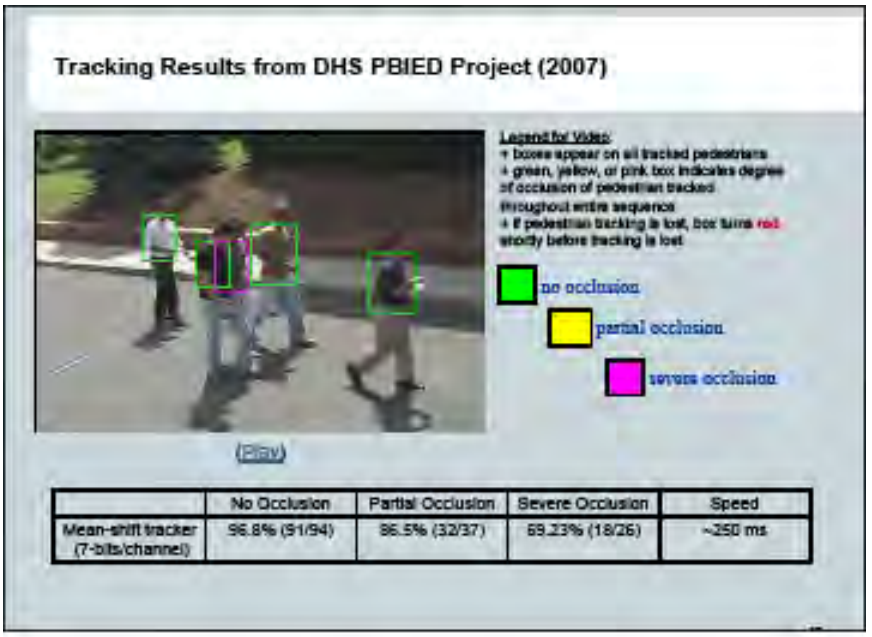
Tracking Approach used in DHS PBIED Project (2007)

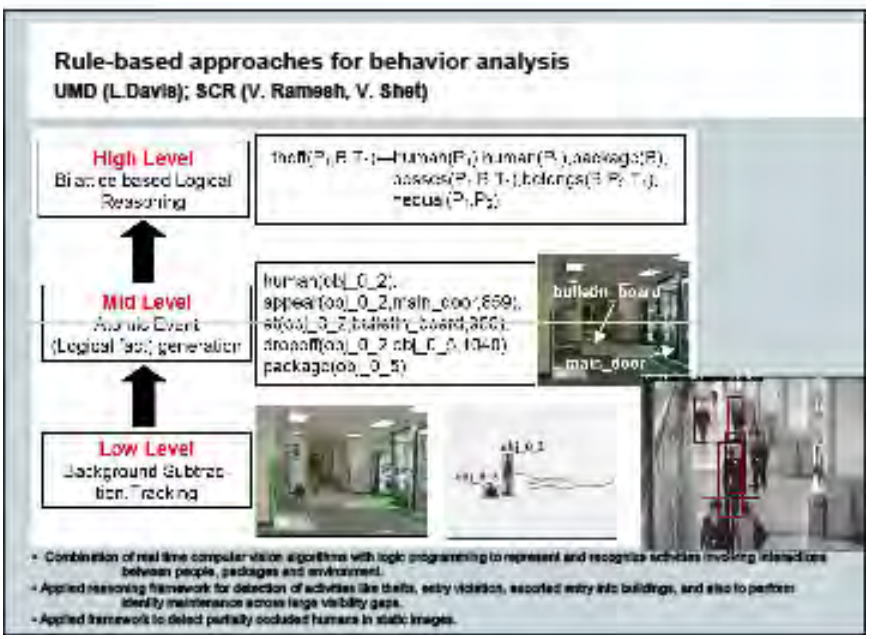
Develop model of each detected pedestrian

- Color histograms (Comaniciu et. al. CVPR 2000, ICCV 2001)
  - Simplest model, not accurate but versatile
- Multiple-part color histograms (Parameswaran CVPR 2006)
  - More complex, more accurate, more computationally expensive
  - Not tested in phase I, but may need to bring into phase 2

Find Matching pedestrians in neighboring video frames

- Gradient search
  - Easiest and fastest, but not the best
- Other methods that could be used
  - Multiple-hypotheses particle filtering
    - Resolving possible ambiguities
  - Deformable model matching


Tracking Results from DHS PBIED Project (2007)
Legend for Video:
• boxes appear on all tracked pedestrians
• green, yellow, or pink box indicates degree of occlusion of pedestrian tracked throughout entire sequence
• if pedestrian tracking is lost, box turns red shortly before tracking is lost
no occlusion
partial occlusion
severe occlusion
(Play)
No Occlusion
Partial Occlusion
Severe Occlusion
Speed
Mean-shift tracker (7-bits/channel)
96.8% (91/94)
86.5% (32/37)
69.23% (18/26)
~250 ms


Rule-based approaches for behavior analysis
UMD (L.Davis); SCR (V. Ramesh, V. Shet)
High Level
Mid Level
Low Level
Background Subtraction, Tracking
bulletin_board
main_door
• Combination of real time computer vision algorithms with logic programming to represent and recognize activities involving interactions between people, packages and environment.
• Applied reasoning framework for detection of activities like thefts, entry violation, escorted entry into buildings, and also to perform identity maintenance across large visibility gaps.
• Applied framework to detect partially occluded humans in static images.

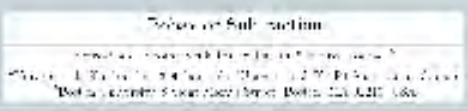
Detecting anomalous behavior by modeling motion paths: overcoming clutter with clustering

(a) Tracks of low-level features exhibiting significant noise – not useful for characterizing or modeling the motion of the crowd.

(b) Smooth robust model of crowd motion derived from clustering and statistical processing of the individual feature tracks.

Detecting anomalous behavior without modeling motion paths – "behavior subtraction"

Behavior Subtraction detects abnormal behaviors without explicitly using motion paths. It is statistically motivated and general enough to monitor humans, cars or any other moving objects in a scene. It is well suited to both uncluttered and highly-cluttered scenes, and requires little processing power.



Slides with more detailed information not presented or discussed

Slides with more detailed information not presented or discussed

Input from Rick Moore and Dan Kopans on the use of double-rea

Visual Tracking for Surveillance: State of the Art

- Blob tracking: tracking by comparing a background model, cannot handle crowd by itself
  - Classical: [Wren 97]
  - Modeling "normal" changes (thus ignoring these "normal" changes):
    waving trees et al: [Stauffer 99], dynamic background (ocean waves) [Mittal04],
    shadow [Mittal 06] [Singh 08], normal dynamics[Jodoin 08]
- Local gradient search methods
  - Classical methods: [Lucas-Kanade 81], SSD: [Hager 98]: restricted to parametric motion models
  - Mean shift trackers: can handle non-rigid deformations of targets
    - Original: [Comaniciu 00],
    - With bandwidth adaptation: [Comaniciu 01], [Collins 03a],
    - Multiple-kernels for articulated objects [Parameswaran '06]
- Tracking in *low contrast* and/or clutter
  - Online feature selection [Collins 03b]
  - Classifying/segmenting foreground/background: [Avidan 07], [Lu 07]

Visual Tracking for Surveillance: State of the Art (cont.)

- Avoiding visual distracters
  - Keeping multiple hypotheses using particle filtering: [Isard 98]
  - Density propagation [Han 09]
  - Using context [Sigal 04], [Wu 09]
- Tracking in crowd
  - Multi-camera tracking [Mittal 03] [Zhao 04]
  - Embed people detection in tracking [Andriluka 08]
  - Crowd density estimation [Paragios 01]
  - Dominant motion estimation [Cheriyadat 03]
  - Utilizing physical constraints (no interpenetration between two objects) [Khan 04]

References

[Avidan 07] S. Avidan: *Ensemble Tracking*, *IEEE TPAMI*, Vol. 29(2), pp 261-271, 2007

[Collins 03a] *R.Collins, "Mean-shift Blob Tracking through Scale Space," CVPR '03, Madison, WI, June 16-22, 2003, pp 234-240.*

[Collins 03b] *R. Collins and Y. Liu: On-Line Selection of Discriminative Tracking Features*, ICCV'03

[Comaniciu 00] D. Comaniciu, V. Ramesh, P. Meer: *Real-Time Tracking of Non-Rigid Objects Using Mean Shift*, CVPR 2000: 2142-2149

[Comaniciu 01] D. Comaniciu, V. Ramesh, P. Meer: *The Variable Bandwidth Mean Shift and Data-Driven Scale Selection*, ICCV 2001: 438-445

[Dong 07] L. Dong, V. Parameswaran, V. Ramesh, I. Zoghlami: *Fast Crowd Segmentation Using Shape Indexing*, ICCV 2007

[Hager 98] G. Hager and P. Belhumeur, *Efficient Region Tracking with Parametric Models of Geometry and Illumination*, TPAMI, 20(10),

[Jodoin 08] P. Jodoin, J. Konrad, V. Saligrama, *Modeling Background Activity for Behavior Subtraction*, ICDSC 2008

[Lu 07] L. Lu and G.D. Hager, *A Nonparametric Treatment on Location/Segmentation Based Visual Tracking*, CVPR'2007

[Mittal 01] A. Mittal, N. Paragios: Motion-Based Background Subtraction Using Adaptive Kernel Density Estimation. CVPR (2) 2004: 302-309

[Mittal 03] A. Mittal, V. Ramesh: An Intensity-augmented Ordinal Measure for Visual Correspondence. CVPR (1) 2006: 849-856

[Paragios 01] N. Paragios, V. Ramesh, R., Stenger, F. Coetzee, *Real-time crowd density estimation from video*, US Patent 7139409

[Parameswaran 05] V. Parameswaran, V. Ramesh, I. Zoghlami: Tunable Kernels for Tracking. CVPR (2) 2005: 2179-2186

[Shet 07] V. D. Shet, J. Neumann, V. Ramesh, L.S. Davis: *Bilattice-based Logical Reasoning for Human Detection*. CVPR 2007

[Sigal 04] L. Sigal, Y. Zhu, D. Comaniciu and M. Black, *Graphical Object Models for Detection and Tracking*, NIPS'04.

[Singh 06] M. Singh, V. Parameswaran, V. Ramesh, *Order Constrained Change Detection via Fast Statistical Significance Testing*, CVPR 2008

[Stauffer 99] C. Stauffer, E. Grimson, "Adaptive background mixture models for real-time tracking", CVPR 1999.

[Wren 97] C.R. Wren, A. Azarbayejani,T. Darrell, and A. P. Pentland, *Pfinder: Real-Time Tracking of the Human Body. TPAMI 97*

References

[Isard 98] M. Isard and A. Blake, CONDENSATION - conditional density propagation for visual tracking, IJCV 1998

[Wu 03] Y. Wu and J. Fan, "Contextual Flow", CVPR 2009

[Han 09] B. Han, Y. Zhu, D. Comaniciu and L. Davis, *Visual Tracking by Continuous Density Propagation in Sequential Bayesian Filtering Framework* , TPAMI, 2009

[Mittal 03] A. Mittal and L. S. Davis, *M2Tracker: A Multi-View Approach to Segmenting and Tracking People in a Cluttered Scene*. IJCV 03

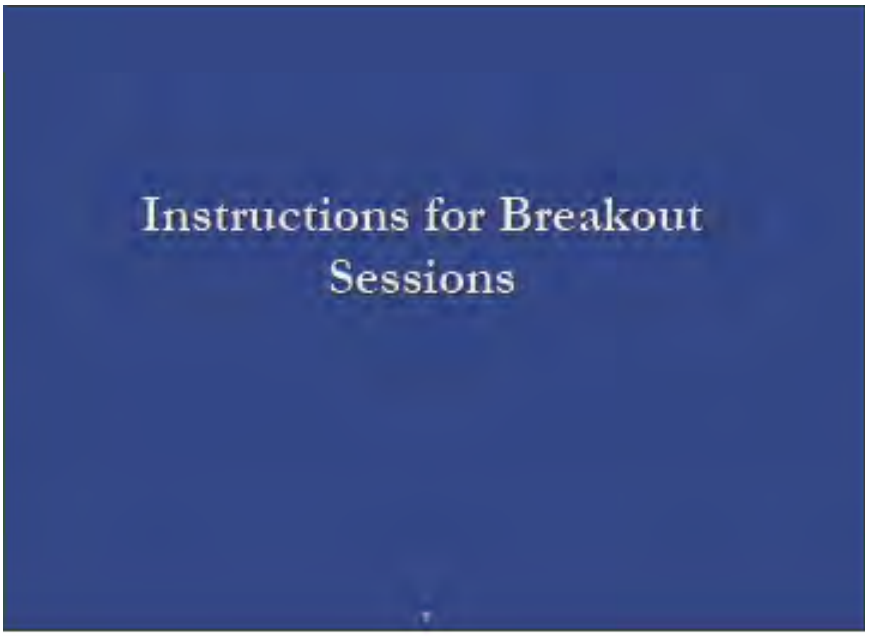
[Cheriyadat 03] A.M. Cheriyadat and R.J. Radke, *Detecting Dominant Motions in Dense Crowds*, IEEE Journal of Special Topics in Signal Processing, Special Issue on Distributed Processing in Vision Networks

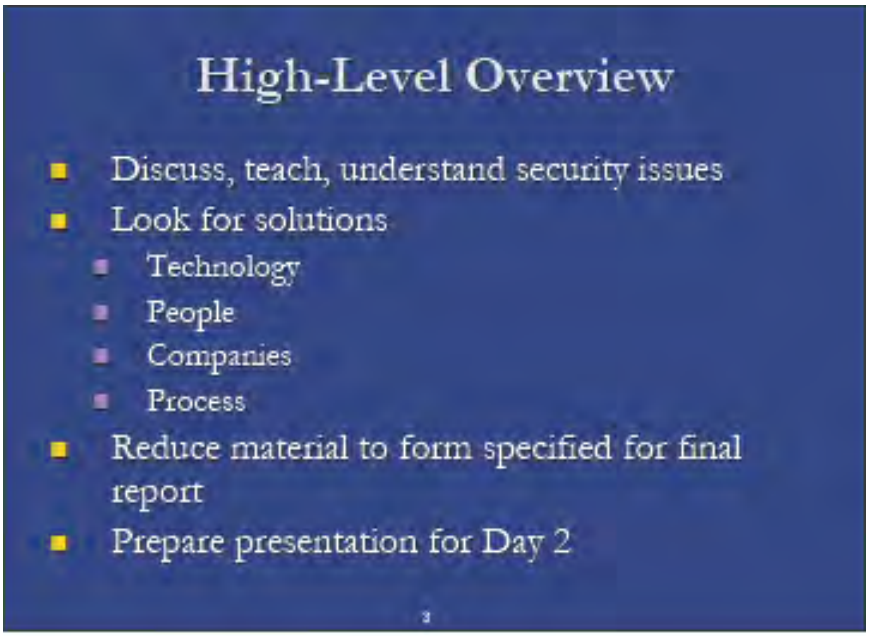
[Khan 04] Z. Khan, T. Balch, and F. Dellaert, *An MCMC-based Particle Filter for Tracking Multiple Interacting Targets*, ECCV 2004

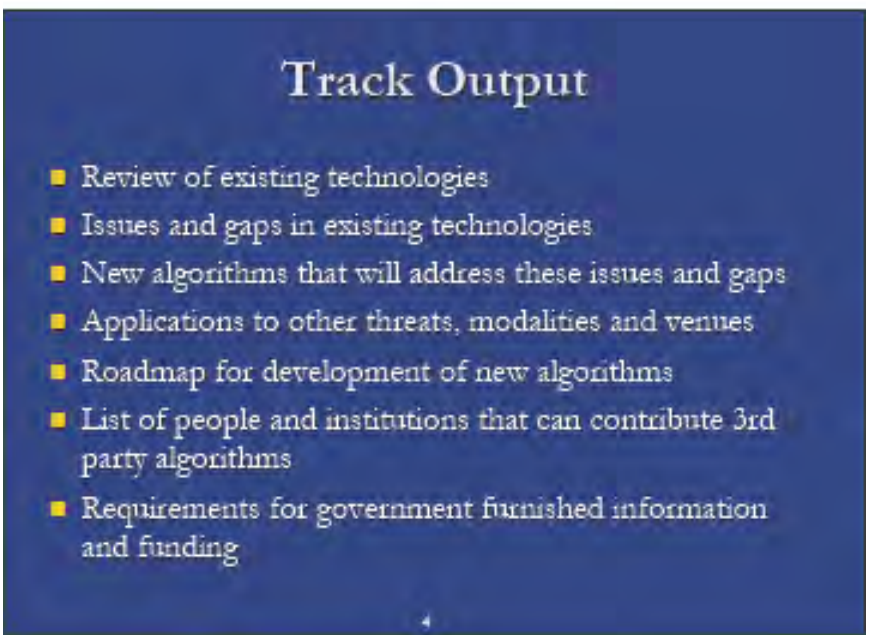
[Andriluka 08] M. Andriluka S. Roth B. Schiele, *People-Tracking-by-Detection and People-Detection-by-Tracking*, CVPR 2008

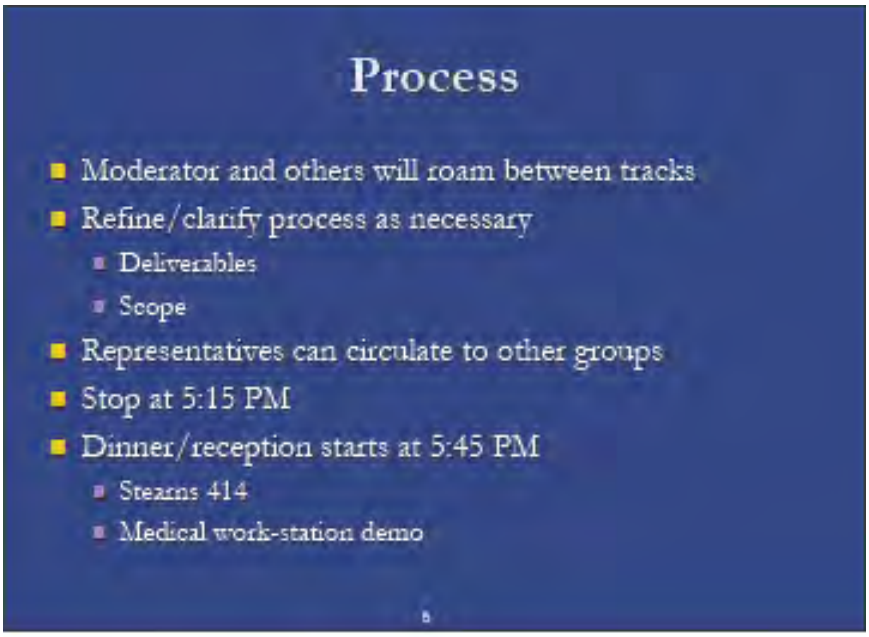
[Zhao 04] T. Zhao and R. Nevatia, *Tracking multiple humans in complex situations*, PAMI, 2004

23.8 Carl Crawford Presentation 2 Slides

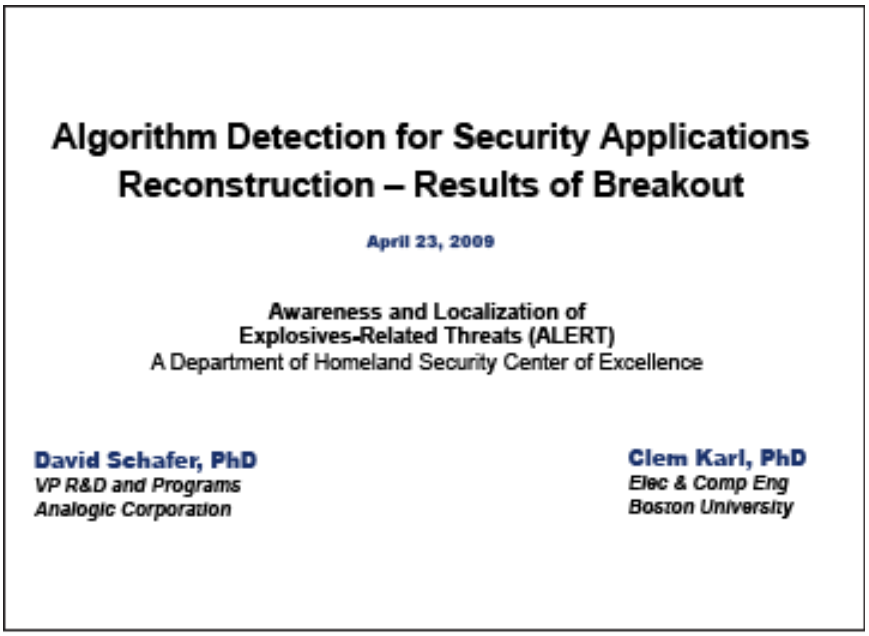


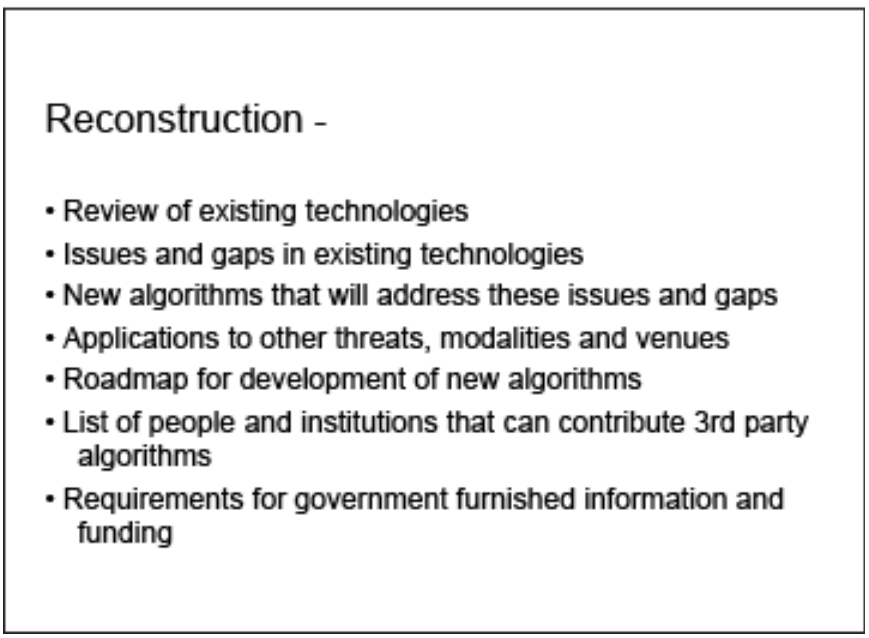

High-Level Overview
Discuss, teach, understand security issues
Look for solutions
Technology
People
Companies
Process
Reduce material to form specified for final report
Prepare presentation for Day 2
3


Track Output
Review of existing technologies
Issues and gaps in existing technologies
New algorithms that will address these issues and gaps
Applications to other threats, modalities and venues
Roadmap for development of new algorithms
List of people and institutions that can contribute 3rd party algorithms
Requirements for government furnished information and funding
4


Process
Moderator and others will roam between tracks
Refine/clarify process as necessary
Deliverables
Scope
Representatives can circulate to other groups
Stop at 5:15 PM
Dinner/reception starts at 5:45 PM
Stearns 414
Medical work-station demo

23.9 David Schafer Presentation Slides

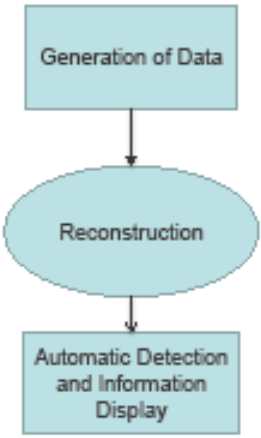




Review of existing technology

- CT reconstruction
  - Helical Cone Beam Recon
  - Algorithm varies by Vendor
  - Algorithm tuned to specific scanner by vendor
- Multi-view
  - ART or other limited view recon
- MMW
  - Holographic methods

Algorithms are generally developed by vendors to produce images that are optimized for either automatic detection or image presentation.



Issues and Gaps

- CT artifacts
  - Physical artifacts
    - Cone Beam, Scatter
  - Source / Spectral artifacts
    - Beam Hardening, Photon Starvation, multiple source
  - Application specific artifacts
    - Metal Artifacts
  - Improved image in presence of clutter
- Good sensor models are not available to academia
- Security industry not as mature as DoD in working with Academia
- Publication of results (sometimes SSI?)
- Use of international students for research

New algorithms that can address gaps

- CT
  - Targeted reconstruction to specific threats
  - Segmentation oriented reconstruction methods
  - System modeling
  - Local reconstructions
  - Targeted reconstruction to detection vs. display
- Other/General
  - 2 ½ D algorithms for limited view scanners
  - Parametric reconstruction

Opportunities for new algorithms

- Get better sensor models into academia
- Use developed tools to model physical phenomena
  - Scatter, Spectral, etc
- Model next generation sensors
- Review how to bring prior information into the reconstruction problem

Opportunities for working relationships

- Take lessons from DoD programs
- MURI – multi-university research initiatives
  - Example – Synthetic aperture radar
  - Proper time horizons
  - 5-6 year research horizons
- Support short term vendor/university collaborations targeted at specific problems
  - Shorter time horizon
  - 2-3 years feasible
- Question – does time frame limit work to existing sensors?

Applications to other threats, modalities or venues

- Algorithm work can provide platform for checked bag and / or Cargo applications of CT and multi-view scanners
- Application specific recons can be tuned to allow targeting of new threat scenarios – e.g. – liquids
  - Possible algorithms to detect motion of liquid?

Who should be Contacted

- Many of the experts are here at this meeting
- Recommend continue networking effort
  - Develop list of research labs, universities, companies that can do this type of work

Roadmap for Development

- Expand role of centers of excellence
- Continue to conduct meetings such as this one

- Short Term road map
  - Develop funding methods that support collaborative work
    - Help resolve issues such as publishing, use of international students, intellectual property
  - Fund targeted reconstruction advancements through vendors for maximum return on investment in near term
- Longer Term road map
  - Develop models such as MURI for longer reaching issues

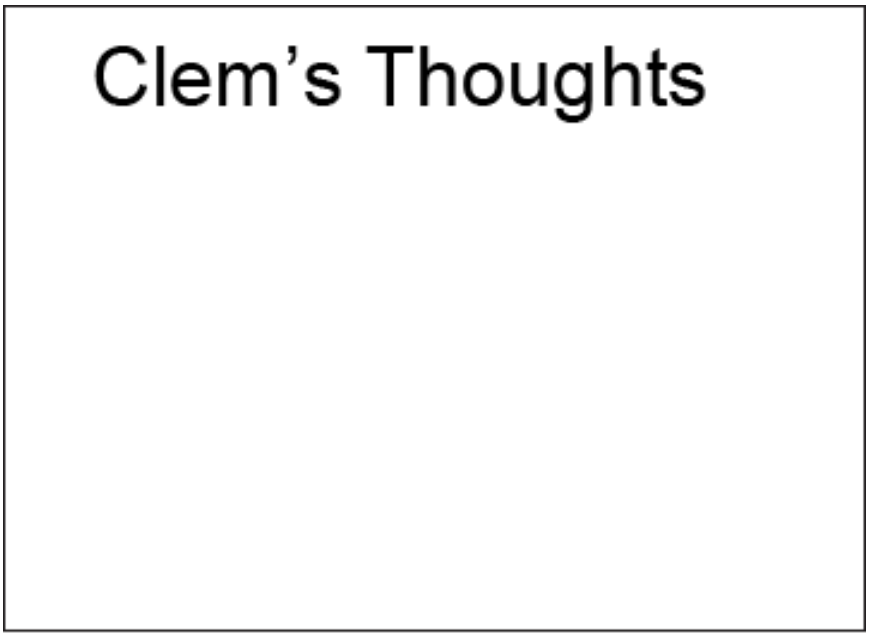
Requirements for Government funding

•Address opportunities to fund industry/academia/national lab collaborations
•Address opportunities to fund academia directly such as MURI

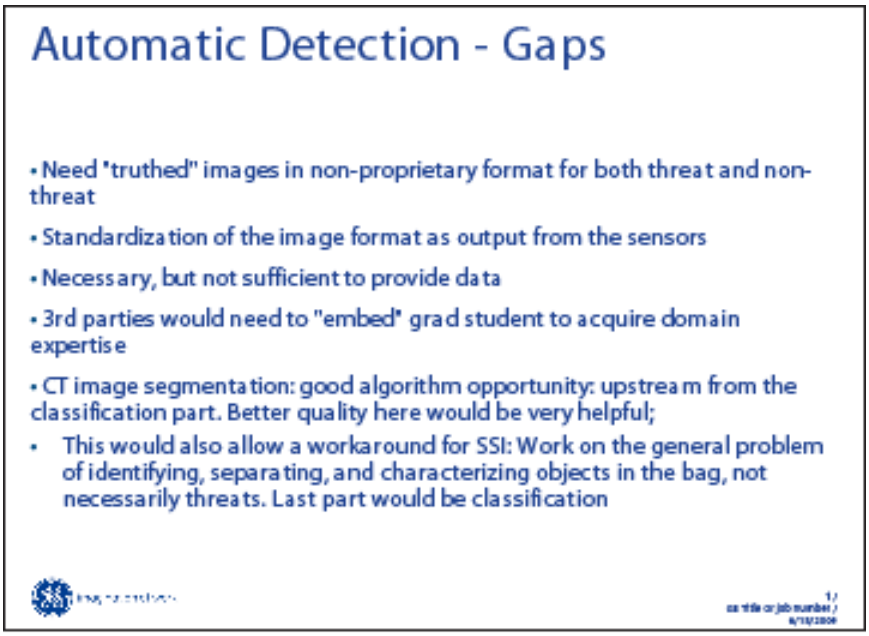
•Discussion

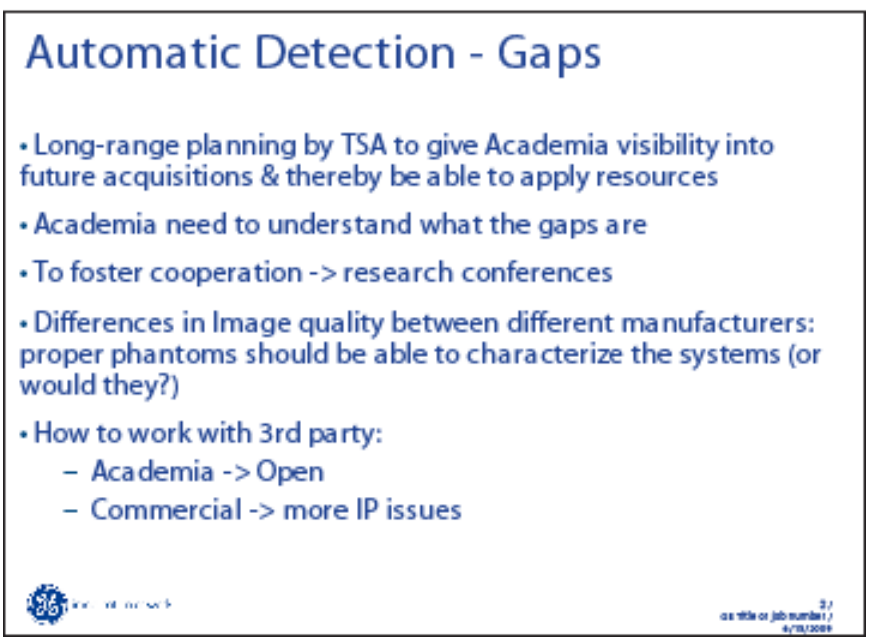
Clem's Thoughts as an Academic

- Is there is a gap in the understanding of the gaps?
- Need ways to experiment and explore
  - Behavior of the problem
  - Tradeoffs
  - What you get for what you "spend"
  - Limits to performance
- Need "playground"
  - Idea: CT centered simulation suite for DHS applications??
  - Unclassified data, database of scenarios
- Culture of community involvement

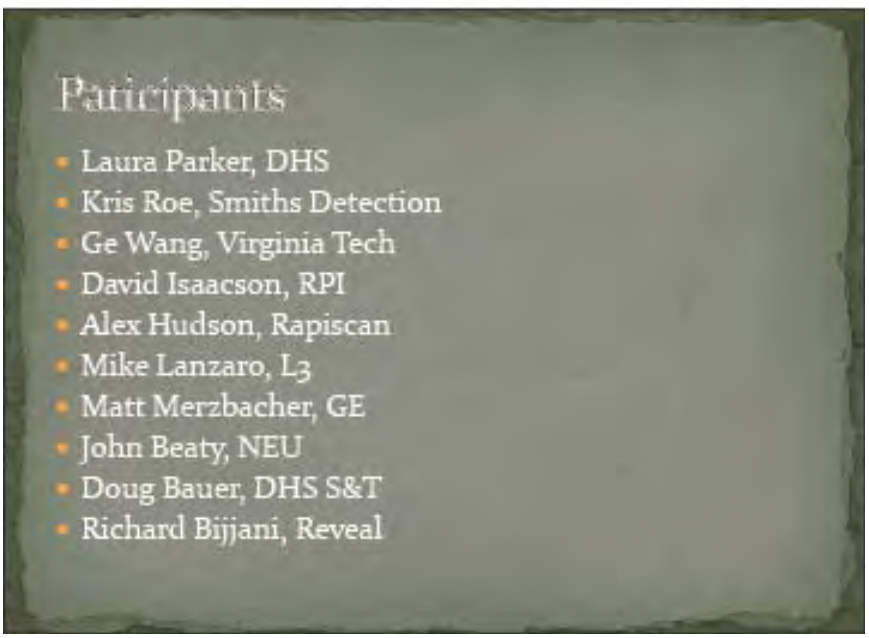

Clem's Thoughts

23.10 Sondre Skatter Presentation 2 Slides





23.11 Richard Bijjani Presentation 2 Slides



How do you bring new Technologies to the field?
Most 'long term' R&D efforts allow for only incremental improvements. Not enough invested in basic science/research to allow for revolutionary development
DHS wants to get out of the endless spiral development
High Risk R&D efforts should not be done in vacuum
Gaps need to be identified, may be different for different modalities.
Insure research relevance by coupling academia with industrial partners
Avoid DHS endless spiral development by defining a clear exit strategy through procurement contracts
DHS S&T to help bring the 2 sides together by sponsoring conferences where researchers present new ideas to potential industrial sponsors looking for orthogonal sensor / algorithm development

23.12 David Castáñon Presentation Slides

Key Questions

- Do we have enough information to do the task of detection for the diverse target set?
  - Understanding of targets, environments, objectives
  - Resolution, signal strength
  - Discriminating signatures
- Where is the throughput gap?
  - Data collection
  - Image formation/reconstruction
  - Image processing/detection/information extraction
  - Others?
- Are there concepts that provide needed complementary information?
  - Penetration, separation signatures for different targets
  - Scattering, better specificity for transformative materials?
  - Adaptive sensing/processing: Are we collecting/processing too much information or not the right information?
- Can we create an environment to focus increased attention on research to address these issues and to allow comparative evaluation and maturation of promising ideas?

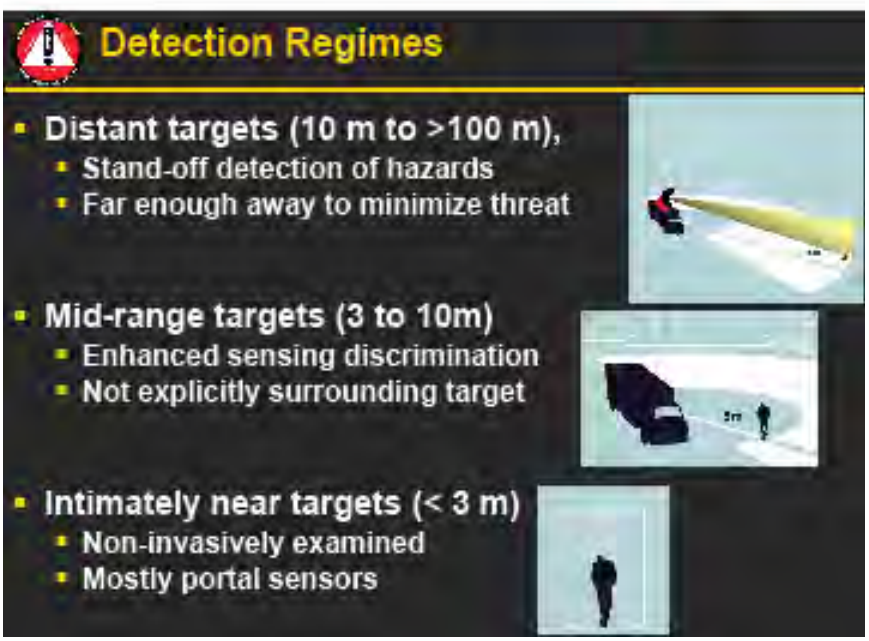
A Nucleating Idea: Challenge Problems and Testbeds

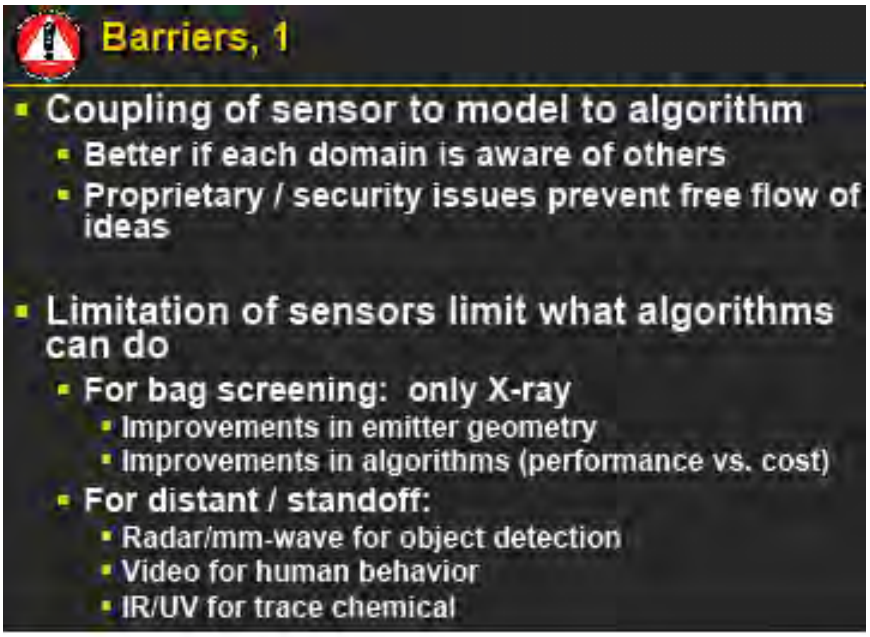
- Releasing data is not enough
  - Data without models or ground truth
- Collecting imagery in common formats is not enough
  - Restricts and pigeonholes innovation to what you can do with specific sensing geometries, modalities, image formation
  - Focuses on small incremental improvements
- What are the design degrees of freedom in innovation one is interested in fostering interest and innovation?
  - Modalities, sensing configurations and design, reconstruction algorithms, segmentation/detection, adaptive processing
- Challenge problems
  - Motivated by identified gaps created by difficult cases or evolving requirements
  - Releasable without significant security restrictions
  - Data sets + sensor models + benchmark processing + simulation, with well-defined metrics
  - Allow evaluation of new ideas at many different levels in a modular fashion with small overhead
  - Defined by Industry/National Labs/academia dialogue
  - Evolve new challenge problems to address emerging gaps

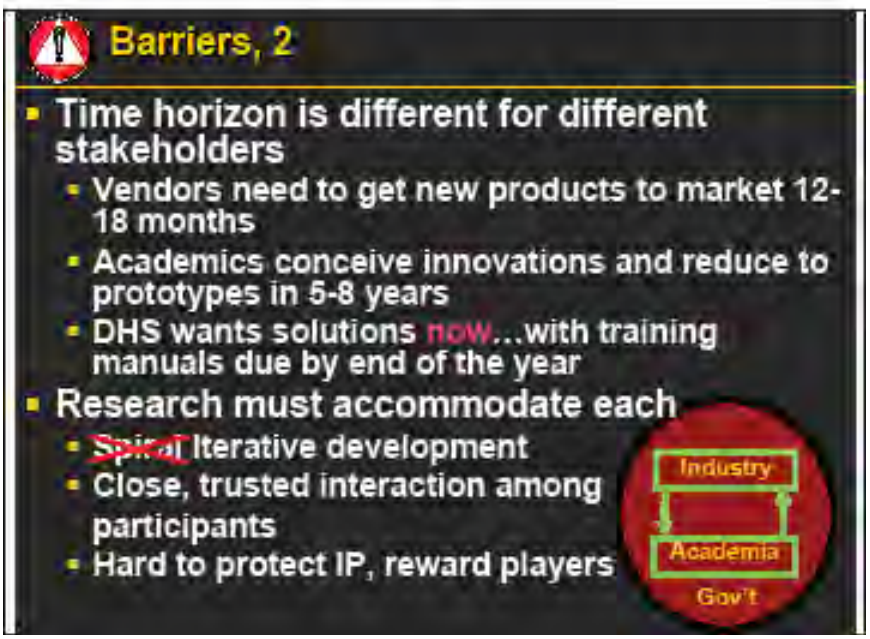
Other Ideas: Technology Transfer

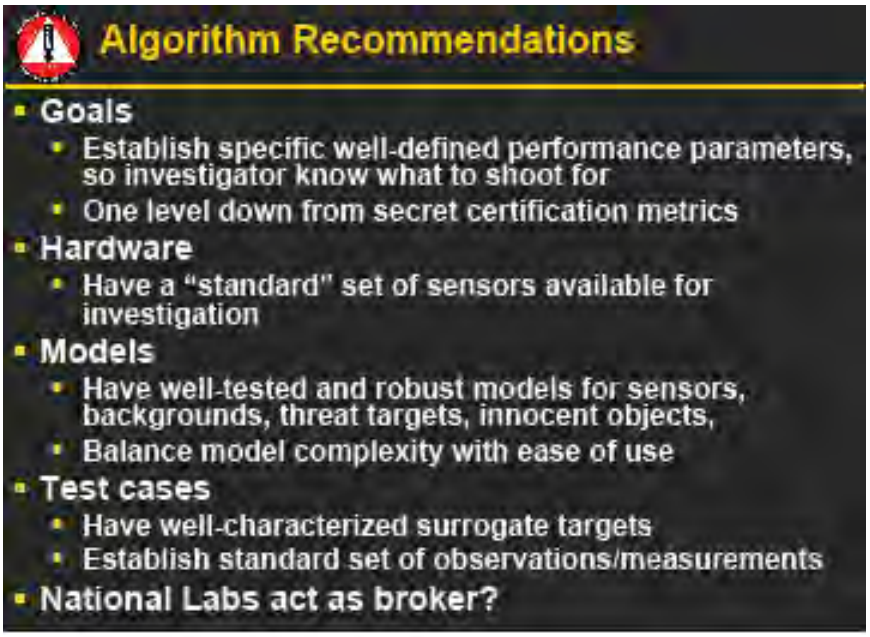
- Create a mechanism for transferring the challenge problems to the academic community
  - Organize sessions at non-DHS conferences to present challenges and progress (e.g. SPIE, Medical imaging)
- Create vehicles for personnel interactions/technology transfer between academia and industry
  - Goal 1: bring emerging technology expertise and results into applications domain
  - Goal 2: bring domain expertise and realism to focus basic research thrusts on relevant problems
  - STTR
  - Industry/National Lab internships
  - Faculty internships

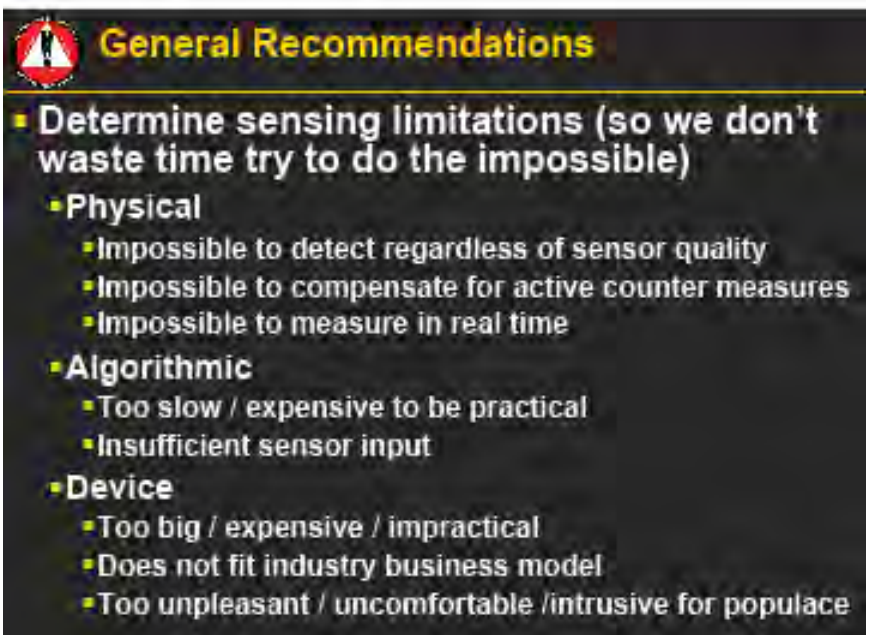
23.13 Carey Rappaport Presentation Slides



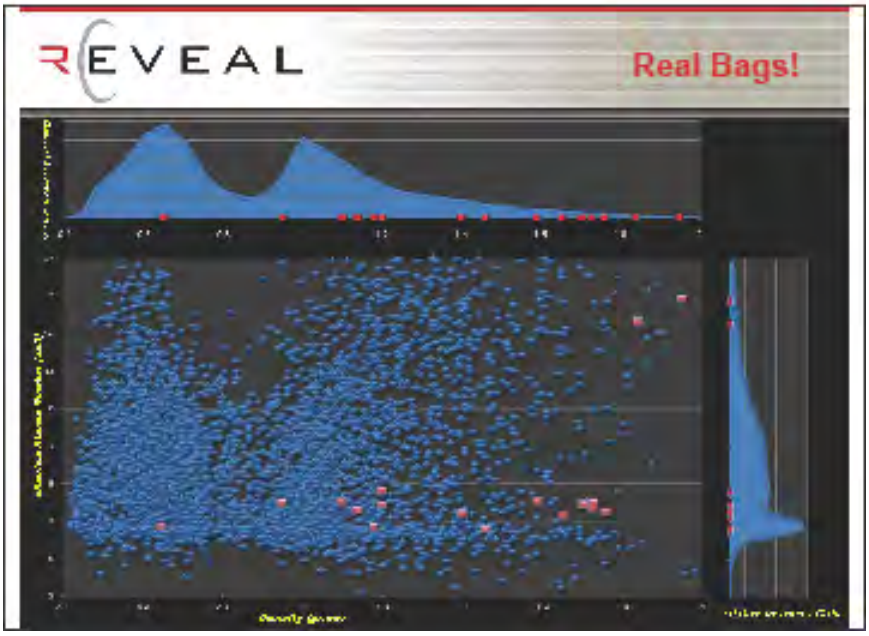

Barriers, 1
Coupling of sensor to model to algorithm
Better if each domain is aware of others
Proprietary / security issues prevent free flow of ideas
Limitation of sensors limit what algorithms can do
For bag screening: only X-ray
Improvements in emitter geometry
Improvements in algorithms (performance vs. cost)
For distant / standoff:
Radar/mm-wave for object detection
Video for human behavior
IR/UV for trace chemical

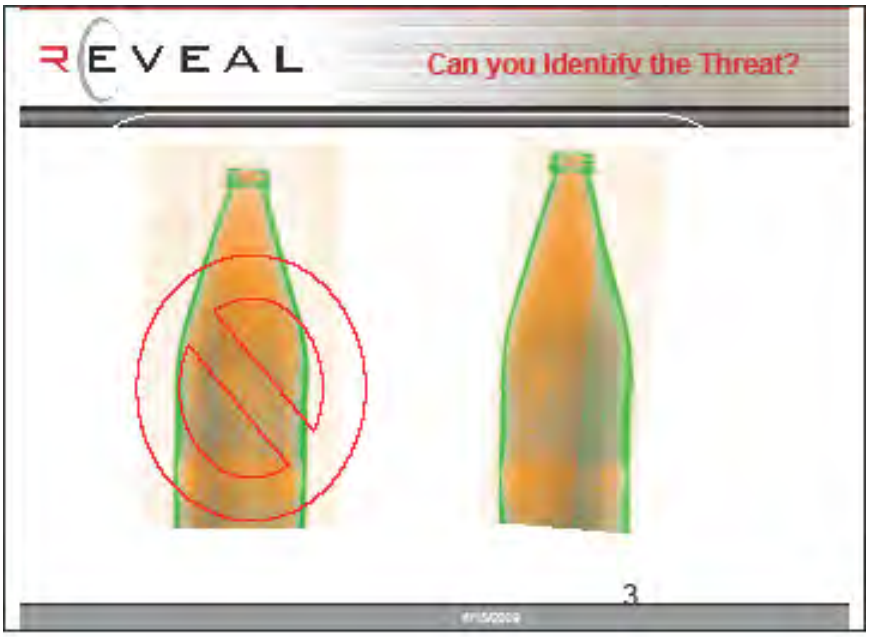

Barriers, 2
Time horizon is different for different stakeholders
Vendors need to get new products to market 12-18 months
Academics conceive innovations and reduce to prototypes in 5-8 years
DHS wants solutions now…with training manuals due by end of the year
Research must accommodate each
Iterative development
Close, trusted interaction among participants
Hard to protect IP, reward players
Industry
Academia
Gov't


Algorithm Recommendations
Goals
Establish specific well-defined performance parameters, so investigator know what to shoot for
One level down from secret certification metrics
Hardware
Have a "standard" set of sensors available for investigation
Models
Have well-tested and robust models for sensors, backgrounds, threat targets, innocent objects,
Balance model complexity with ease of use
Test cases
Have well-characterized surrogate targets
Establish standard set of observations/measurements
National Labs act as broker?


General Recommendations
Determine sensing limitations (so we don't waste time try to do the impossible)
Physical
Impossible to detect regardless of sensor quality
Impossible to compensate for active counter measures
Impossible to measure in real time
Algorithmic
Too slow / expensive to be practical
Insufficient sensor input
Device
Too big / expensive / impractical
Does not fit industry business model
Too unpleasant / uncomfortable /intrusive for populace

23.14 Michael Ellenbogen Presentation Slides

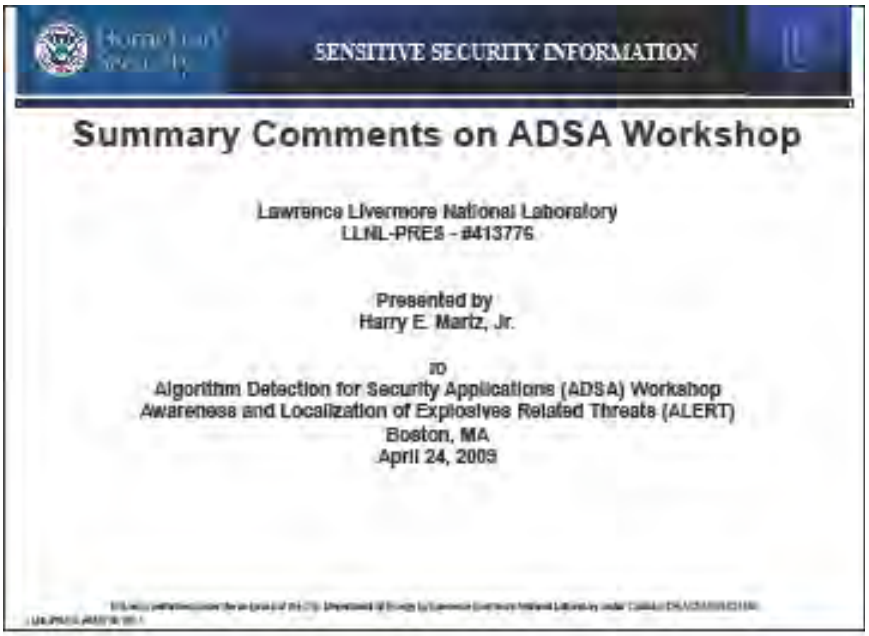


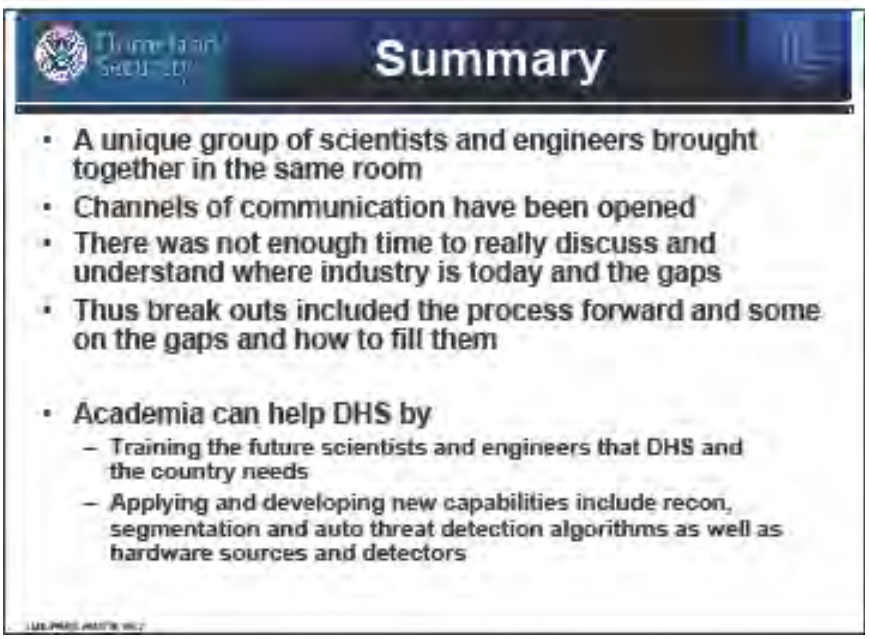

REVEAL
Can you Identify the Threat?
3

REVEAL
Our Goals
• Create physical screening solutions that allow our customers to move more people, more quickly, more securely
• Achieve the proper balance between Detection and False Alarm Rate
• Very little has changed since the first (1990) FAA Symposium on Explosives Detection Technology
•The 95% Doctrine
• We are EAGER to identify / develop / partner / acquire / co-develop / license …

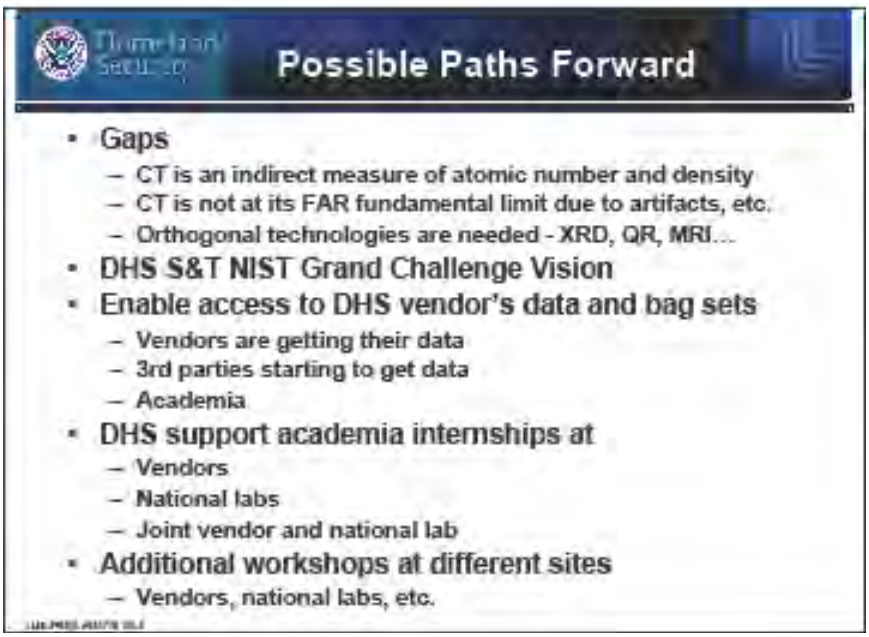
REVEAL
Challenges
• We know our problem set very well
• If you've seen one airport…
• We don't know what we don't know
• We need a means to see who is expert in which fields
• Database of capabilities
• Identify something that can be carved off
• This is where we've had our greatest success with 3rd parties
• ALERT – provide a neutral middle ground
• Make it easier to license from academia
• Licensing from Academia is *HARD*
• How eager is academia to participate in the security market?

23.15 Harry Martz Presentation Slides





Future directions
• Security needs to evolve to deter and thwart future terrorist threats, accurate threat analysis and action is key
• A system of systems approach needs to be implemented for defending the homeland
• More red team testing and use it to improve security effectiveness, not penalize and embarrass failures
• Human factors and operational environments need to be better incorporated into future security technologies
• Operational and laboratory data needs to be better understood
• More focused operational data needs to be acquired, analyzed and utilized
• Machine false alarms need to be reduced, better combination of existing technologies and develop chemical specific technologies
• New explosive, chemical/biological agent, nuclear and drug simulants need to be developed
There are no silver bullets...
security requires a system of systems architecture


Possible Paths Forward
• Gaps
– CT is an indirect measure of atomic number and density
– CT is not at its FAR fundamental limit due to artifacts, etc.
– Orthogonal technologies are needed - XRD, QR, MRI...
• DHS S&T NIST Grand Challenge Vision
• Enable access to DHS vendor's data and bag sets
– Vendors are getting their data
– 3rd parties starting to get data
– Academia
• DHS support academia internships at
– Vendors
– National labs
– Joint vendor and national lab
• Additional workshops at different sites
– Vendors, national labs, etc.

23.16 Michael Lanzaro Presentation Slides

Awareness and Localization of Explosives-Related Threats
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