Strategic Study
Workshop Series

Algorithm Development for Security Applications

Explosives Detection in Air Cargo

ADSA10
May 2014 Workshop
Final Report

ALERT
AWARENESS AND LOCALIZATION OF EXPLOSIVES-RELATED THREATS

A Department of Homeland Security Center of Excellence

Northeastern University

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1. Executive Summary

A workshop focusing on explosives detection in air cargo was held at Northeastern University in Boston on May 6-7, 2014. This workshop was the tenth in a series dealing with algorithm development for security applications (ADSA10[1]).

The topic of explosives detection in air cargo was chosen for the workshop in order to support the Department of Homeland Security's (DHS) objective of improving the performance of existing technologies. Improved performance is defined as: increased probability of detection (PD); decreased probability of false alarms (PFA); lowered detected threat mass; increased number of types of explosives detected including more homemade explosives (HME); increased throughput and reduced operating costs. Another goal of the workshop was to support DHS's objective to increase the participation of third parties, such as researchers from academia, national labs and industry other than the incumbent vendors.

The topics that were addressed at the workshop are as follows:

- Technology being used for explosive detection
- X-ray, neutron and gamma-ray interrogation
- Trace detection, nuclear resonance fluorescence (NRF), advantages and disadvantages of the different scanning methods
- Limitations based on concealment, containment, explosive type, minimum mass and other factors
- Container hardening; time and barriers for commercialization
- Concept of operations and applications
- Review of past and present solutions
- Differences between cargo inspection, baggage inspection and passenger inspection

The key findings from the workshop, per the editors of this report, are as follows.

- There are advantages and disadvantages with all the deployed and the potential, future technologies, especially in light of the following considerations:
    - Type of containment: break-bulk, palletized, containerized
    - Type of cargo: hydrogenous, highly attenuating, heterogeneous

1 The title of this series of workshops was recently changed from "*Algorithm* Development for Security Applications" to "*Advanced* Development for Security Applications." The change was made to broaden the scope of the workshops to include hardware, such as sensors.

  - Location of screening: off-site or at airport
  - Expense: equipment, labor
  - Concept of operation: throughput, alarm resolution
  - Type of explosive: mass, thickness, density, elemental composition

Many promising technologies were discussed, including high-energy X-rays, neutrons, nuclear resonance fluorescence, trace, risk-based screening, sparse view sampling and interior tomography. However, many may not be suitable for deployment as stand-alone devices. Instead, these technologies may be more suitable for fusing with other technologies.

- The workshop was successful in fostering interaction between third parties, vendors and the government, and reducing barriers to these parties working together. This statement is based, in part, on the feedback received after the workshop.
- The next ADSA will continue to address air cargo inspection. The topics that should be discussed include the following as applied to cargo inspection:
  - Concept of operations
  - Financial considerations
  - Canine inspection
  - Trace and vapor inspection including sampling
  - More viewpoints of the following stakeholders: airlines, freight forwarders, insurers and non-US governments
  - Differences between screening and scanning
  - Risk-based screening and scanning

2. Disclaimers

This document was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor Northeastern University nor any of their employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation or favoring by the United States government or Northeastern University. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or Northeastern University, and shall not be used for advertising or product endorsement purposes.

This document summarizes a workshop at which a number of people participated by discussions and/or presentations. The views in this summary are those of ALERT and do not necessarily reflect the views of all the participants. All errors and omissions are the sole responsibility of ALERT.

This material is based upon work supported by the U.S. Department of Homeland Security under Award Number 2013-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.

3. Introduction

The Explosive Division (EXD) of US Department of Homeland Security (DHS) Science & Technology Directorate (S&T), in coordination with the Transportation Security Administration (TSA), has identified detection requirements for future explosive detection scanners that include a larger number of threat categories, lowered false alarm rates, lowered threat mass, increased throughput and reduced total operating costs, all at a constant or increased probability of detection. One tactic that DHS is pursuing to achieve these requirements is to create an environment in which the capabilities and capacities of the established vendors can be augmented or complemented by third-party algorithm and hardware development. A third-party developer in this context refers to academia, National Labs and companies other than the incumbent vendors. DHS is particularly interested in adopting the model that has been used by the medical imaging industry, in which university researchers and small commercial companies develop technologies that are eventually deployed in commercial medical imaging equipment.

A tactic that DHS is using to stimulate third-party algorithm and hardware development is to sponsor a series of workshops addressing the research opportunities that may enable the development of next-generation technologies for homeland security applications. The series of workshops are entitled "Algorithm Development for Security Applications (ADSA[2])." The workshops are convened by Professor Michael B. Silevitch (NEU) as part of the DHS Center of Excellence (COE) for Awareness and Localization of Explosives-Related Threats (ALERT[3]).

The tenth workshop in the ADSA series was held on May 6-7, 2014, at NEU. The workshop addressed explosives detection in air cargo. This report discusses what transpired at the workshop and to report a summary of the findings and recommendations.

2 The title of this series of workshops was recently changed from "Algorithm Development for Security Applications" to "Advanced Development for Security Applications." The change was made to broaden the scope of the workshops to include hardware, such as sensors.

3 ALERT in this report refers to the COE at NEU.

4. Discussion

4.1 Objectives

The objective of the workshop was to explore explosives detection in air cargo. The issues that were addressed centered on the following points:

- Technology presently being used for explosive detection in cargo
- X-rays, neutrons and gamma-rays interrogation to detect explosives
- Trace
- Nuclear resonance fluorescence
- Advantages and disadvantages of the different scanning methods
- Limitations based on concealment, containment, explosive type, minimum mass and other factors
- Container hardening
- Time and barriers for commercialization
- Concept of operations and applications
- Review of past and present solutions
- Differences between cargo inspection, baggage inspection and passenger inspection

The purpose of this section is to synthesize the discussion and recommendations in response to these and related questions that surfaced during the discussion.

4.2 Ideal Cargo Inspection Systems

We learned that the ideal cargo system has the following characteristics:

- Screened in a manner consistent with checked baggage
- Detect small masses of explosives
- High PD
- Very low PFA
- High throughput
- Small footprint
- Reliable
- Low purchase price (< $50k)
- Low operating costs (labor, maintenance)

Explosive Trace Detection (ETD) may have all of the above characteristics. Other technologies that are on TSA's qualified product list for cargo inspection may meet some of the above requirements. However, ETD and these other technologies have advantages and disadvantages and therefore new methods for screening cargo may be required.

4.3 New Methods

Options for methods that may overcome the disadvantages of ETD and the other technologies include the following:

- Regulations revisions
- Concept of operations changes
- Use/fuse manifest information
- Combined photons, neutrons, ETD, etc.
- Determining the best combination of technologies
- Reduced size and costs, especially personnel costs
- Eliminate unpacking; scan before consolidation
- Sparse view reconstruction
- Interior tomography

Many methods may not be suitable for deployment as stand-alone devices. Instead, these technologies may be more suitable for fusing with other technologies.

4.4 Future ADSA Workshop on Cargo

The next ADSA should continue the discussion of cargo inspection. The following topics should be discussed in context for cargo inspection:

- Concept of operations
- Financial considerations
    - Total cost of ownership
    - Impact of an event
    - Buying down risk
- Canine inspection
- Trace and vapor inspection including sampling
- More on viewpoints of the following stakeholders: airlines, freight forwarders, insurers and non-US governments
- Differences between screening and scanning
- Risk-based screening and scanning
- Manifest verification
- Alarm resolution (secondary inspection)
- Hardening

- Neutron sources and detectors
- High-energy X-ray sources
- Automated threat recognition
- On-screen resolution
- Automated methods to determine type of screening
- Testing and validation
- Shield alarms
- X-ray backscatter
- Molecular specific detectors
- Simulants
- Funding methods

5. 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 (retired), Laura Parker, DHS, and George Zarur, DHS & TSA (retired), for their vision to involve third parties in the development of technologies for security applications.
- Laura Parker, DHS, and Greg Struba, DHS, for coordinating DHS/ALERT activities.
- Northeastern University for hosting the workshop.
- Tim White, Pacific Northwest National Lab, for providing extensive written feedback about the workshop.

The workshop would not have been a success without the participants and the speakers. We extend our heartfelt thanks to them for their contributions.

6. Workshop Planning and Support

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

David Castanon, Boston University

Carl Crawford, Csuptwo

Harry Martz, Lawrence Livermore National Laboratory

Michael Silevitch, Northeastern University

The workshop was moderated by:

Carl Crawford, Csuptwo

The body of the final report was written by:

Carl Crawford, Csuptwo

Harry Martz, Lawrence Livermore National Laboratory

The final report was assembled by:

Teri Incampo, Northeastern University

Logistics for the workshop were led by:

Melanie Smith, Northeastern University

Other logistics, including minute taking and audiovisual assistance, were handled by:

Deanna Beirne, Northeastern University

Seda Gokoglu, Northeastern University

Kristin Hicks, Northeastern University

Teri Incampo, Northeastern University

Anne Magrath, Northeastern University

The SSI review was performed by:

Horst Wittmann, Northeastern University

7. Appendix: Notes

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

1. The timing in the agenda was only loosely followed because of the amount of discussion that took place during the presentations and to allow for additional times for participants to network.
2. Some of the presenters edited their material (mainly redacted information) after the workshop.
3. The minutes were edited for purposes of clarity. All errors in the minutes are due to the editors of this report and not due to the speakers themselves. Minutes were only recorded during the question and answer period for each presentation.
4. PDF versions of the presentations from this workshop can be found at the following link: https://myfiles.neu.edu/groups/ALERT/strategic_studies/ADSA10_Presentations/.

8. Appendix: Agenda

8.1 May 6, 2014 - Day 1

TIME	TOPIC	SPEAKER	AFFILIATION
7:30	**Registration/Continental Breakfast**		
8:30	Welcome - ALERT	Michael Silevitch	ALERT / NEU
8:35	Welcome - DHS	Laura Parker	DHS
8:40	Introduction	Carl Crawford	Csuptwo
9:00	DHS Activities in Cargo Inspection	Stephen Surko	DHS
9:25	Photon and Neutron Interrogation Techniques for chemical Explosives Detection in Air Cargo: A Critical Review	Tim White	Pacific Northwest National Laboratory
10:00	What's the Problem with Neutrons for Explosive Detection?	Harry Martz	Lawrence Livermore National Laboratory
10:25	**Break**		
10:50	Hurdles to the Adoption of New Methods II: The Regulators Strike Back	Tim Rayner	MultiX
11:15	Air Cargo Explosives Detection Pilot Project - Over	Doug Bauer	DHS (Retired)
11:25	Air Cargo Explosives Detection Pilot Project - Details	Amy Waters	Lawrence Livermore National Laboratory
11:50	SPAC: CT Scanning of Palletized Air Cargo and Security Challenges for Overnight Cargo	Walter Garms	Morpho Detection
12:15	**Lunch**		
1:00	Neutron Resonance Radiography	Dave Perticone	L-3 Communications
1:25	Two Particle Correlations in Low Efficiency Detector Systems	Edward Hartouni	Lawrence Livermore National Laboratory
1:50	Nuclear Reaction Based Monoenergetic Gamma Ray Radiography System for Detection of Nuclear Materials	Richard Lanza	Massachusetts Institute of Technology
2:15	Hardened Unit Load Device (HULD) Research and Development History	Nelson Carey	DHS
2:40	DHS Applications of PaX Source	Rajiv Gupta	Massachusetts General Hospital/ Harvard University

TIME	TOPIC	SPEAKER	AFFILIATION
3:05	Statistical Framework for Assessing Trace Detection Methods for Air Cargo	Michelle Clark	MIT Lincoln Laboratory
3:30	3D CT with Few Projections for Sea Freight Container Inspection	Stefan Moser	Fraunhofer EMI
3:55	DNDO's Integrated Threat Detection Platform	Kevin Cronk	DHS
4:20	Signature Discovery Initiative	Mark Tardiff	Pacific Northwest National Laboratory
4:40	Two Strategies for Signature Discovery: Small and Large Data Spaces	Alejandro Heredia-Langner	Pacific Northwest National Laboratory
5:00	"Big Data" Machine Learning for Prediction and Classification	Daniel Acuna	Northwestern University
5:25	**Reception and Networking Session**		
6:55	Adjourn	Carl Crawford	Csuptwo

8.2 May 7, 2014 - Day 2

TIME	TOPIC	SPEAKER	AFFILIATION
07:30	**Continental Breakfast**		
08:00	Call to Order/ADSA11	Carl Crawford	Csuptwo
8:10	Cargo Scanning with X-Rays and Neutrons and the Challenge of Effective Detection	Nick Cutmore	Commonwealth Scientific and Industrial Research Organization (CSIRO)
8:35	Quantitative and Qualitative Approaches to Neutron Imaging	Jens Gregor	University of Tennessee
9:00	From Steady State to Pulsed: A Review of Neutron Interrocation Techniques for Explosives Detection	Dan Strellis	Rapiscan Laboratories, Inc.
9:25	Sparse View CT	Synho Do	Massachusetts General Hospital/ Harvard University
9:50	Radar Threat Detection	Stuart Harmer	Radio Physics Solutions, Ltd.
10:15	**Break**		

TIME	TOPIC	SPEAKER	AFFILIATION
10:40	Femtosecond Laser Based Truck Mounted Trace Detection	Theodore Goodson	University of Michigan
11:05	Interior Tomography and Spectral CT	Ge Wang	Rensselaer Polytechnic Institute
11:30	**Lunch**		
12:15	MVCTC	Simon Bedford	Astrophysics Inc.
12:40	Misc. Topics	Dan Strellis	Rapiscan Laboratories, Inc.
1:05	Challenges and Solutions of Air Cargo Screening	Martin Hartick	Smiths Detection
1:30	Passport's Explosive Detection Technology	Stephen Korbly	Passport Systems Inc.
1:55	L-3 Commercial Offerings	Steward Hampton	L-3 Communications
2:20	A Mobile X-Ray/Neutron Cargo System for Aviation Security	Seth Van Liew	AS&E
2:45	Next Steps	Harry Martz	Lawrence Livermore National Laboratory
3:50	Closing Remarks - ALERT	Michael Silevitch	ALERT / NEU
3:55	Closing Remarks - DHS	Laura Parker	DHS
4:00	Adjourn	Carl Crawford	Csuptwo

Note: The timing in the agenda was only loosely followed due to the amount of discussion that took place during the presentations and to give additional time for participants to network.

9. Appendix: Previous Workshops

Information about the previous nine workshops, including their final reports, can be found at:

www.northeastern.edu/alert/transitioning-technology/strategic-studies

10. Appendix: List of Participants

NAME		AFFILIATION
Daniel	Acuna	Northwestern University
Anatoli	Arodzero	RadiaBeam Technologies
Erez	Attias	P.M.O
Kumar	Babu	Ccuneus solutions, LLC
Douglas	Bauer	University of Connecticut
John	Beaty	Northeastern University
Edmund	Becker	Self
Moritz	Beckmann	XinRay Systems, Inc.
Simon	Bedford	Astrophysics Inc.
Deanna	Beirne	Northeastern University
Glenn	Bindley	Redlen Technologies
Ralf	Birken	Northeastern University
Carl	Bosch	SureScan Corporation
CJ	Bourn	Reveal Imaging Technologies, Inc.
Peter	Boynton	Northeastern University
Emel	Bulat	Northeastern University
Nelson	Carey	Department of Homeland Security
David	Castañón	Boston University
Ke	Chen	Boston University
Charles	Choi	General Dynamics Advanced Information Systems
Michelle	Clark	MIT Lincoln Laboratory
Allan	Collier	Transportation Security Administration
Carl	Crawford	Csuptwo
Kevin	Cronk	Department of Homeland Security
Nick	Cutmore	Commonwealth Scientific and Industrial Research Organization
Eric	DiNoto	U.S. Military
Synho	Do	Massachusetts General Hospital
Denis	Dujmic	L-3 Communications

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Tal	Geva	P.M.O
Seda	Gokoglu	Northeastern University
Brian	Gonzales	XinRay Systems, Inc.
Borja	Gonzalez-Valdes	Northeastern University
Theodore	Goodson	University of Michigan
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Jens	Gregor	University of Tennessee
Christopher	Gregory	Smiths Detection
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Rajiv	Gupta	Massachusetts General Hospital
Jeffrey	Hamel	IDSS
Steward	Hampton	L-3 Communications
Stuart	Harmer	Radio Physics Solutions, Ltd.
Peter	Harris	Yankee Foxtrot, Inc.
Martin	Hartick	Smiths Detection
Edward	Hartouni	Lawrence Livermore National Laboratory
Roy	Herbert	Radio Physics Solutions, Ltd.
Alejandro	Heredia-Langner	Pacific Northwest National Laboratory
Kristin	Hicks	Northeastern University
Margery	Hines	Northeastern University
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Gunther	Hoffmann	Applied Materials, Inc.

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Theresa	Incampo	Northeastern University
Olof	Johnson	Photo Diagnostic Systems, Inc.
Eric	Johnson	SureScan Corporation
Stephen	Korbly	Passport Systems Inc.
Ronald	Krauss	Department of Homeland Security
Shiva	Kumar	Rapiscan Laboratories, Inc.
Pierfranscesco	Landolfi	Morpho Detection
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Yulan	Li	Tsinghua University
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Andrew	Litvin	Analogic Corporation
Anthony	Macadino	Photo Diagnostic Systems, Inc.
Anne	Magrath	Northeastern University
Edwin	Marengo	Northeastern University
Jose	Martinez-Lorenzo	Northeastern University
Harry	Martz	Lawrence Livermore National Laboratory
Michael	Massey	Beth Israel Deaconess Medical Center
Harry	Massey	National Electrical Manufacturers Association (NEMA)
Matthew	Merzbacher	Morpho Detection
Eric	Miller	Tufts University
Richard	Moore	Massachusetts General Hospital
Stefan	Moser	Fraunhofer EMI
Siegfried	Nau	Fraunhofer EMI
Boris	Oreper	L-3 Communications
Ricardo	Osiroff	Tracense Systems Ltd.
Peter	Pandolfi	Transportation Security Administration
Laura	Parker	Department of Homeland Security
Julia	Pavlovich	Analogic Corporation

NAME		AFFILIATION
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Simon	Pongratz	L-3 Communications
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Patrick	Radisson	MiltiX
Carey	Rappaport	Northeastern University
Tim	Rayner	MultiX
Francois	Richard	Embassy of France
Peter	Rothschild	Heuresis Corporation
David	Rundle	Kromek Group plc
Franco	Rupcich	Self
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David	Schafer	Analogic Corporation
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Larry	Schultz	Los Alamos National Laboratory
Anthony	Serino	Raytheon Company
Jing	Shea	Rapiscan Laboratories, Inc.
Bob	Shepard	Leidos
Michael	Silevitch	Northeastern University
Sergey	Simanovsky	Analogic Corporation
Jeremy	Simon	Comet
Stephen	Skrzypkowiak	Booz Allen Hamilton Inc.
Melanie	Smith	Northeastern University
Michael	Snell	American Science and Engineering, Inc.
Edward	Solomon	Triple Ring Technologies, Inc.
Serge	Soloviev	Reveal Imaging Technologies, Inc.
Samuel	Song	TeleSecurity Sciences, Inc.
Marion (Rocky)	Starns	ScanTech IBS
Louis	Steen	Applied Materials, Strategic Consulting
Dan	Strellis	Rapiscan Laboratories, Inc.

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Zachary	Sun	Boston University
Stephen	Surko	Department of Homeland Security
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Ling	Tang	Rapiscan Laboratories, Inc.
Mark	Tardiff	Pacific Northwest National Laboratories
David	Taylor	Department of Homeland Security
Frank	Thibodeau	Bruker Corporation
Philip	Top	Lawrence Livermore National Laboratory
Brian	Tracey	Tufts University
Alex	Van Adzin	Photo Diagnostic Systems, Inc.
Seth	Van Liew	American Science and Engineering, Inc.
Lou	Wainwright	Triple Ring Technologies, Inc.
Ge	Wang	Rensselaer Polytechnic Institute
Amy	Waters	Lawrence Livermore National Laboratory
Francois	Weller	Force 5 Networks, LLC
Dana	Wheeler	Radio Physics Solutions, Ltd.
Alyssa	White	Massachusetts General Hospital
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William	Worstell	Photo Diagnostic Systms, Inc.
Dong Hye	Ye	Purdue University
Vitaliy	Ziskin	Physical Sciences, Inc.

11. Appendix: Presenter Biographies

Daniel E. Acuna

Daniel E. Acuna (Ph. D. '11) received his Bachelor's and Master's Degrees from the University of Santiago, Chile and his Ph.D. in Computer Science from the University of Minnesota - Twin Cities. He is currently a Research Affiliate in the Biomedical Engineering, and School of Engineering and Applied Science departments at Northwestern University and a Research Associate in the Sensory Motor Performance Program (SMPP) at the Rehabilitation Institute of Chicago. During his Ph. D., he received a NIH Neuro-physical-computational Sciences (NPCS) Graduate Training Fellowship (2008-2010) and an International Graduate Student Fellowship from the Chilean Counter of Scientific and Technological Research and the World Bank (2006-2010).

He is currently interested in studying large data sets to understand how science evolves and scientists collaborate. More specifically, he uses big data machine learning techniques to predict young scientists' publications, funding levels, and teaching abilities.

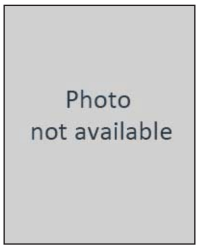
Doug Bauer

Dr. Douglas Bauer is the Emeritus Program Executive for Basic Research within the Explosives Division of the Science and Technology Directorate at the Department of Homeland Security (DHS). 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.

Since 2012, Dr. Bauer has been a research associate at the University of Connecticut (UCONN). He is counseling students and faculty on how to more successfully transition research into commercial usage - either in DHS components or in the economy, generally. He has written about ten case studies on different technology transitions and the lessons to be learned for success. Dr. Bauer has presented seminars on DHS research priorities and acquisition policies and written on the relationship between university research and economic growth and jobs. He is also participate in the UCONN Technology

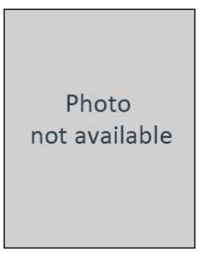
Incubation Program (TIP), an initiative of the Economic Development Office, evaluating start-up company projects and advising on how to improve the prospects for commercialization. Dr. Bauer consults as a subject matter expert (SME) on threat detection technologies and practices in assignments with Quasars for various federal agencies.

Simon Bedford



Mr. Simon Bedford graduated from Imperial College London and has more than 20 years of experience developing new technologies and products for explosives and weapons detection using a diverse range of technologies including X-ray transmission and CT, coherent X-ray scattering, NQR and magnetic sensors. He has worked on and led R&D and engineering teams on numerous commercial and government development programs including work for TSA, DHS, DARPA and DNDO. Simon joined Astrophysics in 2009 and leads government contract R&D and qualification programs.

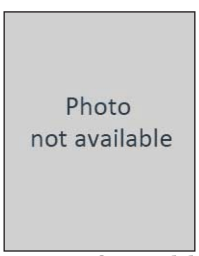
Nelson Carey



Department of Homeland Security, Science and Technology Directorate (S&T)

Transportation Security Laboratory

Michelle L. Clark



Dr. Clark is currently a staff member at MIT Lincoln Laboratory. She received her Ph.D. in chemistry from MIT and Sc.B. from Brown University. Prior to joining MITLL she worked as a senior systems engineer at Raytheon and as a principal scientist at Physical Sciences Inc. She was also a National Research Council postdoctoral research fellow at JILA/NIST/CU. The majority of her research has focused on the development of novel laser based ultrasensitive spectroscopic detection techniques spanning the UV to far-infrared region. Her current work focuses on phenomenology measurements of homemade explosives using a variety of standard analytical methods as well as development of optical measurements for trace detection of explosives, and chemical and biological agents.

Carl R. Crawford

Carl R. Crawford, Ph.D., 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 computerized imaging for more than thirty 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 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 scanning for medical CT scanners, and at Elicit, Haifa, Israel, 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), 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. He is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), is a Fellow of the American Association of Physicists in Medicine (AAPM), and is an associate editor of IEEE Transactions on Medical Imaging.

Kevin Cronk

Kevin Cronk is a program manager at the Department of Homeland Security's Domestic Nuclear Detection Office (DNDO). Kevin is the advanced technology program lead for the Transformational and Applied Research directorate at DNDO. Prior to joining DNDO Kevin served as a nuclear engineer in the United States Navy, during which he earned his Bachelor of Science in Nuclear Engineering Technologies.

Kevin is currently focusing his research portfolio on integrated multi-threat detection platforms for cargo scanning applications. Kevin is the lead DNDO program manager for the coordination of international Government funded enhanced radiological and nuclear detection technologies research and development.

Kevin earned his Master of Science in Engineering and Technology Management from The George Washington University, and is currently pursuing his Master of Business Administration at the University of Michigan.

Nick Cutmore

Nick Cutmore graduated with a B.Sc (Hons 1st) in 1977 and a PhD in Physics in 1981, both from the University of New South Wales (Australia). He joined CSIRO in 1983 as a research scientist after completing a postdoctoral appointment at the University of New South Wales School of Mining. He has undertaken numerous leadership roles with CSIRO since this time and is currently a Theme Leader in the CSIRO. He also manages the CSIRO-Nuctech Joint Venture for the global commercialisation of the Air Cargo Scanner.

His research interests are in the development and commercialisation of online analysis technologies. His career achievements are recognised in him being a recipient of the Australia Prize (1992), the CSIRO Medal for Research Achievement (2006), the Eureka Prize for Outstanding Science in Support of National Security (2009) and the Australian Innovation Challenge award (2011). He was elected a Fellow of the Australian Academy of Technological Science and Engineering in 2003.

Synho Do

Synho Do, PhD, is an Assistant in Physics at Massachusetts General Hospital, where he is a technical committee member of Webster Center for Advanced Research and Education in Radiation, and Instructor at Harvard Medical School. Dr. Do received the Ph.D. degree in Biomedical Engineering from University of Southern California. He is currently a member of IEEE Signal Processing Society, Bio-Imaging and Signal Processing (BISP). He is a MGH site PI for nVidia CUDA Research Center (CRC). Dr. Do's current research interests include statistical signal and image processing, estimation, detection, and medical signal and image processing, such as computed tomography. He has been a Co-Investigator for multiple medical imaging projects, and Co-PI/PI on medical (i.e., GE, Siemens, and Philips etc) and security (i.e., DHS, DARPA etc) image reconstruction projects.

Walter Garms

Walter Garms has been involved in high technology research and development for over thirty years, specializing in scientific algorithms, software design, imaging, and measurement sciences. He has developed advanced flight simulations at NASA Ames Research Center. He spent twelve years developing electron beam lithography equipment in the semiconductor industry, during which time he produced algorithms for electron beam focusing, fiducial mark detection, and calibration.

Mr. Garms joined Invision Technologies (now Morpho Detection LLC) in 1992 and played a key role in the development of InVision's first CTX-5000/5500 series products, responsible for machine control, user interface, calibration, and image reconstruction. Mr. Garms was engineering director for the InVision log scanner, for which he developed automated sawing algorithms. In the last decade Mr. Garms has focused on automated image analysis and detection algorithms and dual energy image reconstruction. He designed and developed the automated explosive detection for Morpho's megavolt cargo container scanner, and was principal investigator for the final phase of that project. He was the lead engineer for Morpho's prototype dual energy break bulk cargo scanner. Mr. Garms has worked closely with GE Global Research developing the technology for large area x-ray detectors, and is currently principal investigator and project manager for Morpho's the Scanning Palletized Air Cargo (SPAC) program that incorporates those detectors into 6MV CT system capable of high resolution imaging of palletized cargo.

Mr. Garms received a B.S. in Mathematical Sciences from Stanford University and holds ten U.S Patents.

Theodore Goodson

Theodore Goodson III received his B. A. in 1991 from Wabash College and earned his Ph.D. in Chemistry at the University of Nebraska-Lincoln in 1996. After postdoctoral positions at the University of Chicago and at the University of Oxford, he accepted a position as Assistant Professor of Chemistry at Wayne State University in 1998. In 2004 he moved to the University of Michigan as Professor of Chemistry. In 2008 he was appointed as the Richard Barry Bernstein Professor of Chemistry at the University of Michigan. Dr. Goodson's research centers on the investigation of nonlinear optical and energy transfer in organic multi-chromophore systems for particular optical and electronic applications. His research has been translated in to technology in the areas of two-photon organic materials for eye and sensor protection, large dielectric and energy storage effects in organic macromolecular materials, and the detection of energetic (explosive) devices by nonlinear optical methods. He has investigated new quantum optical effects in organic systems which have applications in discrete communication systems and sensing. Goodson's lab was also the first to investigate the fundamental excitations in small metal topologies which are now candidates for tissue and other biological imaging. In 2009 he founded Wolverine Energy Solutions and Technologies Inc. a start-up company with contracts to produce high energy density capacitors for military, automotive, and medical devices. The company also developed a new system for the detection of IED's remotely with one of the patents award Goodson at the U of Michigan.

Jens Gregor

Dr. Jens Gregor received a PhD in Electrical Engineering from Aalborg University, Denmark in 1991. He then joined the Department of Computer Science at the University of Tennessee, Knoxville. Following a recent merger, he currently holds the rank of Professor in the Department of Electrical Engineering and Computer Science. His research spans the fields of pattern recognition, image reconstruction and parallel computing. This work has been published in a combined total of more than 80 book-chapters, journal articles and conference papers. He has developed and implemented statistical and algebraic imaging algorithms for medical and preclinical applications as well as waste management and nondestructive testing applications for several different data modalities. He was a participant in ALERT Task Order 3 which dealt with iterative reconstruction for luggage screening. He currently participates in ALERT Task Order 4 in regard to automated threat recognition. He has served as a consultant to Oak Ridge National Laboratory, Siemens Medical, Hexagon Metrology and various small companies in East Tennessee.

Rajiv Gupta

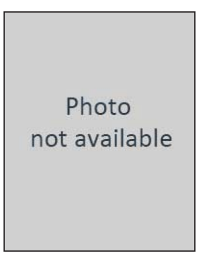
Raj Gupta is an Associate Radiologist in the Neuro and Cardiovascular Divisions at the Massachusetts General Hospital, an Assistant Professor of Radiology at the Harvard Medical School, and a Lecturer in Mechanical Engineering at MIT. Dr. Gupta earned his MD at Cornell University and his PhD in Computer Science at the State University of New York at Stony Brook. In addition to serving as the CIMIT Site Miner for MGH, he also directs the Advanced X-ray Imaging Sciences (AXIS) Center at MGH. Prior to joining MGH, Dr. Gupta was a Computer Scientist at GE Global Research Center in Niskayuna, NY, conducting research in medical imaging, non-destructive evaluation of aircraft engine parts, and computer vision. He also served on the faculty of University of Southern California, Los Angeles, in the Department of Electrical Engineering Systems. Gupta's research interests include: (1) Development and clinical applications of novel X-ray imaging modalities including phase contrast imaging and ultra-high resolution computed tomography (CT), and dual-energy CT; (2) Development of low-cost, lightweight robots for image-guided interventions; and (3) Study of traumatic brain injury (TBI) using advanced, quantitative MRI techniques.

Stewart Hampton

Stewart Hampton is Director of Marketing at L-3 Security & Detection Systems, Woburn MA. He received his BSEE and Marketing MBA from Southern Methodist University and over the last two decades has held marketing leadership roles in a number of leading telecommunications and security technology companies.

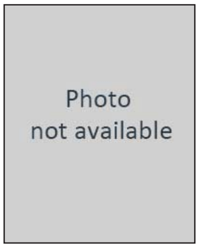
Expert in assessing needs, developing product requirements, defining marketing objectives, and devising creative strategies that deliver ROI, Stewart is presently focused on bringing new advanced security and detection solutions to the worldwide marketplace.

Stuart Harmer



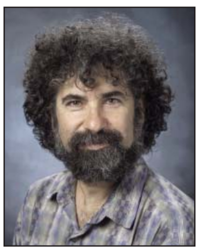
Dr. Stuart Harmer holds a BSc in Physics & Astrophysics and a PhD from The University of Sussex (UK). From 2000 to 2006 Dr. Harmer held the position of Research Fellow in Photonics at Sussex University and Later the position of Senior Research Fellow at Queen Mary University of London. Dr Harmer has worked in industry at SELEX ES and is now a Reader in Physics and Engineering Science at Manchester Metropolitan University and is on Radio Physics Solutions staff as the Chief Scientific Officer. Dr Harmer has more than fifty publications and twenty patents.

Martin Hartick



Dr. Martin Hartick is currently Manager Physics Technology for Smiths Detection in Wiesbaden, Germany. In this position, Dr. Hartick is responsible for evaluating X-ray technologies in view of their applicability to Smiths Detection products in the areas of people screening, carry-on and checked baggage, and air cargo. Dr. Hartick leads a development group which performs detector developments and feasibility studies mainly within funded projects for various Smiths Detection programs. Dr. Hartick participated in various DHS, EU and German funded programs. He earned his Ph. D. at the Technical University Darmstadt, Germany.

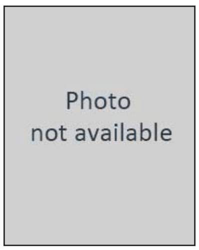
Edward Hartouni



Edward Hartouni received a B.A in physics from the University of California at Berkeley in 1976 and an M.A., M.Ph., and Ph.D. from Columbia University in 1978, 1979, and 1984, respectively. He was a postdoctoral fellow at the University of Massachusetts from 1985 to 1988 and an assistant professor there from 1985 to 1994. He joined Lawrence Livermore in 1995 as a physicist involved in high-energy physics research. In 1995 Ed Hartouni joined the Lawrence Livermore National Laboratory N Division. At LLNL he became the Program Leader in the proton radiography program a collaboration with LANL. Work for this program culminated in the Scrounge-atron, a proposal to build an accelerator from existing parts at the Nevada Test Site to enable proton radiography experiments on relevant, dynamic objects. During this time period maintained an attenuated presence in basic research with the collaboration MINOS (Main Injector Neutrino OScillation) experiment at Fermilab as well as the PHENIX experiment at BNL Relativistic Heavy Ion Collider (RHIC) and the MIPP experiment at Fermilab. Recent experimental research has centered on active interrogation using neutron time correlations induced by external x-ray sources. In addition, he has worked in the NIF Nuclear Diagnostics group as a responsible scientist for one the neutron time-of-flight detectors as well as performing statistical analyses of NIF data. Over this time period he has advised DOE Office of Science Nuclear Physics and High Energy Physics directorates, DOE NNSA Defense Programs, NA-22, and participated in reviews of proposals, projects, co-chaired numerous workshop working groups and co-authored a number of workshop reports. Also, co-authored over 200 refereed publications in high energy physics, relativistic heavy ion physics, HEDS and radiology in the peer reviewed literature.

Ed served as N Division leader (2002-2008). He served as the Deputy Associate Director for Science & Technology in the Physical and Life Sciences Directorate (2009-2010). Currently he has returned to research working on the detection of Special Nuclear Material (SNM) and various other topics. In addition, he plays the role of Director of Laboratories for the Nuclear Science and Security Consortium (NSSC), a collaboration of seven universities and four national laboratories.

Alejandro Heredia-Langner

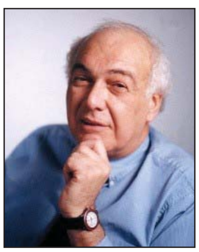


Dr. Alejandro Heredia-Langner is a Research Scientist in the Applied Statistics and Computational Modeling Group at Pacific Northwest National Laboratory (PNNL). While at PNNL, Dr. Heredia-Langner has worked on building, applying and analyzing results from statistically designed experiments in areas of sensor modeling and optimization for the detection of explosives and chemical weapon related compounds, studying the effects of particle size on the transport of chemical waste, and other projects. Dr. Heredia-Langner also has experience in linear and nonlinear modeling, which he has applied in studying the effects of nanomaterials in the development of zebrafish embryos, prediction of academic performance of students in Washington State high schools, and a variety of responses arising from a program dedicated to the processing and cleanup of legacy nuclear waste. In optimization, he has created genetic algorithms for improving the design of a gamma-ray spectrometer, maximizing signal detection using data from a portal detector, the creation of an algorithm for peptide sequencing, and the implementation of a feature-selection algorithm for subject re-identification. Dr. Heredia-Langner has been a member of the editorial board of Quality Engineering since 2006.

Steve Korbly

Dr. Stephen Korbly is the Director of Science at Passport Systems. He received his Ph.D. from the Massachusetts Institute of Technology (MIT) in plasma physics with a concentration in accelerator physics, and his AB in physics from Princeton University. At Passport Systems, Dr. Korbly has managed the research and development efforts for the design of two products: 1) a scanner based on several new technologies for the inspection of air, land and sea cargo, and 2) a system of networked radiation detectors. Dr. Korbly has seen the cargo inspection system go from the feasibility stage through government testing and is now leading the effort to deploy a system in an operational port. Prior to Passport, Dr. Korbly led the testing of the 20 MeV, 17 GHz linear electron accelerator at the Plasma Physics Laboratory at MIT to measure the length of the sub-picosecond electron bunches produced by this accelerator. Dr. Korbly is an experienced project leader/manager who has delivered various projects on time and within budget from the beginning requirements to development, testing and product rollout phases. In addition to being an experienced practitioner of experimental physics, Dr. Korbly has extensive experience in developing new technologies and managing a diverse set of people and technical requirements.

Richard C. Lanza



Dr. Richard C. Lanza is a Senior Research Scientist in the MIT Department of Nuclear Engineering. His interests are primarily in the area of application of nuclear techniques and development of instrumentation to problems in materials science, medicine and national security. More recently he has been active in development of new imaging methods for nuclear medicine and also in the problem of detection of illicit materials such as explosives, contraband, and special nuclear materials. He has recently served on review panels for these areas for DNDO, DOE (IN-10), FAA, NIH and the National Academy of Sciences and has been an Expert Advisor to the International Atomic Energy Agency (IAEA). More recently he was a member of the APS/IEEE Technical Review of the Domestic Nuclear Detection Office (DNDO) Transformational and Applied Research Development Program, an examination of long term research possibilities for the detection of nuclear materials. He is the Past Chairman of the IEEE Radiation Instrumentation Steering Committee and was General Chair for the 2009 IEEE Nuclear Science and Medical Imaging Conference.

His professional interests include: High speed electronics, nuclear instrumentation, particle and radiation detectors, application of physical instrumentation to medical problems, medical imaging, computerized tomography (CAT), image reconstruction, application of imaging techniques to non-destructive testing and evaluation, neutron radiography, neutron tomography, applications of nuclear and x-ray techniques to aviation security, land mine detection and characterization technologies and strategies, accelerator based isotope production, applications of tomography to metal processing and production, neutron phase-contrast imaging, remote sensing and standoff detection for nuclear materials, nuclear forensics, and development of novel radiation detectors

He has more than 150 papers published in these areas; has been awarded 18 patents and has received research grants from National Institutes of Health, National Science Foundation, Department of Energy, Whitaker Health Sciences Fund, Federal Aviation Agency, US Air Force Office of Scientific Research, American Iron and Steel Institute, Office of National Drug Control Policy, Transportation Security Administration (TSA), Department of Defense (TSWG), Homeland Security (DHS), Defense Threat Reduction Agency (DTRA), Domestic Nuclear Detection Office (DNDO) and DARPA.

Harry Martz

Harry Martz is currently the Center Director for Non-destructive Characterization and PI on DHS S&T Explosive Division Explosive Detection Projects and DNDO Nuclear and Radiological Imaging Platform. Harry joined the Laboratory in 1986 as a Physicist to develop the area of x-ray and proton energy loss computed tomography for the non-destructive inspection of materials, components, and assemblies. He received his M.S. and Ph.D. in Nuclear Physics/Inorganic Chemistry from Florida State University, and his B.S. in Chemistry from Siena Collage.

Harry's interests include the research, development and application of non-intrusive characterization techniques as a three-dimensional imaging instrumentation to better understand material properties and inspection of components and assemblies, and generation of finite element models from characterization data. He has applied CT to inspect one-millimeter sized laser targets, automobile and aircraft components, reactor-fuel tubes, new production reactor target particles, high explosives, explosive shape charges, dinosaur eggs, concrete and for non-destructive radioactive assay of waste drum contents. Recent R&D efforts include CT imaging for explosives detection in luggage and radiographic imaging of cargo to detect special nuclear materials and radiological dispersal devices. Dr. Martz has authored or co-authored over 200 papers and is co-author of a chapter on Radiology in Non-destructive Evaluation: Theory, Techniques and Applications, Image Data Analysis in Non-destructive Testing Handbook, third edition: Volume 4, Radiographic Testing, and contributed a chapter entitled Industrial Computed Tomographic Imaging to the Advanced Signal Processing Handbook: Theory and Implementation for Radar, Sonar and Medical Imaging Real-Time Systems. He has also served on several National Academy of Sciences Committees on Aviation Security and is the Chair of the Committee on Airport Passenger Screening: Backscatter X-Ray Machines. Harry has been co-chair of ALERT ADSA Workshops. Dr. Martz has presented a short course on CT imaging at The Center for Non-destructive Evaluation, Johns Hopkins University and a course on X-ray Imaging for UCLA's Extension Program. Currently Dr. Martz is writing a text book on Industrial X-ray Imaging.

Stefan M. Moser

Mr. Moser received his diploma in Physics from the Albert-Ludwigs-University in Freiburg, Germany, in 2009. The focus of his studies was applied Quantum Dynamics and Physical Chemistry. In his thesis, he investigated the tribological running-in mechanics of diamond and diamond-like carbon coated friction interfaces via atomistic simulations.

Since 2009 he has been conducting research at the Fraunhofer EMI in Efringen-Kirchen, Germany, being a project leader for security-related projects working on X-Ray imaging and Computed Tomography (CT). Currently he is advancing the topic of flash X-Ray High-Speed Computed Tomography (HSCT) in the scope of his PHD thesis. He is responsible for the EMI NDT CT laboratory.

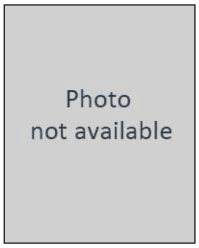
Laura Parker

Laura Parker works as a Program Manager in the Explosives Division of the Science and Technology Directorate at the Department of Homeland Security (DHS). She works on multiple projects for algorithm development for improved explosives detection as well as in the trace explosive detection area. Laura is also the Program Manager for the ALERT Center of Excellence, a DHS-sponsored consortium of universities performing research that address explosive threats co-lead by Northeastern University and University of Rhode Island. Previous to her present position at DHS, Laura has worked as a contractor providing technical and programmatic support of chemical and biological defense and explosives programs for several Department of Defense (DoD) offices. She has also worked in several DoD Navy laboratories in the field of energetic materials. She obtained her Ph.D. form the Pennsylvania State University in chemistry.

David Perticone

Biography not available

Tim Rayner



Dr. Tim Rayner – Founder of Bagtronics Ltd, a UK-based consultancy specializing in security system business development with a client that includes both US and EU based security companies. Prior to forming Bagtronics, Dr. Rayner was the Director of Technology for R&D programs at Rapiscan Systems Ltd in the UK. Before this he worked in senior research and development roles at Daylight Solutions, QR-Sciences, General Electric, InVision Technologies and Quantum Magnetics.

Dr. Rayner has over twenty-five years' experience in the security business, developing technologies and sensors for various applications based on transmission and backscatter x-ray, including multi-spectral x-ray detection, quadrupole resonance (QR), magnetic resonance (MR), computed tomography (CT) and mid-IR absorption spectroscopy.

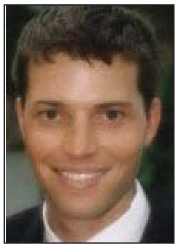
Michael B. Silevitch

Michael B. Silevitch is currently the Robert D. Black Professor of Electrical and Computer Engineering at Northeastern University in Boston, an elected fellow of the IEEE, and the Director of the Homeland Security Center of Excellence for Awareness and Localization of Explosives Related Threats (ALERT).

His training has encompassed both physics and electrical engineering disciplines. An author/co-author of over 65 journal papers, his research interests include laboratory and space plasma dynamics, nonlinear statistical mechanics, and K-12 science and mathematics curriculum implementation. Of particular interest is the study of the Aurora Borealis, one of nature's most artistic phenomena. Avocations include long distance hiking and the study of 17th Century clocks and watches.

Prof. Silevitch is also the Director of the Bernard M. Gordon Center for Subsurface Sensing and Imaging Systems (Gordon-CenSSIS), a graduated National Science Foundation Engineering Research Center (ERC). Established in September of 2000, the mission of Gordon-CenSSIS is to unify the methodology for finding hidden structures in diverse media such as the underground environment or within the human body.

Dan A. Strellis



Dr. Strellis manages the US Government R&D program portfolio at Rapiscan Laboratories, the Research and Development center for Rapiscan Systems. In addition to overseeing the government-funded projects, he leads the proposal team to submit responses to government solicitations, and briefs government officials on Rapiscan capabilities. His research work at Rapiscan has focused on the use of pulse neutron interrogation systems for detecting contraband using both microsecond and nanosecond pulsed sources. He has authored numerous technical publications in these areas of research and has served in an advisory role to the IAEA on neutron-based interrogation techniques. He joined Rapiscan Laboratories as a Scientist in October 2000 with a background in nuclear physics and chemistry. His dissertation topic was investigating the fission properties of neutron deficient americium isotopes while performing experimental work at the LBNL 88-in Cyclotron.

Stephen Surko

Stephen Surko, P.E. is currently the Explosives Division Air Cargo Program Manager at Department of Homeland Security, Science & Technology (DHS S&T). After graduating with distinction from the U.S. Naval Academy in 1982 with a Bachelor of Science degree in Ocean Engineering, he served as a naval officer for 22 years in numerous operational, ship maintenance, and research & development positions. After working in private industry for several years he returned to government service as a Homeland Security Advanced Research Projects Agency (HSARPA) Program Manager leading the development of an advanced bottled liquid scanner (BLS) system employing nuclear magnetic resonance (NMR) technology. Listed as Co-Inventor on 2 patent applications with NMR BLS performers. He has served in his current position for more than three years. In addition to Air Cargo, Mr. Surko is responsible for the Standoff Detection and Checkpoint Programs.

Mark F. Tardiff

Mark Tardiff is a Senior Research Scientist in the National Security Directorate at PNNL. He received a Masters in Biology from the State University of New York in Syracuse, and has over 30 years of experience as a research scientist. He has extensive experience in designing experiments; test planning; conducting operational test and evaluation experiments; and exploratory data analysis and algorithm development. Mr. Tardiff has worked in environmental radiation and chemical detection and characterization for over 20 years and in trace gas, explosives, and radiation detection for nonproliferation and homeland security for nine years. Recent work includes strategies to predict the detectability of trace gases in hyperspectral images, comparisons of gamma radiation detection algorithms, evaluation of replacement instruments for 3He-based neutron detectors, and strategies for detecting person-borne improvised explosive devices in unstructured crowd at large public events. He is leading a project to develop methods for anticipating the loss of control of nuclear materials and weapons, and is a member of the leadership team for the Signature Discovery Initiative responsible for signature construction and validation. Mark has authored or co-authored over 70 journal articles, conference papers, and technical reports.

Seth Van Liew

Seth received BS degrees in Physics and Mathematics from the University of California, Riverside in 1999. He earned a PhD in Physics from the University of Washington in 2004, where he studied single ion trapping. He then went to the University of Maryland, where he was a postdoc in medical physics, studying real-time correlations and corrections for moving tumors. He joined the faculty at Harvard Medical School and the staff at Massachusetts General Hospital as a medical physicist in 2007, before joining American Science and Engineering in 2010. Since coming to AS&E he has worked on keV and MeV x-ray sources, detectors, and integrated systems, as well as doing work with protons, neutrons, and ultrasound, mostly for security applications.

Ge Wang

Ge Wang (F'03), PhD, is Clark & Crossan Endowed Chair Professor and Director of Biomedical Imaging Center/Cluster, Rensselaer Polytechnic Institute, Troy, New York, USA. His research expertise includes x-ray computed tomography (CT), molecular tomography, simultaneous CT-MRI, and omni-tomography. He wrote the first paper on spiral/helical multi-slice/cone-beam CT, which is now a main mode of CT scanners with about 100-million multi-slice/cone-beam scans annually performed worldwide. He is also the lead author of the first paper on bioluminescence tomography and holds initial patents. His group published the first papers and holds patents on interior tomography and omni-tomography for grand fusion of all relevant tomographic imaging modalities ("all-in-one") to acquire different types of datasets simultaneously ("all-at-once") with CT-MRI as an initial example. His research accomplishments were featured by Nature, Science, and PNAS, and recognized by awards for academic excellence. He published >365 peer-reviewed journal papers (http://scholar.google.com/citations?user=pjK2mQwAAAAJ), in addition to numerous conference articles, presentations, and patents. His group has been in long-term collaboration with General Electric Global Research Center, Wake Forest Institute Regenerative Medicine, ZEISS/Xradia, and others, being continuously well funded by federal and industrial agents ($19M as PI/Contact PI, $28M as Co-PI/Co-investigator/Mentor). He is the lead guest editor of four IEEE Trans. Medical Imaging special issues on x-ray CT, molecular imaging, compressive sensing, and spectral CT respectively, the founding Editor-in-Chief of International Journal of Biomedical Imaging, Associate Editor of IEEE Trans. Medical Imaging, Medical Physics, IEEE Access, and others. He is Fellow of IEEE, SPIE, OSA, AIMBE, and AAPM, and welcomes superb research and educational opportunities (ge-wang@ieee.org; http://www.rpi-bic.org).

Amy M. Waters

Amy Waters received her Ph.D. in Materials Science and Engineering, specializing in Nondestructive Evaluation techniques from the Johns Hopkins University in Baltimore, Maryland. Her research interests include x-ray imaging for security applications including explosives detection, and operational test and evaluation of threat countermeasures technologies.

Dr. Waters is currently the Program Leader for Explosives and Infrastructure Security at the Lawrence Livermore National Laboratory, where she is responsible for overseeing multiple projects executed on behalf of government sponsors, primarily Department of Homeland Security. Prior to joining LLNL in 2002, Dr. Waters worked for Varian Medical Systems as Product Manager for their line of industrial Linear Accelerators.

Tim White

Tim has a PhD from the Optical Sciences program at the University of Arizona and a history of developing CT solutions for a wide range of problems for longer than he cares to remember. Prior work includes development of a stationary single-photon emission CT system for medical imaging, laboratory micro-CT systems for nondestructive evaluation, field-portable, medium- and high-energy CT systems for environmental-remediation applications, and investigations of spectral CT for security applications. More recent work includes evaluation of the feasibility of emission CT for verification of the integrity of spent nuclear fuel and development of a single-pixel gamma camera.

12. Appendix: Questionnaire

Attendees were asked to fill out a questionnaire providing feedback on the workshop. The questions are listed below; the answers appear in the next section. Responses are grouped by question and then by person; the first respondent is response A for each question, the second respondent is B, and so on.

1. What is your relationship to ALERT?
2. Which technologies discussed during this workshop show promise?
3. What promising emerging technologies were not discussed at the workshop?
4. What should be done to expedite the deployment of emerging technologies?
5. How should concept of operations be changed for air cargo inspection?
6. How can third parties be involved in the deployment of new explosive detection equipment?
7. Do you have recommendations for future workshop topics?
8. What did you like about this workshop?
9. What would you like to see changed for future workshops?
10. What other comments do you have?

13. Appendix: Questionnaire Responses

Question 1: What is your relationship to ALERT?

A Government

B Industry

C Government

D Government

E Government

F Industry

G Industry

H Industry

I Industry

J Industry

K Industry

L Consultant

M self

N self

O National Laboratory

P Academia

Q Government

R Industry

S Industry

T Academia

U Government

V ALERT team member

W Industry

X Academia

Y Industry

Z Director, National Guard Homeland Security Institute

AA ALERT team member

AB Industry

AC Industry

Question 2: Which technologies discussed during this workshop show promise?

A X ray and Neutron Technology for scanning air cargo

B Combination systems with x-ray and CT

C Combined neutron/x-ray scanning.

D Unclear if a single technology will meet the need.

E I think all the technologies showed a great deal of promise. It is hard to assess which ones would be the most useful without being able to discuss potentially sensitive data.

F Both x-ray and neutron. I was not aware that portable neutron sources existed - this is promising.

G No response

H One technology in particular did not stand out, however, each complementing one another may have promise. As was mentioned at the workshop, there is - unfortunately - no one "silver bullet" solution to the current challenge in our security approaches.

I LD-3 container hardening is an obvious technology that shows promise.

J Sparse view CT / neutron imaging for cargo applications

K Big Data analysis

L Trace Detection as it is the fastest and least expensive for end users who only want to satisfy a mandate.

M I'm not well-enough informed to give an opinion.

N I'm not well-enough informed to give an opinion.

O The technologies which exhibited molecular specificity were the most promising for explosives detection, along with the hardened ULD talk. These two concepts together show the most promise.

P 9MeV system Other novel X-ray based technologies

Q Neutron resonance radiography, Passport NRF

R That is a broad question. Show promise of what - achievability, applicability, feasibility, etc..? Short term or Long term? They all show "promise", For different reasons to different people. The technology and subsequent material was well conceived, demonstrated and presented. No laws of Physics are in jeopardy. and

S 1. ETD's 2. A combination of X-Rays and some other technology able to distinguish between materials based on "signature"

T All sound interesting.

U No response

V Fused systems

W A combination of x-ray and neutron detection seems to be the best way to image large containers. However, it seems unlikely these systems will ever be widely deployed due to their cost and complexity.

X CT X-ray imaging, side scatter imaging, neutron and gamma ray imaging, some trace techniques. Limited view reconstruction.

Y Within "the cost box" given, nothing looked particularly promising. The cost / throughput / regulatory balancing would have to change for anything to start to look promising.

Z As an end user I found the entire program insightful and informative. I have personal experience with the Rapiscan and Backscatter systems while deployed to Afghanistan in 2011-2012.

AA No response

AB ETD, Mass Spec, projection X-Ray, CT

AC DHS applications of PaX Source HULD Research Big Data

Question 3: What promising emerging technologies were not discussed at the workshop?

A None

B There was no discussion of vapor detection technology

C No response

D We did not discuss optimizing conops to maximize Pd and minimize Pfa. I think this is a real low-hanging fruit.

E There were only a few talks on trace and nothing related to mass spectrometry. A comparison of the capabilities of trace vs bulk would great. If there are limited signatures then maybe bulk is the way to go but I did not see any data related to Pd and Pfa of bulk technologies. It seems that there is a knowledge gap between the ETD developers and developers of bulk technologies and it would be useful for everyone involved to understand the benefits and challenges of both approaches. A full system incorporating a hybrid approach maybe the best in the end which incorporates the sorting based on the LLNL work presented by Dr. Waters where there are ETD and bulk sensors.

F Hard to say. There are several, but whether or not they can meet the requirements is the issue. I cannot think of any off the top of my head that would apply.

G No response

H More discussion is needed on “non-physics” solutions - software supplementation of data based machine learning to enhance ATR, for example, would be a good topic of discussion and approach to dealing with the challenges of discussion. Incorporating more and more machine-learning is critical in the expansion of threat detection systems.

I Phase contrast with x-rays was briefly described.

J Effectiveness of trace detection for cargo applications, esp. since this is the dominant choice of screening technology currently applied due to economics. The question “how can we make trace detection more effective ... at what incremental cost ... time ... “ could have been addressed.

K No response

L Improvements in trace detection

M No response

N No response

O More extensive discussion about molecular specific detections were not a central part of the workshop.

P Pretty comprehensive. Could not think of any other except more more traditional techniques such as canine units, etc.

Q I don't know

R 1. Everything outside of X-ray well not covered in great detail.

S New ETD technologies (non-contact) adapted to air cargo

T THZ imaging?

U More information on existing cargo inspection process (including federal requirements) would be beneficial

V No response

W Energy discriminating/photon counting detectors.

X Unclear I know others.

Y Automated projection image analysis

Z I found the individual "footwear" scanning technologies promising.

AA No response

AB Data Fusion

AC Nanosensor based detection

Question 4: What should be done to expedite the deployment of emerging technologies?

A Understand the air cargo marketplace

B There has to be partnership between academia, industry, and the government. Workshops like ALERT help to foster these partnerships but government then needs to commit to a procurement. Companies will never see the value in building a technology without profit at the end. A process similar to the recent NGCD military procurement would be useful. A specification was released with a clear statement on the number of instruments expected to be purchased in a given timeframe. This makes it easier to go to management to fight for a program.

C I would presume more money would be very effective at expediting the technologies, but absent that a couple of test facilities at airports that could divert a small amount of the cargo to new scanners and multiple scanners would be boon to expeditious testing

D We need an engaged and proactive DHS, with transparent priorities. We also need to find a way to provide data to technology developers earlier in the development cycle, and OUTSIDE of the government acquisition cycle.

E Simply put more funding. However since funding is finite, it might be worth evaluating how to build systems that serve CBPs and EXD or develop joint requirements. Also it might make sense to set up an independent facility where vendors can 'red team' their products, without them having to invest funds into the effort, or DHS having to fund the same types of exercise multiple times over and over again. At the minimum, I can imagine a large red team exercise once a year where all the vendors participate and get data.

F Tough question. Continued gov't funding can help reduce the component costs, reduce device size, and make it more likely to be adopted.

G This is difficult. It would be overly simplistic to say that the security-technology community has to become more effective in informing Congress and the agencies of the need to improve security technology because in any large-population, heterogeneous nation like ours, the entire situation is more or less a moving scrum. Still, at a high conceptual level, unsullied by the realities of politics and large organizational behavior, that is what needs to be done. Doing it is much harder, however, than saying it.

H Increase collaboration between commercial vendors through government initiatives. Increase in complementing technologies initiatives vs. what at times may be orthogonal approaches in dealing with security applications.

I Legislation may be required to bring about container hardening.

J Deployment depends on the mission (needs, gaps, etc.), economics, available technology, etc. in order to generate a viable business case. The cargo screening mission is complex, and does not motivate a compelling business case for applying complex technology like neutron imaging.

K Testing algorithms without having access to real data will not lead to mature systems, even if you continue such discussions for more years. You need to make restricted data on 1) threats and 2) real-life representative data collections available for (qualified) researchers. Real-life data collection does not need to be fully annotated.

L Concentrate on the threat - this is a reactive industry with federal agencies and airlines only reacting to threats that have actually occurred - they also have a very short memory. Perhaps insurance companies should be consulted on economic chaos that would result from a negative impact on the $30 billion air cargo system

M Emerging technologies, virtually without exception, are more expensive than what is in place today - often MUCH more expensive. Industry has no vested interest in deploying more than the minimum requirement unless they can be brought to believe that there are threats which may have severe financial consequences should they occur in future, (e.g. a fission device), and that ALL carriers and cargo handlers will be impacted. Engaging the carriers and handlers in a risk/consequences analysis might result in a concerted effort to deploy specific technologies.

N Emerging technologies, virtually without exception, are more expensive than what is in place today - often MUCH more expensive. Industry has no vested interest in deploying more than the minimum requirement unless they can be brought to believe that there are threats which may have severe financial consequences should they occur in future, (e.g. a fission device), and that ALL carriers and cargo handlers will be impacted. Engaging the carriers and handlers in a risk/consequences analysis might result in a concerted effort to deploy specific technologies.

O This is a difficult question to answer. Boot strapping off of DoD explosives detection initiatives as appropriate for the detection of explosives in cargos may be an expeditious avenue. The deployment of new emerging technologies would require a change in regulation. At this time, only the national governments have a role in establishing risk and "buying down" that risk. The time scale of catastrophic events is long compared to the time the CEOs and CTOs of the air cargo industry are in their positions, it is very likely that they would not have to deal with a catastrophic event. This must be a large disincentive to address any of the problems, along with the very small profit margins the air cargo industry works under. In that environment there does not seem to be a "technology pull" from the vendors who are in the market for such technologies.

P Programs for Industry-Academic partnerships

Q You can't deploy emerging technologies without fully developing and testing them. That costs a lot of money and S&T EXD does not have enough. DNDO has considerable funds, but does not integrate its efforts with EXD or BMD. Pooling resources could go a long way to at least getting technology to a testable stage. And EXD may not be willing to engage since TSA is not buying systems. Unless there is a significant security event and the regulation paradigm changes, and industry economics warrant, these technologies won't be deployed.

R 1. Favorable regulations and customers with money.

S Government support. (1) funding the development of new technologies (2) faster evaluation of new technologies (3) funding consortia of academia/relevant start-ups/national laboratories/established industry to carry out projects from idea to product (4) involve end-users in the design phase --> use their facilities to test prototypes (5) have a permanent facility (like TSIF) to test/evaluate/improve new technologies

T Support to academic groups will be great.

U No response

V Regulation changes create incentives for using the best not the cheapest equipment make LCCB case to avoid comparison of capital expense upfront, which can be neglected in the long run compared to operational cost

W The emerging technologies discussed where large complex systems. It seems the only way to advance these technologies is for large Government investment in the research and development stages.

X We have unclear goals and requirements, so there are many versions of a solution. The main requirement seems to be to have some form of inspection. Unclear goals of Pfa and Pd.

Y Clear statement of problem. With an existing inexpensive product on QPL, it's not clear why the regulator perceives a need for an emerging technology, and without a clear vision of that, industry will be reluctant to invest resources

Z Getting the information to the decision makers at all levels of government and private sector.

AA No response

AB Bring more policy makers into the discussion

AC This is a big topic and needs much discussion and clarification. There is a HUGE disconnect between the academics and markets that needs to be bridged. The DHS needs to address the issues and reasons these technologies never make it to market.

Question 5: How should concept of operations be changed for air cargo inspection?

A Centralized scanning facility for air cargo.

B No response

C Based on what I saw, profiling and simple scanning is going to be the most effective. I can't say that any of the scanning technologies talked about are going to be extremely effective, therefore the only solution as of yet is a multilayer approach, combining process flow, intelligence, spot checking and active interrogation.

D Some research into development of optimized technology configurations and processes is needed in order to quantify any increases or decreases due to ConOps.

E I think this hard to answer without feedback from the end users. In particular getting feedback from not only the leadership in the airlines, but maybe actually the managers of the individual facilities would be useful. It might be worth considering funding an effort looking at how well the current system works and identify any gaps.

F Not experience enough with the current conops. But clear that they cannot affect business.

G No response

H A ConOps based on a risk approach is necessary. In other words, as mentioned at the workshop, A constant assessment of risk and keeping cost in perspective is needed.

I No response

J I don't think many of the ADSA 10 members are able to make informed recommendations on this. There was unclear information on the "current state" ... what is currently screened by what method at what cost ... or the mission-critical success criteria. For the shippers the mission-critical success criteria seems to be satisfying the regulations at minimum cost/delay. There doesn't appear to be a priority on detection since the "true positive" rate is zero and there is no TIP or other detection metric.

K No response

L Stricter mandates on types of screening

M No response

N No response

O The current “concept” is to look inside every package. This has driven the current technologies which are heavily radiographic. This concept seems a natural extension of the idea of inspection, but is not workable for the current problem. This is further complicated by the very small sizes of objects, and the very rare occurrence of an actual “event” (of an illicit explosive in cargo). It would seem the “visual inspection” even with the aid of signatures will not scale (and has not scaled).

P No response

Q The CONOPS is not based around security, it is based on commerce. The whole paradigm needs to shift to a security-inclusive paradigm (but I am not advocating excessive government either).

R That is a workshop by itself. Technology is advancing, however the operations are quite dated and need process improvement.....maybe more so than “technology”. For example, the majority of presentations seemed to focus on improving Detection and Imagery, not process or throughput speed.

S 1. Risk based criteria 2. Adapt and combine technologies to specific cargo contents

T Interior tomography should be a good direction.

U No response

V No response

W No response

X Depends on the requirements...

Y No response

Z Move the scanning facilities out of the terminals. While in Afghanistan, I found that our scanners were placed inside the “wire” thus defeating the purpose of the technology (identification of a threat from a safe distance). Our scanners were moved outside of the “wire” with sustainable standoff measures, while continuing operations without much delay. I found that our threat levels were substantially higher (immanent threat) than this we face here in the US. Thus, these technologies should be commensurate with the intended threat level. In my estimate, I believe there would be a higher threat using an air cargo carrier to deliver a chem/bio attack than an explosive attack. This type would be quite sensational and could possibly shut down air commerce with the slightest event.

AA No response

AB I'm not sure that it should - see prior suggestion

AC Centralized cargo screening facilities; off-site if at all possible.

Question 6: How can third parties be involved in the development of new explosive detection equipment?

A n/a

B No response

C In any active test there should be third party verification and review, and test design

D More access to data and materials to support technology development EARLIER in the development cycle. DHS should support the creation of safe and appropriate T&E facilities with proven QA/QC for vendors to work with as they develop new systems.

E The SBIR program and BAA mechanism is great, but it can be limiting and it might be helpful to use these funding mechanisms to in effect partner smaller companies and government labs with larger entities who have proven capability fielding, manufacturing, deploying, and supporting products over their lifespan.

F Separating ATR and OSR from the device. Possibly via DICOS.

G I'm not sure that I understand what "third parties" means in this question, so it's hard to respond. Who are the first and second parties, as distinguished from the third parties? Are third parties, parties other than industry, government, and academe?

H Supplementing "niche" markets of challenge by the current dominant scanning equipment vendors by providing vender-independent solutions. This, however, needs to be initiated by the customers (TSA for example) of the large vendors to provide an incentive for change. As you know, complacency is in many instances the greatest challenge to innovation and eventual change. A process change or enhancement has to occur to the current baseline model to solve this ever increasing problem of cargo and baggage security.

I Involving insurers in the workshops may bring about pressure to adopt techniques that are better than those currently employed (primarily trace detection).

J Collaboration with established team in government, industry and academia. Propose/win BAA contracts, etc.

K 1) Government should provide realistic data sets that can be used to measure algorithm performance. The data sets should be such that good performance will enable third parties to qualify for cooperation on the project 2) Government should specify open system architecture (OSA) when procuring hardware from vendors. OSA will enable testing & integration of third party algorithms Open Systems Architecture (OSA), Office of the Deputy Assistant Secretary of Defense for Systems Engineering (DASD(SE)) http://www.acq.osd.mil/se/initiatives/init_osa.html

L Provide more testing facilities

M Can we identify obstacles that delay or prevent development of new equipment?

N Can we identify obstacles that delay or prevent development of new equipment?

O A great deal of work has been engaged in by the DoD, it may be possible to expand the partners in cargo detection to include these entities.

P No response

Q These workshops have been good to eventually get medical researchers in the same room with the security researchers. That type of connection can be beneficial but it all has to be done within a security environment, which will unfortunately disallow many from participating because of foreign citizens or those without security clearances.

R Providing a forum for the entire inspection/detection chain, especially the Inspection analysts (IA's). The IA's are critical path, as important as, any technology presented or under development.

S See 4(3) above Involve the end users

T Data sharing is a key.

U No response

V No response

W Algorithm development for improving image quality and developing ATR for existing dual-view and multi-view systems.

X Third parties can provide some assistance in reconstruction techniques, but much of the effort is at the sensor development front.

Y No response

Z I am not as familiar with third party involvement. In my experience, I found the shelf materials are both cost effective and expedites deployment of mitigation technology.

AA No response

AB Solving the alarm resolution problem. Without a solution to that, ETD will rule.

AC Again, a big topic on its own and warrants substantial time along with #4 above.

Question 7: Do you have recommendations for future workshop topics?

A Maritime cargo workshop

B A connection to the end users that operate the equipment would be helpful. It would be great to have someone from operations at an airline or independent cargo facility walk through the movement of cargo in their facilities and discuss the issues they have with the current process. Also, having cargo container manufacturers as part of the discussion would be useful. There was a technology described at the workshop that would work very well for screening the interior of cargo containers if there was a door on the container. You need a container manufacturer to buy into this idea and then it gets a lot easier to screen the middle of a container.

C Perhaps something with human factors, process flow, and economics. Giving people a better understanding of how technologies help or hurt and understanding into how they might fit into a larger system of protection.

D - Commodity based screening - how do you do it?

E No response

F More on using software to solve various challenges? Continued inspection into reconstruction methods, ATR, possibly even OSR interfaces?

G Yes. One topic is whether and, if so, how we can make the entire "enterprise" more effective by harmonizing security standards and procedures worldwide, or at least, as a start, in regions of the world. Having varying standards and procedures makes everything harder, messier, and more porous, and the malefactors will waste no opportunity in exploiting the gaps and inconsistencies in the present, uncoordinated worldwide system. Since it behooves all countries, including the richer ones, to erect meaningful security barriers throughout the entire system, the richer countries arguably have an interest in subsidizing the poorer countries in helping the poorer countries to install and operate "first-world" security technologies.

H Suggest more computer science related topics / solutions vs. the current focus on physics-based solutions. Image reconstruction, segmentation and threat detection.

I Fixed-source / fixed detector geometries for CT of checked baggage and some cargo applications where sufficient penetration can be achieved. Compressive sensing.

J DHS S&T is awarding lots of R&D funding on applying X-ray diffraction and compressive sensing to detect a chemical-specific signature. ADSA should conduct a future workshop(s) on these topics as another mechanism to motive collaborations and accelerate learning and development. The Duke contract generated lots of data on government funding, including diffraction signatures of a large material database. ADSA should explore how this and other information can be presented and shared to prevent redundant expense in the development pathway.

K Realistic data sets- possibly a separate restricted workshop or a special restricted session open system architecture (OSA) for DHS hardware

L These workshops are great, but they tend to get academia and research working on issues and problems without the benefit of the people who are actually purchasing the equipment - I would get more of the end users in!

M No response

N No response

O A workshop exploring the molecular signatures of explosives in cargo would be appropriate. While there may be many good applications of signature assisted radiography (e.g. large quantities of contraband, 10s to 100s of kilograms), the molecular signature may be the the best detector for explosives. Another topic would be integrating the entire problem, including the ULDs.

P No response

Q Simulant validation. Integrating the RDTE of Borders and Maritime, Explosives, and DNDO for key technology development. Or at least sponsoring an exchange so that other agencies know what each other is doing. But I understand the “E” in ALERT stands for explosives.

R Include things outside of X-ray technology, MMW, etc... Also things outside of technology, process, Users, etc..

S Have more chemists. Combining orthogonal methods, i.e. chemical detection + radiation technologies, might offer a new range of solutions. Invite end-users (shippers) to come and present their perspective

T Big data based imaging and inspection.

U In addition to inclusion of technologists, you should give some consideration to inclusion of members of the air cargo industry (airlines, air freight companies, freight handling equipment manufacturers). Hearing from these groups may spur the though process of technology developers with regards to air cargo industry constraints/opportunities as well as open a dialog to develop technologies and methodologies for screening cargo that would more seamlessly integrate within the air cargo infrastructure.

V Try to find a way to get customers involved as well (airlines, insurances), then have CARGO II workshop and tackle issue from non-technical side

W Non-traditional CT including: Sparse View CT and non-circular CT. This could include the systems currently being developed that are commonly referred to as multi-view and few-view. There seems to be a large amount of interest in both vendors and academics in this field. It has been talked about a lot but not in a dedicated way. The topic could cover the algorithms, systems, future concepts. People talk a lot about how good the image quality can be in these systems but no one really talks about how this will affect the ATR and CONOPS.

X No response

Y No response

Z As an end user, I would like to see what the operators of the technology experience, best practices and lessons learned to make these tools more efficient.

AA It seems as though another workshop should be held around the same topic, but involving other key decision makers and stakeholders. Involving policy makers, social scientists, and customers may lead to a more lively discussion on how to solve the problem, and even more insight to what the ultimate goal is for the end user.

AB New Security Domains - a discussion of areas where low-tech solutions rule and technology might help. It would be interesting to start with domain experts to discuss what the key factors/drivers/CTQs are for their area and then build a technology shortcoming matrix for several solutions. For example, Rail is old-school. If we wanted to "technologize" security there, what are the key problems to be overcome? Then academics can get to work solving those problems.

AC Development of integrated technology platforms. Development of technologies to facilitation integrated detection. How to encourage/ support emerging technology development by private/small companies - From inception through QATT.

Question 8: What did you like about this workshop?

A Great location and facilities

B No response

C Seeing the overview of the technologies and speaking with people from industry and academia

D I enjoyed the spirited exchanges and dialogue.

E I learned a great deal and I had the opportunity to interact with a number of people.

F Good mix of people. Industry, gov't, academia, national labs, etc.

G The involvement of industry representatives, which I know can sometimes be difficult to arrange because of competitive concerns and the like. Still, having industry people at ALERT, in addition to academics, is beneficial in rounding out the whole picture.

H The expertise in and industry and some technology cross-representation was excellent given the topics of discussion.

I Networking. Greater understanding of problems with neutron detection.

J Networking.

K lots of interesting and knowledgeable people

L Easiest question - the high caliber of people across the spectrum of industry, government and the vendors was very impressive

M Open atmosphere. Mix of academia, industry, government. Emphasis on networking. Format of presentations (who cares; interrupt with questions).

N Open atmosphere. Mix of academia, industry, government. Emphasis on networking. Format of presentations (who cares; interrupt with questions).

O It was a very good introduction to the topic area and to the people working in the area.

P Variety of topics, depth of conversation, and informality of the event.

Q Well it was good to see some old faces again but this is a huge problem and I doubt that this workshop will "change the world". There are huge economic forces and shipping schedules in play. Without stronger government oversight and regulation, or even acquisition, I think ALERT might have been better off not having this workshop in the first place. So I liked that you had the workshop and the agenda was reasonable, but what will come out of it? What were the expectations?

R Excellent overview of technology being worked on by Academia, other markets and Fed agencies. Good networking opportunities.

S Informed by an Israeli colleague

T Different ideas.

U Diverse group of attendee's and presenters, offered good networking and information exchange opportunities.

V participant group diversity networking size good presentation highlighting many of the aspects from a variety of point of views

W The open environment and the wide range of perspectives.

X A lot of ideas were presented. However, there was little discussion or presentation of the limitations of those ideas, perhaps because of the unclassified nature of the workshop.

Y No response

Z This was my first ALERT workshop, I found the networking opportunities priceless, I hope to be invited back.

AA Open discussion was great. There was a lot more back and forth than previous workshops.

AB Discussions, lots of government attendees (relative to other conferences)

AC The entire forum and quality of information.

Question 9: What would you like to see changed for future workshops?

A Ability to have smaller classified discussions

B No response

C I think there are some topics for which a panel discussion would be more appropriate than a single presenter.

D No response

E It might be useful to add a session where sensitive information can be discussed in order for the audience to get a better understanding of the benefits and limitations of particular technologies, and identify gaps that need to be addressed. I understand that this may be had especially if vendors can't release proprietary information. It may be useful to have an overview from DHS on all the different efforts they are funding and what technological challenges they see in the near and far term.

F Include airport stakeholders - buyers of approved devices.

G An increase in, or at least a continuation of, the industry participation alluded to in my answer to question 8.

H As mentioned above, an increase list of "computer science based solutions" would be helpful. A discussion too on what initiatives are currently in progress and show promise but need further enhancements to improve the probability of success. Please increase air circulation in the conference area. The stuffy air situation made the long days even more challenging by the end of the day.

I No response

J When new applications are introduced, start with a better "state of the application" presentation so everyone is informed of the mission, success criteria, current practices, economics, technologies, etc. This should be presented by someone from TSA and/or DHS.

K focus on outcomes. There were many discussions about ways forward and they led either nowhere or to toy projects, like segmentation competition, that was not realistic enough

L Rather than individuals giving sequential talks, I'd like to see more panels where Carl might be moderating a panel on the use of neutrons in cargo interrogation

M No response

N No response

O Perhaps more directed discussions. If discussion areas were outlined in a bit more detail and available before the workshop it is possible that the participants would have at least thought of talking points regarding some of the more specific ideas. Maybe "homework" to do before coming to the meeting? It might be unrealistic, but even if a fraction of the participants did the "homework" it might help facilitate a deeper better targeted discussion period.

P May be have two parallel track, or divide into groups of like-minded people/technologies.

Q There were several presentations that were nothing more than vendor marketing. That is really annoying and wastes time for folks who have PhDs and want to see and talk technology. There is a time and place for such marketing, but these workshops are not it. Also, please try to safely deploy some power cords and strips in the meeting room.

R I think ADSA has or will come to a fork in the road. What is the charter of the group? To-date it has been a "technology" round table. I think it is time to broaden the scope. Moderators have to be very careful with the words used during the work shop and in summary. A good example of this is the confusion that remains around ETD and the word Ideal solution. The ideal solution is in the eye of the beholder. If the definition of ideal is revenue from equipment sold. The answer is the vendors who have sold TSA, et al - equipment from some sort of "approved" suppliers list.

S See 7 above.

T Hot food will be better.

U Increase to three days in order spread out presentations. A lot of information was presented each day that made it difficult to absorb and assimilate. May want to consider addition of a breakout session during which SSI or classified info can be discussed.

V nothing

W Including more of the final customers including the airlines and TSA.

X No response

Y No response

Z Nothing

AA There needs to be an afternoon break scheduled for both days. Attendees seem to get very antsy without enough time to break from the workshop.

AB More students and discussion time with them. Less overt direction

AC No response

Question 10: What other comments do you have?

A none

B No response

C No response

D No response

E No response

F Always a good workshop.

G No response

H No response

I No response

J Excellent facility, food and support staff.

K No response

L Keep up the great work -

M I have been out of the Security area for several years. My goal in attending was to come up to speed as quickly as I can, without the need to travel far and wide. The Workshop met my needs very well.

N I have been out of the Security area for several years. My goal in attending was to come up to speed as quickly as I can, without the need to travel far and wide. The Workshop met my needs very well.

O No response

P Overall, excellent meeting. I am glad I attended it.

Q No response

R Nice to see some chart on accuracy of detection per some units of cost by technology, today and in the future. Lastly, what are some things that would create significant inflection points?

S Have some space for 1-on-1 meetings next to the auditorium.

T Like to see funding opportunities to academic groups.

U No response

V No response

W No response

X No response

Y No response

Z Thank you for the invitation, the speakers were first class and the staff made the program run effortlessly.

AA No response

AB No response

AC Great workshop. Looking forward to August.

14. Appendix: Acronyms

TERM	DEFINITION
ADSA	Algorithm Development for Security Applications (name of workshops at ALERT; The term advanced is used at times in place of algorithm to reflect that topics other than algorithms are discussed at these workshops.
ADSA01	First ADSA workshop held in April 2009 on the check-point application
ADSA02	Second ADSA workshop held in October 2009 on the grand challenge for CT segmentation
ADSA03	Third ADSA workshop held in April 2010 on AIT
ADSA04	Fourth ADSA workshop held in October 2010 on advanced reconstruction algorithms for CT-based scanners.
ADSA05	Fifth ADSA workshop held in May 2011 on fusing orthogonal technologies
ADSA06	Sixth ADSA workshop held in November 2011 on the development of fused explosive detection equipment with specific application to advanced imaging technology
ADSA07	Seventh ADSA workshop held in May 2012 on reconstruction algorithms for CT-based explosive detection equipment
ADSA08	Eighth ADSA workshop held in October 2012 on automated target recognition (ATR) algorithms
ADSA09	Ninth ADSA workshop held in October 2013 on new methods for explosive detection
ADSA10	Tenth ADSA workshop to be held in May 2014 on air cargo inspection
AIT	Advanced imaging technology. Technology for find objects of interest on passengers. WBI is a deprecated synonym.
ALERT	Awareness and Localization of Explosives-Related Threats, A Department of Homeland Security Center of Excellence, at NEU
ATR	Automated threat resolution; a synonym of ATD
COE	Center of Excellence, a DHS designation
CONOP	Concept of operations
CT	Computed tomography
DHS	Department of Homeland Security
DHS S&T	DHS Science & Technology division
ETD	Explosive trace detection
EXD	Explosive detection directorate of DHS
FA	False alarm

TERM	DEFINITION
HME	Homemade explosive
IED	Improvised explosive device
IMS	Ion mobility spectrometry
NEU	Northeastern University
NRF	Nuclear resonance fluorescence
OSARP	On screen alarm resolution protocol/process
OSR	On screen resolution
PD	Probability of detection
PFA	Probability of false alarm
SNM	Special nuclear materials
SOP	Standard operating procedure
SSI	Sensitive security information
TBD	To be determined
TCO	Total cost of ownership
Trace	Synonym of ETD
TSA	Transportation Security Administration
TSL	Transportation Security Lab, Atlantic City, NJ
TSO	Transportation security officer; scanner operator
ULD	Unit load device (a container used for aviation cargo). LD3 is a type of a ULD.
XBS	X-ray back scatter
XRD	X-ray diffraction

15. Appendix: Minutes[4, 5]

The ADSA10 minutes were edited for purposes of clarity. All errors in the minutes are due to the editors of this report and not due to the speakers themselves.

15.1 Day 1 Minutes: May 6, 2014

Michael B. Silevitch: Director of ALERT, Welcome. Intro to ADSA, intro to Ceremony to Launch ALERT Phase 2.

Laura Parker: Intro to DHS COE, intro to Ceremony, intro to

Matt Clark: How many academics? (1/3 raise hands) How many industry? (2/3 raise hands) How many students? (2 or 3). Intro to DHS COEs.

Speaker: Carl Crawford

Q: Are there people here from government who know about current legislation?

Q: Alan Cargar from TSA, I can help a little with that. We're tied to congressional mandates, so I can help with that. Pending mandates or enhancements, the 100% screening mandate is there.

Q: What's considered screening in that scenario?

Q: TSA has a different definition: we physically or electronically scan. CDT definition is the paperwork.

Q: Does that include manifest verification?

Q: Yes.

Q: What is the legal status?

Q: There's a congressional mandate that 100% of domestic cargo be screened by August of 2010. The international mandate was July of 2013. They have been met.

4 "Q" indicates a question or comment made by an ADSA10 attendee.
5 Inaudible or missing portions of the minutes will be indicated in parentheses as (???).

CC: So there's a discrepancy of the definition of screening in the room.

Q: Is there a limit of the workshop?

CC: The workshop is dealing with explosive detection in air cargo. We'll talk a bit about other things like drugs, but only to talk about the technology being used.

Q: Over 50% of cargo is shipped with passengers onboard. We usually think about cargo dedicated airplanes, but at least in the Middle East that's not the case. Also, how much time do you need to get the detection?

CC: Good points.

Speaker: Stephen Surko

Q: Certified shipper program shows that there's a process and there's a guarantee for safety. The Known Shipper Program…

Q: What do you mean by inspect? Who does that? When is it done?

SS: There are approved methods by TSA. TSA has something called the ACSEL that's like an approved products list. It lists all of the proved systems vendors that can be used in X-ray and trace, and vendors can only purchase equipment from that list. It's a $30 billion per year industry. So, in my opinion, these sites are driven by profit motive and what's most cost effective, rather than what's most appropriate. Most employed systems are trace because it's the most cost effective.

Q: But there are other threats outside of explosives, for example nuclear.

SS: I can't answer that question well. DNDO and others deal with that threat area. We're not looking for contraband. We're looking for a detonator and an activation system.

Q: How often do they check screening points?

Q: They're checked pretty often. They depend on the size and number of screeners in the area but it is part of the workplan.

Q: Do they tell screeners when they're coming?

Q: Sometimes they do, sometimes they don't.

SS: Trace is easy to use and low cost. Southwest, for instance, has made the business decision to not use X-ray in anything. They swab all cargo because of cost.

(???)

SS: The same individuals who operate the machines are also the same people who conduct the swabbing.

Q: From my perspective (???) The cargo screenings around the world are run by airlines. It's not the same as a checkpoint. We'll talk at this meeting about (???) We should know as a group that this is a market that doesn't necessarily want to buy the equipment. (???) It's not a federal licensure. It's the airlines and they're an enormous business.

Q: Does there exist a list of gaps with the existing technology? All of the technologies have a certain performance level, and there's no technology that's perfect. So is there something that exists where improvements can be made in technologies? I think that's an important point.

SS: It took me time to realize that that is important information to have and we didn't have it. This year we started an efficacy meta-study and we're looking at all available equipment qualification studies, qualifying different systems to identify, for example, what works well on frozen fish. We have all commodities, container types and screening technologies to identify where we have gaps. With capability gaps we can work with TSA and guidelines can be instituted or we need to develop improvements.

Q: In 2006 there was work done to develop those technology matrices that you're speaking of. That may be of use to you and I'll talk a bit about that later.

Q: Some of this information, we have to remember, SSI or Classified and we have to assume that some of this audience doesn't have access to this information. We have to figure out how to pose the problem. Also, any comments on how it differs outside of the US?

SS: I have the impression that other countries use more centralized screening systems, and they may be interested in more expensive systems.

Q: Can you say what the false alarm rate has to be?

SS: I don't think I can. I can talk to you in relative terms though. Separate from improving performance of equipment, through the ETD testbed, we've discovered that the false alarm rate is nearly half for cargo than TSO's experience at checkpoints. It could be for a variety of reasons including environmental difference. If there could be a way for us to collect performance data and operator issues that would be interesting.

Q: What happens if something tests positive?

SS: They go to another approved screening method, usually physical.

Q: Related to this, we're putting together a symposium in August and it is in the hopes that we can develop an industry-wide standard. Steve Beaudoin at Purdue is the chairman of that.

Q: Can you talk a bit of how air cargo is looked at by airlines and give some more information on how that all works?

SS: He's asking about who's doing the screening, where it's being screened and the issues. It's a dynamic picture and when (???) Over time that's gone down. I believe that air carriers are doing around 45% mark; the other 55% is screening by other providers.

Q: I haven't seen those numbers in a while.

(???)

Q: There are some systems that cost $500k, you say. (???)

SS: I don't want to put words in TSA's mouth. I think it's an observation that when they have the choice of what to purchase, they're probably more likely to purchase what's less expensive. Perhaps things could be mandated by TSA but it would require a change in the current system.

Q: Do you have any feeling for the balance of labor versus equipment?

SS: I think most of the bill is labor.

Q: It suggests, as in medicine, that you can afford capitalizing larger equipment if you can minimize labor costs.

SS: Many of these centers don't use these technologies. They just use visual verification.

Q: Labor costs are around 60% of the total cost. Lifecycle cost optimization may be better. Is there any way that the criteria used could be an engagement that seeks to optimize lifecycle cost?

Q: (???) I believe there's only about 6 of those facilities in the US.

Q: What I'm hearing is that the airlines are doing as little as they can to get by with the cheapest equipment available. Your challenge, to my mind, may be to give incentives to airlines to keep people safe.

SS: Well that's not technology so I'd hand that over to TSA.

Q: There are a lot of people trying to do work and it's difficult for TSA to get in. The incentive is to do things well so TSA isn't bothering you. Financial incentives, I don't know about.

SS: How do we transition new technologies and improve the system? We work closely with TSA officers and capabilities. We're trying to field some advanced capabilities. So when we have more ETDs that have been qualified, (???) They will grandfather currently qualified systems for maybe 3 years, and over that time people have to buy new equipment in that time.

Speaker: Tim White

Q: Do you see anything on the horizon?

TW: No the problem is very hard. The promising things are that because it's larger, it is going to have to involve protons and neutrons. If you can break a container down, and run it through the act system, I ask if I want someone else tearing it apart.

Q: Everything going into the aircraft is inspected for explosives. If they are trusted, they screen before they put it in. Everything on the bottom of the aircraft is scanned

Q: I think we are talking about technology screening, to examine a piece of cargo. A very small portion is examined.

Q: We don't tell them how to do it, but we tell them to do it. They are going to pick the one that is most appropriate for their business model. It may not get some protons or neutrons.

Q: We have big containers on the screen. What proportion are palletized?

TW: I think that goes back to the percentage of things going back to the airport.

Q: I don't have those numbers either, so TSA has evaluated what that piece level is. Things have changed over the years. Shrink wrapping, breaking down something, and the rules are changing and outcomes are changing, etc. It's in that configuration. At some point the aircraft has already been configured for that load.

Q: We already see it's a hard problem. My solution is to change the problem.

Q: The statement I heard was that the screening has to be done at the mandated level. Would that satisfy the requirement?

Q: Different containers have a different definition of a piece.

TW: A trigger device is a metal detector, for cases where you shouldn't have any metal in the container.

Q: The date you list is 2002, but are there not changes since then?

TW: There probably have been studies since then. This was transition radiography.

Q: Couldn't you try to implement a different light source for this?

TW: You could. There are a number of other experiments that are developed for this. This neutron interrogation space is first about the source, if you really want to interrogate stuff.

Q: Were you kidding when you said you had a small neutron source?

TW: Yes, I don't think either one is even close.

Q: Is it even worth talking about?

Q: Have you thought about how complementors work?

TW: We are just not close enough to worry about that.

Q: What took so long for the solution?

TW: The solution has to be tailored to each situation.

Q: Is it possible to initiate in different locations?

TW: Most of these things could be made portable.

Q: There are technological advances, and I wonder if the coherence of the laser will add to the program techniques.

TW: One of the techniques that is used for lasers is one of the most promising.

Q: The statement that it can't be solved with radiation, the key point that we say, is the convergence of those, and is that what the conclusion was based on?

TW: At some level yes. If you are looking for a small size, in the case of transmission radar, because all we have access to, the higher energies the problem gets worse. They have a chance to do molecular interrogation, and not everything contains nitrogen.

Q: You are completely ignoring the phase of this.

TW: I am not aware of any phase of the experiments that penetrate any meter length. The phase contrast still exists.

Q: There was a large program looking at the program.

Q: Can you look at the Morpho object? If you scan a pallet of fish?

TW: If you look at these bulk packages, the transmission imaging stuff is where you find that you can't base detection on shapes.

Q: If the issue is pad length, how about a partially invisible system where you put detectors inside the container.

TW: We suppose that these L3s have a hole in the center. That was on our list for a while, but as you go through the space, that would cut the problem down.

Speaker: Harry Martz

Q: There are technologies you can envision that you can use while looking for more devices. You have to do it in the bigger context.

HM: In the past, you see someone with new and improved systems that see this.

Q: My comment is that they haven't spent a lot of time, and they are rushed, and even if they go in the freezer, the shell fish or flowers, most of that doesn't make it to the freezer. Now being able to add another layer, and saying I know this is crabs, etc., you can't even get them to keep perishable items non-perishable.

HM: It doesn't mean things can't change. I respect the Israelis and they will do what it takes. Things start happening. Things will change. For a long time there was a privacy issue, and if there is a threat that is real, things will change. The technologies have limitations. Things must change, and if they don't it won't happen.

Q: You would hate to think some disastrous things have to happen before change is triggered.

Speaker: Tim Rayner

Q: My only comment, don't get hung up on 550k (???) as long as there is a potential path forward.

TR: That is a good point. 5 years maybe, 10 year probably not. I am not saying we throw this out. We need to be aware that we are developing something that does not necessarily work.

Q: Doesn't work today. It could be useful in 5-10 years. We can anticipate what will develop.

Q: What happens if that company goes out of business because funds were not continued?

Q: Fair enough.

Q: LAG?

TR: Liquids, Aerosols, and Gels.

Q: They keep changing their policies every year.

TR: Yes.

Q: What does fighting mean?

TR: The differences of opinion would be that it would slow the EU to a crawl, like Armageddon type preparation. We need to be cognizant that it takes a long time.

Q: You didn't say solve it in 1994. It says invented.

TR: Interesting you say that. If you look at European regulations, the process has removed conversations. There is like 9 conversations right now.

Q: When you think about regulations and strategies to increase throughput, there is the TSA pre-check program. That is a non-technology oriented solution but it has increased throughput.

TR: All of that is fantastic for a flyer but not good for shipment.

Q: If you have trusted fliers, that isn't a bad thing. If you have a smaller amount of people to screen and going through quicker, that is the goal.

TR: I agree with you. I don't see it leading to sales of high tech equipment. The current level of screening is not suitable for high risk. The ability to find things is degraded. It goes the wrong way in the relationship to developing the market of new technology.

Q: I understand risk based screening and why it is needed. In the shared economy, people are forever putting ads saying "carry this bag for me." Every college has a site.

TR: Cargo screening is based on risk based screening. Risk based is going to come and get more and more present.

Q: Risk based screening is either a thumbs up or a thumbs down. There is much technical intelligence applied, especially in a multi-layer system.

TR: Europe doesn't have background checks for pre-check.

Q: What I get from your talk is that we need to change the laws and push the product.

TR: Yes. That, in essence, is what I do.

Q: I don't think risk based is the death toll. If I can push more people through portal screen check, it is a huge win. There are some benefits there. The technology can perform better. My other point for risk based analysis is that there are many ways of collecting information on people for pre-check. It is not that risk based has no technology. Other agencies handle that information.

Q: We think about risk based as technologies that can be tuned on the fly, algorithms that can change from person to person and bag to bag.

TR: That is an interesting concept. There is the attempt to remove something.

Q: This is a classic problem for technology and policy. How do we get people to adopt rational ideas? Right now we have policy informed technology. What we really want to do is have technology informed policy. If you don't start that early enough, the process is incredibly self-serving. They say "so what?" What you have to think about is what are the policies made and who made them and why were they made.

TR: I agree. One can be part of this process step by step to move forward.

Q: Timed market, there are a lot of small companies in this room challenged by the limited number of test facilities. TSA is considered the gold standard. Many companies can't stand in line for years to get tested. This slide that shows 15-17 years to market can be improved with more testing facilities in the country.

TR: Yes. The EU has testing centers charge so they are making a profit so more emerge every week. The US doesn't have that. Most manufactures are based in the US so there should be more testing bases.

Q: Have you considered the possibility to partner with a larger company with lobbying ability?

TR: That is a key point. It comes down to the fact of who is the biggest company with the strongest lobbyists. As a small company, the only way you can help with this is to help with the manufacture trade groups.

Q: Big companies attend conferences that move things forward.

Q: From a small company perspective, the chance of partnering with a big company is small. They typically don't want to partner unless they have a clear sales channel. As much as we don't like to admit it, there is a disincentive to develop new technologies because they already have a corner on the market.

Speaker: Doug Bauer

Q: Screening, as you are talking about it today, is scanning. We should acknowledge that this workshop is your idea. Can you believe we are at 10?

DB: This community of interest, which in the security field never existed, is huge.

Speaker: Amy Waters

Q: What is ULD?

AW: Unloading Device. L3 is kind of ULD.

Q: What do you mean by efficacy testing?

AW: PD.

Q: How long does it take from truck to inspection on average?

AW: I don't have that data on hand. This is not just a steady flow. Cargo tends to be bunched.

Q: If they added inspection earlier there would be more time?

AW: Absolutely. That is why TSA has encouraged independent certified shipping facilities so that when cargo arrives you can skip steps.

Q: How did you determine which technology was a commodity?

AW: Through the matrix that included expertise and direction from TSA and others.

Q: Combinations of technology or just one?

AW: There was integration.

Q: Are those EDSs different?

AW: They are the same.

Q: Mention that the cost and complexity of the material handling systems was the biggest technical headache. It was a $30 million appropriation and cost an additional $5 million to solve mundane problems with the handling system, such as a jammed box.

AW: Some might say overly engineered.

Q: This looks really expensive.

AW: Yes.

Q: How does that fit into your cost cycle?

AW: You will see. I don't want to give away the punch line yet.

Q: What if they can't rebuild it?

AW: They can always rebuild it. They can make it better, faster and stronger.

Q: The life cycle is 20 years?

AW: We had replacement costs for the equipment, itself. The life cycle is 20 years with equipment within having their own life cycles.

Q: NPV?

AW: Net Present Value.

Q: Is that cost comparable to today?

AW: The numbers I presented up front were results from this life cycle. I might have some numbers I need to double check. It is on the order of 10 to 15 cents a pound. The K9 is one cent per pound.

Q: Labor cost, what is the breakdown?

AW: This slide doesn't have it broken down. The report and modeling report has an extensive break down. This includes all labor such as moving packages and physical transportation. San Francisco was slightly more automated. The labor costs dominate. The handling systems is complicated and expensive.

Q: We did a palette study. The scanning is nothing.

Q: Have you considered a two-step with prescreen and select what would go through the extensive process?

AW: The manifest information was entered into the system and the system would determine where to send it?

Q: Did that have a cost impact?

AW: Yes.

Q: If we had a risk based selection, the cost could go down.

AW: I would include labor.

Q: One of the constraints we were under is we can't delay any flights. We have to try to push this while having 100% screening. We had to be observant of that requirement.

Q: What people want to do is blow up airplanes because it is disruptive. People really want to blow up the scanning facility. So there is a point. If you want to cause trouble, you don't do it by blowing up the plane. You blow up the facility.

AW: We were doing no freighter aircraft in Cincinnati.

Q: If I took out a $30M facility, what would happen to cargo traffic in and out of San Francisco?

AW: It would be bad.

Q: How does that cost per parcel compare to what shippers charge?

AW: Depends on the shipper.

Q: What is the time needed to unpack, screen and repack?

AW: If you were to un-build, scan it and rebuild, it was on the order of an hour.

Q: You have two scanning machines. They are basically running parallel? Are they loaded completely?

AW: We never needed that capacity.

Q: Did you have a bulk system that could scan while in the system?

AW: We had a lot of recommendations submitted from Congress. I am not sure if we got to the level of requirement. We were tasked to develop the baseline for cargo right now. We have the data. We need an effective bulk cargo screening solution. The range of the cargo commodity types exceeds a single technology. You need high capacity because of high bunching.

Q: You have ways to make the operation more efficient. In some facilities they only use EDPPs. What is the recommendation for those facilities?

AW: If you were to build, from the ground up, a modern cargo facility, what would it look like and how much would it cost? It is difficult question.

Q: It's what TSA requires.

Q: Part of what we're trying to do is gain knowledge of what a facility would look like. Congress was telling us to have a large centralized cargo screening facility. Everything goes there and the integrity of the supply chain is the only caveat. We tried to mock up a representation of some major attributes of cargo facilities look like.

Q: I heard $30M. In terms of false alarm rates and scanners themselves, most vendors are thinking of building systems that cost a few percent of that. If that money is allocated to buying scanners instead of breaking things down, then the false alarm rates become much easier problems to solve. Maybe you can solve it that way instead of a huge handling facility.

Q: Of the different facilities I have visited, none had full breakdown. It was done off site. I don't know if the problem of breaking down a palette is a big problem.

Q: Great Pilot. It is snap shot in time at 2006. It had its challenges and lots of data. We used that data to implement policies and procedures. The main focus of this is not to do PD commerce. A $30M piece of technology that would prevent breakdown, we are not going to stop a commerce with a technology that is not out there right now. If a technology is successful, we will use it. AIT rolled out and it had problems. Over the years the technology changed and it is great. When the technology comes out, we will try to implement it but it has to come to us ready to go.

Q: Pre-certifying buyers and pallets?

AW: That would work.

Q: What other costs would occur with this other screener?

AW: I can't speak to that. These life cycle models (???)

Q: Oak Ridge did the life cycle. We did that cost model in 10 different airports and it showed what you need to operate there. When we authorized the certified shipper program, we let them come to us with their plan. We gave them tools without telling them how to do it.

Q: You have a massive database. Is there any way to have access to the detection and false alarm data to develop algorithms?

AW: Part of this data is included in the DHS image database. The broader data is per S&T.

Q: Anything in the public domain?

AW: It's SSI.

Speaker: Walter Garms

Q: Why do they all show up at midnight?

Q: Because the shippers close at 6pm and all the trucks arrive at the same time.

Q: You should see the FedEx sorting facility in Memphis.

Q: Does this include shield alarms?

WG: The purple are shield alarms, yes.

Q: This is the system based on the GD flat panel?

WG: Yes.

Q: How thick are the needles?

WG: 0.2

Q: What the color signal?

WG: Blue is metal.

Q: How do I know it is an explosive?

WG: This inspection that we are using is the same as we do for baggage.

Q: Is that sufficient?

WG: Yes.

Q: What kind of pixel spacing do you use?

WG: (???) or maybe better

Q: Isn't the problem that you could be mocking the shape and concealing to throw them off?

WG: We make them all the look the same. One little bit looks different and we ask if they all look the same and if one does we look at it and forget the rest of them.

Q: Isn't (???) resolution onscreen resolution (???)

WG: Yes. We do have alarm resolution with baggage scanners. What happens when you look at the same thing over and over again?

Q: Are there no other tools (???)

WG: Probably. It has been addressed in baggage scanning.

Q: Straighter resolution but with a camera that can see (???)

Q: You raise a good question about processing and human operators. Separate from these two screening systems, we have a project called OCAST with an MIT professors. It is a tool to assess whether or not it can be screened by an operator. We saw that some operators thought they could tell and they really can't.

Q: Then is it insufficient…

Q: If you can't then you have to break the pallet down or go through another screen?

WG: The next thing is that for CT they think they can analyze this. Some things are too dense. Morpho has a shield alarm that says we can't image something in the pallet and so we have to do something else.

Q: In the boxes, you would have the option…

WG: I wouldn't put the boxes in a pallet.

Q: What is the time it takes to scan a pallet like that?

WG: Three minutes.

Speaker: Dave Peticone

Q: On the last chart you showed the ratios with Ammonium Nitrate. Have you looked at what happens when you have fuel with it?

DP: No, we haven't.

Q: Depending on the fuel, though, the ratios can throw you off.

DP: Well you can redesign with the spec.

Q: What's the interrogation time?

DP: This one isn't fair to talk about, but our calculations are about 10 minutes.

Q: Would it make sense to do that dynamically somehow?

DP: No, because you have to back out the calibration.

Q: Is it true you have to move the accelerator to every angle?

DP: In this prototype that's how we did it, but you don't have to. Each time we changed the energy, we did that here and it really only took 10 minutes.

Q: To get a view of the whole container do you have to move it?

DP: You wouldn't want to move the whole thing.

(???)

DP: The ambient dose per hour isn't that big.

(???)

DP: This is a concern especially with shipping containers, and you do need a lot of space for this. There's no way around it unless you build a bunker.

(???)

Speaker: Ed Hartouni

EH: Highly enriched uranium was 95%.

Q: Cross sections?

EH: You're talking about orders of magnitudes more cross section. You have to simulate the physical processes involved. I don't have an answer to that specifically.

Q: We're seeing a very small amount of the HEU materials. With lower Z materials you'd be seeing (???) of the mass.

EH: Your first visions happen much closer to the surface in this case.

Q: Wouldn't it be easier to do this with a neutron source that's smaller?

EH: Using a photon source helps in this case because you don't see a lot of background.

Q: When you start involving cargo with high energy, that's not a nondestructive evaluation. So with delicate cargo, how do we discriminate what we hit and what we don't hit?

EH: DNDO has removed its limits. The destructiveness of the beam (???) But there is a question of how you get the dosage down as low as possible. I'm not sure that it does damage to the cargo.

Q: Can you talk about false alarm reduction?

EH: It's very important to identify what your likely backgrounds are going to be. I'm not an expert in general cargo. We've learned a lot more about what gets shipped around in the last 10 years. We did an equal amount of study on DU as HEU, because DU is a background to material detection. So when we do a study we have to spend as much time on the physics of the background. So if you do find that you have background characteristics, then certainly that helps you diminish false positives. If you think about what you're looking for is a molecular specificity, you're interested in how the compound is put together. If you know that, you have high discrimination against your background.

Speaker: Richard Lanza

No comments

Speaker: Nelson Carey

Q: Can you apply a procedure to counter this?

NC: It is more of a procedural method for prior to when the aircraft takes off.

Q: By means of what?

NC: By means of comparison. We will get into the terms of cost in a moment.

Q: How did that compare to the previous one?

NC: It was at least the equivalent if not more.

Q: That was a single unit performance method.

NC: To try and get a blast in one container with an adjacent container? They typically don't fill the whole cargo of an aircraft.

Q: In the video, the frame bounced and moved when it exploded. Will people know that happened?

NC: You are definitely going to know something happened.

Q: When forklifts go through this, I have heard it's pretty easy.

NC: I have found containers are more resistant to those. You usually haven't seen those out on the rail. Part of the FAA worthiness process is looking at damaging issues.

Q: That's all outlined in a component maintenance manual.

Q: Is this ready to go and use?

NC: You could put them into service, but you'd have to follow up and look at the utility.

Q: If you gave them to the airline for free, is there a reason they would not use them?

NC: I can't answer that.

Q: We will find the cost benefit assessment hopefully this year. The important point is that the hold will not work independent of other detection technology. You have to have efficiency. That's important.

Q: What's the challenges with the airlines? What's the problem with weight and fuel lines?

NC: That's all in the cost benefit report. We will look at that when we do the analyses.

Q: What's the best resistance?

NC: We are looking at all of the factors, as many things effect that, pressure, etc.

Q: Are there any critical cynics of this program?

NC: Cost, weight, the airline takes that all into account. The $10,000 assumes 1000 units.

Q: If you have a requirement you may not be able to say what that is, relative to where those sizes are today. Can you comment of that?

NC: I can't get into threat mass details.

Q: What TSA will do is that after its proven effective, and we will qualify this system, and then it's available to purchase until its deemed mandatory. But airlines won't put suspect items on their airplane, so they wouldn't want to buy it anyway.

Speaker: Raj Gupta

Q: Is that a vacuum pump source?

RG: Yes that is. It is 60 gauge, so relatively weak, but it will supply it.

Q: How long does it take to get an image?

RG: Seconds right now.

Q: Can you only have one illuminated?

RG: You can have more illuminated. The question is how many projections would you have to do if it was very large? What length can you preserve the signature?

Q: How high of energy can you go?

RG: You can accelerate them in another category

Speaker: Michelle Clark

Q: What do you mean by (???)

MC: TNT ages. It turns red over time. Ammonium Nitrate puddles. There are certain things you need to think about for detection modalities.

Q: Is it (???) or is it a reaction to different elements?

MC: It's both. Our approach is trying to combine real signatures with what's in the room.

Q: Do you ignore (???)

MC: There are set methods for collecting samples. We have a swab. You dry put it on the swab, dry transfer, wipe and see what is left on the swab. If I am swabbing cardboard I get 50% efficiency for X compound. If we do it 100 times we can measure what we will get for different surfaces and different swabs. In a different environment you might want a different swab.

Q: Do you go in a zig-zag, a spiral?

MC: It is a random sample with multiple people. You have a set protocol.

Q: The whole issue of qualifying sample efficiency is going to be examined at the sampling workshop here in August. The invite list is still be crafted. If you are interested in that workshop, email me and I will disseminate.

Q: 1 out of 63 was high in ammonium?

MC: There was one sample that was dirty on the box. It was probably a false positive.

Q: I assume that the figure on the right corresponds to the figure on the left?

MC: They do correspond but (???)

Q: I can see the red threshold number.

MC: It is 1.

Q: How are you taking care from experiment to experiment?

MC: We change gloves and use clean paper. We can mop up with acetone. We try to maintain different areas for different activities. We try to make sure everything is perfectly clean, at least for nitrates.

Q: You mentioned pre-treatment. Is that in reference to adding additives?

MC: We use for Mass Spec to enhance the signal.

Q: There was discussion of that.

MC: Potassium chloride can be really hard. If you can find something that helps, that is good.

Q: What is the area of the ROC curve?

MC: The forklift driver is not a problem. I would be more worried about the information that is out there in terms of making devices. You really want to find them higher on the kill chain. It would be good to find the builder before the package.

Q: In dirty environments, is clutter constant?

MC: That did not fall out of the data. The common ions we know of do not show anything.

Speaker: Stefan Moser

Q: What's a dirty bomb?

SM: An explosive device meant to emanate a large quantity of material. We kept it realistic enough to test if we can detect it.

Q: You mentioned the resolution was a challenge. What stops from increasing the projections? Does that translation to resolution at impact point?

SM: It does relate, of course. The length of the scan is related to the projections taken. Theoretically, you could scan at 400 micro meters but it would take several hours.

Q: This is on a turn table? For a fix scanned time, does it help to take 250 but the view is obstructed or a few but the view is wide?

SM: It depends on the object itself, as well as the reconstruction measures. I can't answer for all cases. It could be investigated for a number of different cargos and scans.

Q: What is the time savings between 25 and 250 scans?

SM: Several hours for a whole scan. This is in a facility that was not optimized for this kind of scan. If it was in an optimized facility it would take 20-25 minutes. It also depends on how you feed the containers into the scanner.

Q: Have you looked at containers that are 90% full?

SM: We have looked at several configurations (???)

Speaker: Kevin Cronk

Q: Does the join system have any relation with what was formally (???)

KC: That was CARS. Can we do novel work with algorithms?

Q: With regards to the contraband (???)

KC: That was based on (???)

Speaker: Mark Tardiff

Q: The only thing I might add is the idea of determination. How you use the (???) is very different. It's not just classifying, and for explosives might not necessary, but for others you should determine.

MT: Absolutely.

Q: There are data sets out there for spikes and drops. DOD is using it, mainly for academy. There is a database.

MT: Yes and they feature what you can use for algorithms.

Q: In the beginning you mentioned looking at 2000 papers. That is a lot like meta-analysis. How do you weight the good ones and the bad ones? What are the uncertainties? How are they distributed?

MT: For the 2000 articles, we use a program that extracts key words and you start to see the structure. Usually if those key words are involved, the paper tends to be more rigorous. For uncertainty, measurement is worth a 1000 dollars.

Speaker: Alejandro Heredia-Langer

Q: If you did this in the dead of winter (???)

AH: We haven't tried, but I believe yes.

Q: What's your target audience?

AH: The methodology is what we're trying to take out to everyone we can, within and outside the lab. It is surprising that a lot of people don't consider statistically designed experiments in the beginning. We're trying to tell people that this is a way to consider. The software is actually commercial software. We're not trying to reinvent the wheel.

Q: This is quite standard stuff that any mass spec person does in Pharma.

Q: The fact is, though, that this community doesn't do this and isn't used to it.

Q: Yes, the point is that it's transferable though.

Q: Google has a similar kind of algorithm and system that they use.

AH: I'm not familiar with it but I think Facebook does it too. I think what they use is a facial recognition.

(???)

AH: We were trying not to do facial recognition.

Q: Facebook just started a lab with NYU that you may want to look into with this.

Speaker: Daniel Acuna

Q: Tell us about the datasets.

DA: It stores the log of the webserver and the raw data.

Q: Does the 0.5 mean it's a coin flip at 10 years out?

DA: No, it's an (???)

(???)

DA: The footnote here is that we're analyzing scientists who've had publications for 5 years, and who've been in the scientific arena for 5-10 years.

Q: I'm trying to draw the relevance of what you're saying (???) dealing with false alarms (???) So what is your take in terms of how big data can help me (???)

DA: When people talk about big data, people say something that doesn't fit into excel. What I mean is issuing complex models.

Q: One challenge is getting access to the data, especially if you're a small company.

Q: When you apply this method to sensor data you have to deal with 1 issue. In the computer application you have a label. In this environment you have mostly unlabeled data. You can assume some luggage is benign but not all of it, and nobody is going to tell you which is which.

DA: You can use this model for outliers as well because you have so few labels for threats (???)

Q: That may not answer the question because when you think of outliers in luggage it's not necessarily a threat.

Q: How do you know when your model is complex enough to have enough data?

DA: You can start training algorithms to predict while it's importing data before it has a full dataset. If it starts overfeeding then it tells you the model is too complex.

Q: How do they correlate the outcomes and results?

DA: You have a labeled dataset. You try to separate your dataset into 2 parts, training, where you can't talk about correlations, and then the other set. If the second is performing poorly then perhaps there's something wrong with your dataset.

(???)

15.2 Day 2 Minutes: May 7, 2014

Speaker: Carl Crawford

Q: It could be a subset of topics for the next ADSA.

Speaker: Nick Cutmore

Q: What is the red cloud?

NC: I think it's just organics (veggies) and hidden is a gun. Something like ½ a meter of organics.

Q: Are there any cargo types damaged by this?

NC: People always come back to neutrons and safety. The dose is equivalent to one hour in flight, very light. In terms of activation, it's nothing.

NC: There is still sensitivity depending on the country.

Q: How many meters per minute?

NC: 6 per minute. We use GPU processes.

Q: Are you providing the colorized image?

NC: Yes.

Q: How much better is a combined system?

NC: If you look at material separation its 20-50x better. Generally, that is around 3 main elements and we throw in neutrons, but if we were using dd neutrons, we could improve by another factor of 3 or 4. But they are not penetrating enough for this.

Q: On that story, what would be the optimum neutron?

NC: 1 produced by a very reliable system. We have used generators from 2 or 3 generators, and the problem with large generators is that they are not reliable. It's mainly done by penetration of the cargo. Could you get it in a system that is going to stay up for 10 hours a day and 360 days a year?

Q: If I was going to talk about cyclotrons, it's 24/7.

Q: What's the situation for the government of Australia?

NC: There are close relations between the US, UK and Australia. They decided what they want to do with customs and cargo between each other. The initial reason is not explosives, it was contraband. They decided they want to detect everything since 9/11. They are responsible for jail contraband. I think for a lot of the time they watched the US. Unless you have incredibly reliable technology, we have not reached that point.

Q: How do you handle the explosives?

NC: If you have very thin items coming in through cargo, it's going to be hard to find. If it's behind peaches, you can't find it.

Speaker: Jens Gregor

Q: Is this metal?

JG: What you are looking at here can be penetrated.

Q: You are looking for build-up of mass? Can you weigh them?

JG: I think it's so narrow that it wouldn't weigh differently.

Q: The problem is that in theory, you can have a number of holes, but that's not true for real objects. So the real question is what the optimal place is for this.

JG: Sure. What is being reconstructed here is black and white. If you had a smooth distribution (???)

Q: It depends on the type of the convolution.

Q: How does it get applied to cargo?

JG: The previous talk was about radiography. Coded source X-rays would work for this.

Q: Is there any optimum mask shape or type?

JG: It depends on what you are looking for, high contrast patterns, but some of it is also machines. You don't drill into it like a sandwich. You don't get the stuffing power.

JG: You can't have a thick layer like this when you have a small hole.

Speaker: Dan Strellis

Q: What element are you looking for?

DS: Chlorine

Q: Was it a pencil beam?

DS: It's more of a cloud. We have a moderator around the source here. It's basically a thermal cloud.

Q: What's being shown here?

DS: Graphite, cocaine, (???)

Q: Could the signal be highlighted?

DS: Yes. The bare samples are easier.

Q: Is this a neutral source?

DS: This is pulsed neutrons. This is not the combined x-ray photo neutron.

Q: Why did you stop testing?

DS: We ran out of funding to support the test. We didn't make it into the next phase.

Q: Could you mention how you packaged the cocaine?

DS: It was in a box. It was a palette of paper.

Q: Was the cocaine wrapped in plastic? I am not asking a trace question.

DS: This is a simulant of cocaine. We produced a simulant with similar ratios to as if real cocaine were wrapped in paper and plastic inside the boxes.

Q: How does the alphatron neutron source scan take?

DS: Nine total. You only detect about 1-5% percent of the solid angles. It took 15 to 20 minutes.

Speaker: Synho Do

Q: What is the difference between red and blue?

SD: No constraints on blue.

Q: What constraints are you putting on red?

SD: I put them through and then throw them away.

Q: Do you wait?

SD: I don't wait. I just throw away.

Q: The images show quantitative differences. Have you tried qualifying that?

SD: I tried, but that is not true ground truth.

Q: Are you scanning it bare because that affects ground truth? You should consider that.

Q: You said that you throw away data. What about sparse view data which already throws away data? Have you thought about how that affects the image?

SD: I don't throw away all the data.

Q: Do you do that even with the sparse view CT?

SD: No.

Q: Are you doing something different with the spiral or is it stationary?

SD: I added additional shifts in the detector as a kind of masking or coding.

Q: What is the difference in time in the upper image and the lower system?

SD: Same.

Q: We had great success with throwing away the metal artifact. Did you have a rule you liked to use? Was it about standard deviation?

SD: I have two metrics so that I calculate the sparseness and image quality. I am not throwing away much.

Q: For the source motion and project spaces, did you expand the range?

SD: My initial role was to reduce the radiation dose. I realized it has a lot of other applications and potential. I don't have a system, right? This is simulation and emulation. I try to test with a real working system so we can build this kind of system.

Q: Do you have a feeling of how the resolution relates to image views?

SD: It is relative. Your sparseness should be adjusted based on distance. If it is far away from center rotation, you need a smarter way to sample. We can modify the CT geometry. If we derive better sampling methods then we can generate better sparseness.

Q: You say you use the iterative technique. What more can you say about that?

SD: I am not stuck on any specific algorithm or variation. I can modify. We can modify the conversion rate and the other things that relate. It depends on the test.

Q: What is the difference between FDB and your technique in time?

SD: Initially, I developed my IRT on (???) cluster. It had 100 nodes and C++. It took hours for reconstruction. With FDP, it is one second. I had my program CPU cluster, 8 CPUs. It reads to the less than hours. I proposed to NIH to speed up this algorithm with the cloud. I can use 10,000 CPUs with little communication delay and it can go down to one minute.

Speaker: Stuart Harmer

Q: (???)

SH: We use a wide band sweep. We run the system in 54 gigahertz. It's that frequency.

Q: Terahertz range?

SH: I will show a slide in a minute with that.

Q: So right now you are looking at the difference between the shoes?

SH: This is the data that comes out. You could look at them and know there's no concealment. You can see if he traveled through chewing gum.

Q: So if you don't see the hot spot?

SH: It is a reflection from up here. There is some difference between the toe and heel. These were encouraging. We could see it quite easily.

Q: Are you familiar with the work of Brooks (???) and Bob (???) at MIT? They transform microwave and millimeter waves. Maybe if you tailor the waves you can see different results. Maybe for nitrates?

SH: It is a good point.

Q: You get about 60 gigahertz.

Q: What about when something is inserted in the shoes?

SH: If you added to one and not the other we can see it.

Q: Arch supports?

SH: You will see the extra length. People were concerned about the metal nails for shoe repair.

Q: Some arch supports have different structures. Look at mine.

Q: What happens if you walk and do that without anything there?

SH: There is proximal discrimination.

Q: What is the distance?

SH: It is a few meters.

Q: You say it is a bomb. How do you know it isn't a laptop?

SH: Difference is basic shape.

Q: Did you try a variety of different shoes from the same manufactures? Different sizes and persons walking?

SH: We use the same brand, style and shape. I used a new pair and my old pair. You could tell which was which based on the worn sole.

Q: Did you get 5 different pairs?

SH: No.

Q: Do you have ROC curves for the shoes?

SH: No.

Q: How long did the shoe scan take?

SH: 2 seconds per shoe. You could make it part of the body scanner.

Q: (???)

SH: Maybe two dozen pairs. Different types, generally.

Q: We did similar testing.

SH: It makes a difference in the sole of the shoe.

Q: Did you try shoes with metal shanks? Metal shoes?

SH: We tried the metal pins. That reflects strongly. If you have metal foil, you can't see through it.

Q: Wet shoes?

SH: They aren't good. If water gets on the top of the system, it's not good.

Q: I am curious as to what you are imaging in the shoe pictures. If you look at dielectric contrast, it is low conductivity. The bright spot?

SH: The amplitude of the return wave from each part of the space. It is an image. If you have a cavity you will see it in the reflection.

Q: Why do you have a spot of response?

SH: You can see inclusion of small ones.

Speaker: Theodore Goodson

Q: What is this exciting (???)?

TG: You're exciting the (???) manifold. (???)

Q: How do you manage the specificity? It seems there are a lot of things in the environment that may cause false positives.

TG: We compare signatures and wavelengths so we can make classifications very well. If you use nanosecond voltages (???)?

Q: How does sensitivity compare to a dog's nose?

TG: The debate is out. We're much lower than what they think and false alarm rates are extremely small as well.

Q: If you're talking about FIDO you may want to talk to Amy (???).

(???)

TG: The molecules, for example, ammonium nitrate, have a lifetime of (???).

(???)

TG: Pie in sky is like 200 m, but now we're talking 25 m for short range.

Q: What happens on surfaces?

TG: If we could do just the surface, we've worked that out. We're talking about what's in air space. If a car door is made of metal, there's enhancement.

Q: Scan times?

TG: We have data giving just a hint of what you want. This was directed at a Hummer at 50mph, so we have data at 10 seconds to a minute.

(???)

TG: The photon detection system was the meat of the work. We started doing things that were homemade, but later we tried to investigate how we use off the bench kind of things and became a challenge.

Q: What about the electric sensor?

TG: We have a photon counting system as well.

Q: Curious if you're rastering your system. How are you sampling?

TG: For cargo, we haven't done that yet. For space, it's rastering in a transverse manner. For cargo, you can imagine the Christmas present going on a scanner and it's quite slow.

(???)

Q: You may think about radiolytic products for the landmine problem because vapor isn't always where the mine is.

TG: Absolutely. We started to look into those and they're sometimes at even lower concentrations. There was an incident where they were looking for where ammunitions were stored. They took the munitions out but the materials were still there.

Q: Is it eye safe?

TG: Yes.

Q: What about atmospheric conditions?

TG: Works better in humid environments.

Q: Order of magnitude for every 10 degrees? (???)

TG: We're aware of the picogram per milliliter. (???)

Q: Are you able to work on classified work?

TG: The issue is working with foreign nationals and non-citizens, especially in an academic environment.

Speaker: Ge Wang

Q: Do you think multi-scale is applicable to area of interest?

GW: Multi-scale can be done, yes I would agree.

Q: True color? Can you explain that?

GW: In medical CT, we believe that (???) We can automatically (???) into 5-8 windows. This can be great for medical application. (???) Low rate. An order of magnitude less than what we need. (???) Within tomography, we can deal with spectral reconstruction (???) We do have global information but we don't have spectral information. The work in this paper includes both modalities. (???) Only over this ROI you can get true color reconstruction. Away from the ROI you still have good results. (???) The high resolution reconstruction you can achieve over ROI. (???) The region of interest can be quite big.

Q: Sounds like what you're describing is what Siemens has done.

GW: We have a solid theoretical foundation with over 20 journal papers. In my opinion, Siemens' approach (???) We utilize cutting edge theory. (???)

Q: One of the virtues of imaging people is that they're not dense, but cargo can be dense. If you can't get radiation into the interior, it's not doable.

GW: (???) We have to make sure the imaging system and the energy is selected properly so the inside is somehow measured.

Speaker: Simon Bedford

Q: Can you rotate as you translate?

SB: We can.

Q: Is this 600 KCU?

SB: This is actually 400.

(???)

SB: We require about 2-3 minutes; multi-parse, multi-view. It's a 2-3 minute scan. It's practical.

Q: What is the tunnel size and weight it can handle?

SB: System is built to take a 4x4x6 pallet, 3500 lbs.

(???)

SB: With CT, you get an idea of the images I show what the resolution is. I don't want to give a number out right now.

Q: Seems the system is operator dependent.

SB: We've been focusing on building on camera and scanner, so now we're turning our attention to operator tools. Automating it is a way we're going.

Q: My understanding is that in the CT mode you send the pallet through the scanner and then rotate. The advantage is that you get multistatic views. How much advantage is there?

SB: Parallel beam architecture is right. The limit is governed by number of views total. What is good about the system is the architecture acquires data quickly and cost-effectively.

Q: What density cargo do you think you can get through at 320 kV?

SB: Penetration specs are around 80mm of steel. So it's pretty capable. 450 is better, always.

(???)

SB: Reliability of the X-ray, these were all commercial off-the-shelf products. They're all stable and good.

Q: How are you addressing artifacts?

SB: We have a very good reconstruction. Artifacts will increase as you angle more. Question is at what point do artifacts become too bad. We'll have to make some decisions about that.

Speaker: Dan Strellis

Q: Is it beneficial to have the X-rays (???)?

DS: Yes that would be beneficial.

Q: What about the cost?

DS: The cost with respect to cargo, it's a lot more money than trace equipment. Systems that go into air cargo facilities, maybe more than that; not a whole lot with trace.

DS: Large tunnel systems need higher energy.

Q: Do you want to say anything about the balance of ATR and staffing?

DS: I don't know the answer to that.

Q: How about diffraction?

DS: It gives you material specificity. It's something that's being looked at right now.

Q: What about false alarms?

DS: I don't have data for false alarms.

Speaker: Martin Hartick

Q: Can you estimate the number (???)?

MH: We are studying images now, and trying to estimate that, but I cannot give you the exact number.

Q: What if you get a penetration alarm?

MH: If the image operator analyzes it, this use is simply opened.

Q: If I can add some info – inside the security program at the TSA, the programs tell them how to screen cargo, what percentage of cargo screen by the number of configurations. Over the last few years we will be done to find out where all of the technologies are. Who has trace, but still we don't know how much they are screening. Don't forget the screening, but it is the alarm resolution. They have to know how to do the screening, and once they get the alarm, it goes through steps to resolve the alarm. For large aperture systems, those a required that the skid is broken down.

MH: One of those is just to get diffraction from the few.

Q: Can they make any measurements from this?

MH: The goal is to use two methods to analyze this.

Q: So these are concepts?

MH: Yes.

Q: You talk about providing better operating support. What do you mean by that? Operator assist tools?

MH: Just to highlight certain information is helpful if you can't really determine the usefulness

Q: We lose resolution in this, and my assumption is that we aren't concerned that there is a gun in a container. How far away are we from what we need to see? Are we losing info that's necessary?

MH: Why is the recognition different from what's in my bag? It contains a number of bags, and I think if they specify the containers that are there, they define the outcome that way. I guess it is delivered as defined materials.

Q: What is the intent of your program?

MH: That was another piece of the question. We did a study of what we did to estimate across. There was no clear estimate from the screening.

Q: We are creating an air force development working group, and this is the first time I have been to a meeting like this. I might reach out to Carl to identify respective people.

Q: How applicable is this to the chem/bio issue?

MH: For chem/bio, you could use what you have but it would be very difficult. I cannot imagine it would work well for that.

Speaker: Stephen Korbly

Q: What cargo protectors are there?

SK: We have a bunch and I have more on the next slide

Q: How does the cargo get moved?

SK: We have something similar to a roller coaster moving it through.

Q: Why is water having the effect?

SK: We are redoing the calibration right now. It's similar to other Z values. It's a C4 simulant.

Q: Where is the gasoline in the vehicle tank?

SK: It shows up close to the water. In the image it shows up in the back of the truck.

Q: What is the dose for this?

SK: Same for checked baggage scan. We (???)

Speaker: Stewart Hampton

Q: (???)

SH: Because you have high throughput and high volume, you have to be efficient and you won't have to open pallets, un-shrink wrap, etc.

Q: If you had to make it better, what would you improve?

SH: I think algorithms would be good. I think we've heard that is one of the steps forward. It is also odd that many fields of technology have a cost curve. I haven't seen that described based on how these things are built. I don't know if there is a curve or any confidence that it would be cheaper in ten years.

Q: Any thoughts on turning the discussion around with freight forwarders? Instead of thinking of this as a burden, how would you turn that around?

SH: It's possible to use the information from images of two views. We could easily store them.

Q: Given your marketing and L-3 product categories, in terms of growth, what percentage of growth would you see happening?

SH: I compare ourselves with the competitors. The pie is getting bigger. Some companies are doing very well with air cargo because it is a growth market. Take 5 to 10% as a rate growth for the industry itself and if you were interested in air cargo, it's not a dying industry.

Q: You do these pie charts every six months. How many machines are in play?

SH: Ten vendors that I could name. There are a low number of thousands.

Q: Which systems do you cost and which do you build in-house?

SH: It is all off the shelf. Building a PC is buying stuff and building inside a case.

Q: (???)

SH: Scanning everything going on a plane, whether it is a palette, bulk, or a package.

Q: Large scale systems?

SH: That is a piece of that number. It is not the majority. This is the latest (???) factor.

Q: Ratio?

SH: I couldn't tell you.

Q: A hundred installed in the world?

SH: Yes.

Q: Large aperture X-ray, can that do a single box? Given the power and resolution?

SH: Same as these large boxes.

Speaker: Seth Van Liew

Q: What is the material?

SVL: Polyethylene radiator that goes through a gas that is ionized which is detected. Nothing can leak out.

Q: What kind of gas?

SVL: Aragon.

Q: Do you amplify the charge or read it out?

SVL: It is amplified. There is a potential field there.

Q: I assume the air bars exist?

SVL: The neutron ones are big. The x-ray ones are small.

Q: With the ammonia nitrate, prill or ground?

SVL: Ground (???)

Q: Chemical composition?

SVL: The purity was very high.

Q: What was your neutron flux?

SVL: We wanted to match the flux we see in the system. I think we targeted a flux of (???)

Q: Over 4 pi?

SVL: Yes (???)

Q: Gamma contamination?

SVL: We did not look at that carefully.

Q: Do you worry about activation issues at all?

SVL: Neutron activation? Gammas are too low for that.

Q: (???)

SVL: They would be on at the same time. We did simulate cross-talk issues.

Q: You could have used regular plastic.

SVL: You need something to detect.

Q: Reliability of detectors are a big issue. How bad?

SVL: The X-ray technology is mature. This is not neutron saturated. The neutron detectors were developed on this project. We haven't fielded any of them or tested for years.

Q: Sighting issues of a mobile system?

SVL: Customs and border control wanted a cabinet system. It is a challenge. A rate and exclusion zone is tough.

Q: Is that possible?

SVL: Yes but you can't have fast, good detection and small.

Speaker: Harry Martz- Next Steps

Q: I heard that 95% are trusted and the remaining 5% are ETD.

HM: Is that correct, Alan?

Q: 70-80% are screening using ETD. It is more than 5%. 45% of the cargo is screened and the rest is ETD.

Q: Given enough research, the physics don't preclude you from solving this problem. If you can relax the strain on cost and size (???)

HM: I don't know if I would read that as the physics can do that. You say the size is small and there would be no clutter? The size of the system?

Q: I am not saying make it smaller. You have to take a hit in order to get what you want.

Q: There is stuff we just can't measure sensitively enough. What is the definition of C? Where are you measuring?

Q: Around a jug of something we built.

Q: It is not background contamination. If you're in an air cargo setting, false alarming on TNT all the time doesn't make sense, or RDX or Potassium Chloride.

Q: There are improvised explosives.

Q: How do you define ideal system?

HM: It was that one can take this and build on that.

Q: It's ideal because that is being done now but is that really ideal?

Q: Is it this system on the slide?

HM: What is missing?

Q: It's not a silver bullet yet.

HM: Mass Spec is not yet but is getting closer.

Q: I have a problem with saying ideal system and silver bullet. What is the lowest price solution?

HM: This is what we heard at this meeting. PD is ideal. What happens if that is not a silver bullet?

Q: I don't think we've seen the data.

HM: Are you questioning the data that ETD is the silver bullet?

Q: Yes.

Q: ETD is not the silver bullet. It is the choice industry is making based on those categories.

Q: It's the silver bullet freight forwarders are using.

Q: ETD for primary screening. Under what circumstances do we think ETD has (???)

HM: I am not saying I agree. I am saying it "seems to be."

Q: Commonly used piece of equipment. Most prevalent.

Q: ETD is on the buy list because these categories are listed as qualified. Try to sell a CT into that.

HM: It's the cheapest thing on the list. You don't have to swipe anything. It's easy to use. The government chose what do to for checked baggage. They choose the more expensive system and ETD for other (???)

Q: ETD are for checked baggage secondary screening.

Q: All certified systems have a CT in them.

Q: False.

Q: I stand corrected.

Q: ETD vs EDS- If you look at it by airport, there are more airports that use ETD than EDS. If you look at volume of baggage, more is going through EDS than EDT. When EDT is primary, it is the small airports. They don't get a large volume.

HM: I thought primary screening for EDT was secondary?

Q: That is not correct.

HM: Okay.

Q: Using today's regulations, what does it cost to break down pallets that cannot be imaged or inspected to get these kinds of results?

HM: Amy?

Q: I don't know the number off the top of my head. With the semi-automated cargo handling system we used, it was approximately 8 to 10 cents per pound. I'd have to recheck those numbers, depending on the size.

Q: The question from the end user standpoint the question missing from this conference is we ought to tackle by hearing from people who buy the products.

Q: I tried to get a speaker and they wouldn't answer my phone calls.

Q: The incentive for the cargo handlers is if you come up with the technology that can downsize their labor cost. They will like that.

Q: You say incentivize and I say they have to eat the cost.

HM: We are kind of agreeing.

Q: David made the point that it is cost.

Q: You are a technology group. You are being skewed by cost. If you want the outcome to be this result, you need to consider that.

HM: I don't want this to be the outcome of this. I thought it was the outcome of this workshop.

Q: I didn't hear that EDT was mandated. If something was developed better, it would probably be put on the list and EDT migrated off in tie.

HM: If that number gets smaller, yes.

Q: It had to perform better. I don't hear that in today's discussion.

Q: I heard yesterday that "when I have difficult problem, I change the problem." That is interesting. What's happening is that 100% of cargo has to be screened. We qualified and approved technologies. Industry made their decisions. What is happening is that cargo is being screened. Nobody is complaining about the cost. Industry will pick what they pick based on their economic process. There is not going to be a significant change unless something happens. We are trying to find better solutions. If there's not regulatory requirement to change, even with a better piece of technology, they won't change. They have to be told to change.

Q: The cost of running the operations of screening is the true cost we should be thinking about. We should look at the full operation.

HM: It seems that the people who buy equipment don't care about operation cost.

Q: Another absence in our discussion that I hope we address in the future is risk. We haven't talked about it in a quantifiable way. One example would be aviation safety under the FAA. The second example is energy management. We are talking about buying down the public risk. We have no idea what the real risk to the public is associated with the systems we have. It is rather embarrassing that we would have to wait for the next incident to assess that risk.

Q: There are variables that are difficult (???) with either of those numbers.

Q: DNDO is investing a significant amount of money in this. It can be vetted but there are different risk assessments.

Q: The big difference, though, is that the passengers, the cost is born by the government. The risk is the society. Cost is to society if something happens.

Q: What is regulation other than a government entity looking at costs and figuring out to what extent they should be internalized?

Q: Well what's the right balance?

Q: The shippers are well aware of the risk and they're on top of it actually. They say they want to put in higher solutions to ETD and they want the standard to be higher because they know the cost of if something happens.

Q: I can assure you that industry has spent the time doing risk assessment. The problem is we have perceived risk that is 2 orders of magnitude or more of real risk.

(???)

Q: It's really the risk to the economy we care about.

Q: The discussion about cascading systems (???)

Q: I work with customers. Words are important. We in the customs space do a lot of work in information based targeting. That's a different model than what's being done here. Different models can be used

HM: Depending on what risk based security is defined as, that can be done. We pre-check or not. We spend more time on people who may be suspect rather than on people who aren't.

Q: We're running into the tech piece, the policy piece, and then risk based screening and different models. Where do we think we should head? We need more input from the actual screeners. If we just stick with technology we won't get enough input. It's not realistic. For the next step, when do we do that? We have a handle on the different technologies. We haven't heard a lot about trace, and there wasn't an ETD workshop. Do we meet again, and do we need to talk about this further as a next step?

Q: Do people want to do more cargo for the next ADSA?

Q: Is that a broad focus?

Q: The next ADSA is in the fall. Do we have enough information to come up with a reasonable agenda on cargo?

HM: What about hearing more about regulation and Con-Ops?

Q: Can we get people and speakers?

HM: There seem to be issues to developing the technology to going through regulation and then to use. What is the current? How will it change?

Q: The VPs from the airlines have a responsibility to the CEOs for security. I think they'd be interested in a place like this.

Q: From experience, there's a lot of people who don't want to come here. People don't want to talk in an open environment.

Q: You don't have to have them talk. You just have to have them in the community. Is it a freight forwarder or the airline doing the work? If it's more than just the airline then you need the customer in general and I don't know enough to know that.

Q: We could have a panel discussion.

Q: We had a similar thing for maritime cargo. It was a great conversation with a lot of tension. We didn't come out with a good outcome, but we came out with a good understanding.

HM: People are getting more open as they come here talking about things. Get all the stakeholders together and talk about what to do if we have a problem.

(???)

HM: Airlines realize they're meeting regulations but there's risk.

Q: So why would they do anything.

HM: Maybe they won't. Maybe what they'll start doing is talking about the Con-Ops and the risk and we'll learn. It's difficult to have these discussions in an open forum.

Q: We live with the fear that an event is going to happen and (???) In theory we're supposed to be moving towards (???) We are supposed to be looking ahead as the academic community.

Q: The industry knows how much it would cost to have an event. You just ask them how much it would cost industry if something happened. Then you ask them where they need reduction in risk.

HM: How can this community help you and what do you need?

Q: Yes, frame it the right way.

Q: It seems like they've made their choice and we should ask them why they made their choice. I don't know why regulations are driven either. Where can we be most effective? It's not a cost shoot-out.

Q: Part of the purpose of this forum is under the assumption that we need better technology so we should develop it now.

(???)

HM: We don't know what will happen, but we need to figure out how to develop without worrying about cost and regulation.

Q: The real question is the social and behavioral sciences and talk about the (???) What are the other colleagues we can bring to the table to inform us of different ways of interacting with agencies to get to a golden (???) So maybe we should think of another ADSA to speak of different disciplines.

Q: Insurance companies are very interested in the impact on them because they put out the money first.

Q: I've heard of that in healthcare. Depending on the way you do treatment, your rates go down.

16. Appendix: Presentations

This section contains the slides presented by speakers at the workshop. The slides appear in the order that talks were given as shown on the agenda. Some of the presentation slides have been redacted to ensure their suitability for public distribution.

PDF versions of selected presentations can be found at the following link:
https://myfiles.neu.edu/groups/ALERT/strategic_studies/ADSA10_Presentations/

16.1 Carl Crawford: Introduction

Tenth Algorithm Development for Security Applications Workshop (ADSA10):

Explosives Detection in Air Cargo

Workshop Objectives

Carl R. Crawford
Csuptwo, LLC

1

So What Who Cares?

- Known:
  - Airlines favorite target of terrorists and they have put IEDs in cargo
  - Pending US congressional legislation to mandate the scanning of all commercial air cargo
- Problem: Detecting explosives in cargo very difficult problem in part because of:
  - Size/penetration
    - Neutron do not like water
    - X-rays do not large path lengths or do not create contrast
    - Samples for trace
  - Concept of operations
  - Resolution of false alarms
  - Much different than check-bags and check point
- Solution: Assemble very bright people and allow scientific method to develop improved methods for detecting explosives in air cargo
- Successful workshop: People here working on the problem with DHS, TSA, vendors

2

Rule #1 – Open Discussions

- This is a workshop, not conference
- Conversation and questions expected at all times, especially during presentations
- Moderator responsible for keeping discussions focused and initiating discussion
  - Will *try* to allow speakers to complete their introduction

3

Rule #2 – Speaker Instructions

- 2nd slide has to be "so what who cares"
  - State how technology will improve explosive detection
  - Optimum presentation: stop at 2nd slide
- Don't get trapped into developing the whole story before giving the bottom line.

Beware of Moderators!

4

Rule #3 – Public Domain

- Do not present classified, SSI, FOUO or proprietary material
- Presentations, minutes and proceedings will be placed in the public domain
  - After review for SSI and classified material

5

So What Who Cares?

- Known:
  - Airlines favorite target of terrorists and they have put IEDs in cargo
  - Pending US congressional legislation to mandate the scanning of all commercial air cargo
- Problem: Detecting explosives in cargo very difficult problem in part because of:
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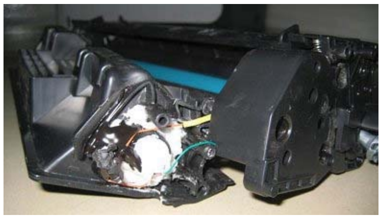
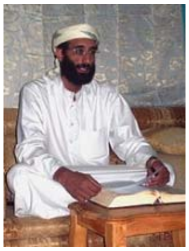
  - Much different than check-bags and check point
- Solution: Assemble very bright people and allow scientific method to develop improved methods for detecting explosives in air cargo
- Successful workshop: People here working on the problem with DHS, TSA, vendors

6

Bin Laden Dead, But …

Terrorists Still Trying





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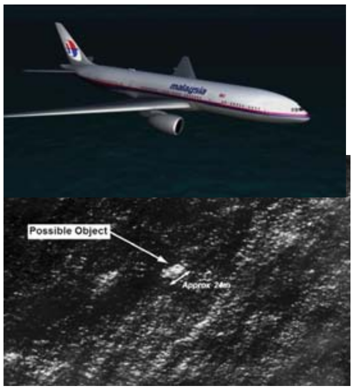
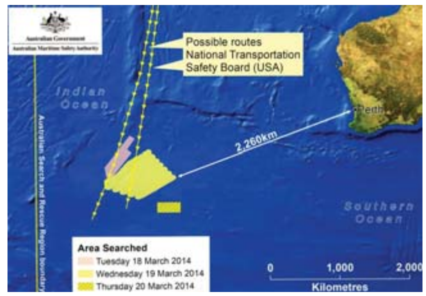
Malaysia Airlines Flight 370





May not be terrorism, but creates terror.

9

DHS Tactics

- Augment abilities of vendors with 3rd parties
  - Academia
  - National labs
  - Industry other than the vendors
- Create centers of excellence (COE) at universities
- Hold workshops to educate 3rd parties and discuss issues with involvement of 3rd parties
  - Algorithm Development for Security Applications (ADSA)
- Forage for technology in other fields

10

Agenda

- Frame the problem
- Past attempts
- Emerging technologies
- Vendor offerings
- Discuss
- Present recommendations to DHS
- Discuss other technology related to aviation security (not cargo)
- ADSA11

11

Threats

- ADSA10 primary focus – explosives
- Secondary
  - Nuclear materials
  - Illegal drugs

12

Cargo Types

13

Scope

In Scope

- Photons
- Neutrons
- Trace
- Hardening
- Algorithms
- Sensors

Speakers not addressing

- Canine
- ATR
- Shield alarms
- Manifest usage
- Deterrence
- Risk-based

14

Equipment Requirements

- Probability of detection (PD)
- Probability of false alarm (PFA)
- FA resolution
- # types of threats
- Minimum mass
- Minimum sheet thickness
- Total cost of ownership
  - Purchase price
  - Siting
  - Labor
  - Maintenance
- Extensibility
- Ability to fuse
- Compatible with risk-based screening
- False alarm resolution methodologies
- Siting
- HVAC, space, weight shielding
- Throughput
- Safety

15

Questionnaire

- Request for everyone to answer questions preferably during the workshop
- ~10 questions – 10 minutes
- Available via Survey Monkey

https://www.surveymonkey.com/s/ADSA010Survey

SurveyMonkey.com
because knowledge is everything

16

Minutes

- Minutes will be taken of discussion
  - Sensitive information to be redacted
- Please identify yourself and institution first time you speak

17

Acknowledgements

- Northeastern University (NEU)
- Awareness and Localization of Explosives-Related Threats (ALERT) DHS Center of Excellence
- Department of Homeland Security (DHS)
- Presenters
- Participants

18

Acknowledgements

- Speaker identification
  - Ron Krauss, TSL
  - Harry Martz, LLNL
  - Laura Parker, PHS
  - Greg Struba, DHS
  - George Zarur, DHS/TSA (retired)

19

Logistics

- Melanie Smith, lead
- Deanna Beirne
- Kristin Hicks
- Teri Incampo
- Seda Gokoglu
- Can Yegen
- Anne Magrath

Let them know if you need support during or after workshop.

20

Final Remarks

- "Terrorism causes a loss of life and a loss of quality of life," Lisa Dolev, Qylur
- Need improved technology
- Thank you for participating

21

BACKUP SLIDES

22

Cargo on Plane

23

16.2 Stephen Surko: DHS Activities in Cargo Inspection

Homeland Security
Science and Technology

DHS S&T Mission

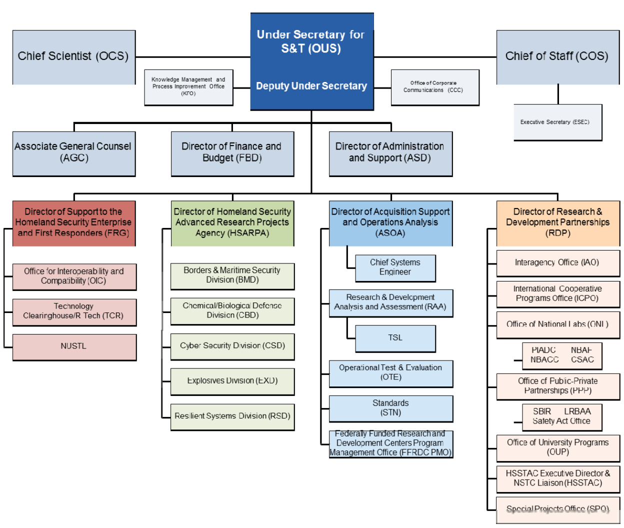
Strengthen America's security and resilience through knowledge

3

Homeland Security
Science and Technology

S&T Structure

Science and Technology Directorate



4

Homeland Security
Science and Technology

Explosives Division Mission

Mission: The Science and Technology Directorate Explosives Division promotes the development of effective techniques to protect our citizens and our country's infrastructure against the devastating effects of explosives by seeking innovative approaches in detection, and in countermeasures. It provides the concepts, science, technologies and systems that increase protection from explosives and promotes the development of field equipment, technologies, and procedures to interdict person-borne bombs, and car and truck bombs.

Customers:

- Transportation Security Administration
- Customs and Border Protection
- U.S. Secret Service
- National Protection and Program Directorate
- U.S. Coast Guard
- Federal, state and local first responders

5

Homeland Security
Science and Technology

Explosives Portfolio Structure

- **Aviation Security:** Checked baggage, check point, air cargo and canine operations.
- **Facilities Protection:** Facility checkpoints and perimeters.
- **Intermodal Security:** Protection of commuters and infrastructure in subway, maritime (ferries), and surface (buses and heavy rail) transportation.
- **Improvised Explosives:** Understanding the homemade explosive threat to improve detection technology and develop detection requirements.

6

Homeland Security
Science and Technology

Aviation Security R&D Plan

- Joint TSA/S&T R&D Strategy developed in FY11
- Aviation security system operates in a dynamic risk environment - sudden change/terrorist adaptation
- S&T and TSA relationship
  - Promotes our ability to respond via coordinated investment in research, development, test, and evaluation
- TSA and S&T have developed a joint R&D strategy with goals for technology investments
  - Goals will guide the identification, evaluation, and management of R&D initiatives

7

Homeland Security
Science and Technology

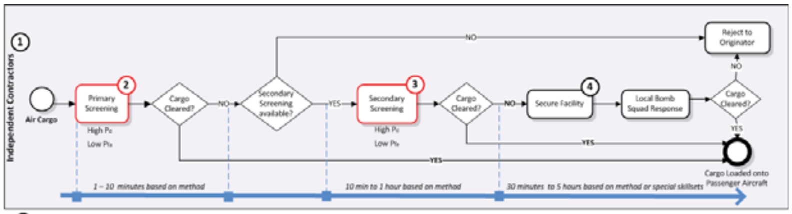
Air Cargo Challenge

- Widely varying commodities
- Any size
- Warehouse cargo environment
- Independent screeners
- Chain of custody

In the US, approximately 12 million pounds of cargo are transported daily on passenger aircraft, and 95 percent of domestic passenger flights carry air cargo.

Homeland Security
Science and Technology

Op Context Chart (As Is)



1 **Independent Contractors**

- As of February 22, 2012 there were 1,100 Certified Cargo Screening Facilities (CCSF) sites not including airlines (1,200):
  - CCSP Indirect Air Carriers (IAC) sites = 520
  - CCSP Independent Cargo Screening Facility (ICSF) sites = 80
  - CCSP Shippers sites = 500

2 **Primary Screening**

- Facility conducts a 100% physical or non-intrusive examination employing: X-Ray, ETD, EMD, EDS, K-9 or other TSA approved method
- Palletized cargo which has not been screened must be broken down to individual pieces
- Alternative security measures are used for cargo which cannot be screened by TSA approved methods (e.g. medical, human remains, etc)
- Commodities/Containers can limit secondary screening options. If system generates an alarm for special cargo (e.g. human remains, 50 gallon drums, perishables, etc) and it cannot be screened via secondary screening, the cargo must be returned to the originator

3 **Secondary Screening**

- Facility conducts alarm resolution with an alternative TSA approved method

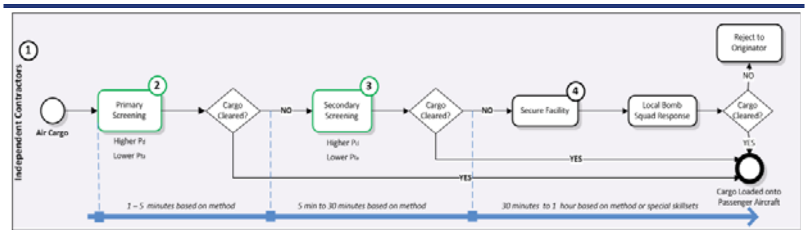
4 **Secure Facility**

- In the event the cargo cannot be cleared thru primary and secondary screening, the facility must secure operations until the Local Bomb Squad responds and addresses the situation
- Cost/Impact can be high

9

Homeland Security
Science and Technology

Op Context Chart (To Be)



1 **Independent Contractors**

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  - CCSP Indirect Air Carriers (IAC) sites = 520
  - CCSP Independent Cargo Screening Facility (ICSF) sites = 80
  - CCSP Shippers sites = 500

2 **Primary Screening**

- Facility conducts a 100% physical or non-intrusive examination employing: X-Ray, ETD, EMD, EDS, K-9 or other TSA approved method
- Palletized cargo can be screened without breaking into pieces, providing greater throughput
- ETD improvements provide greater sensitivity and selectivity

3 **Secondary Screening**

- Facility conducts alarm resolution with an alternative TSA approved method
- Special technology available to screen special cargo (e.g. human remains, ultrasonic drum scanning, etc), avoiding rejecting cargo to Originator

4 **Secure Facility**

- Cost/Impact can be high

Capability Impact:

- Improved explosives detection performance (higher Pd, lower Pfa, greater HME selectivity)
- Additional approved screening methods eliminating the need for alternative screening measures for sealed drums, medical supplies, human remains, live animals and cargo containing hazardous materials.

Homeland Security
Science and Technology

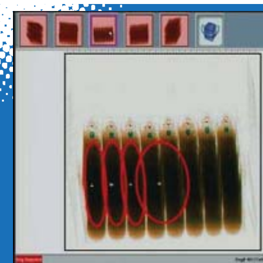
Air Cargo Program

Program Goals

Identify, develop, test and enhance ability of screening systems and operators to detect explosives and IED components within cargo parcels and pallets

Program Objectives

- Conduct laboratory and field assessments of COTS equipment to assist TSA in developing Qualified Technology List
- Develop and test prototype palletized cargo screening systems
- Transition mass spectrometer system
- Develop screener decision support tools
- Develop automated algorithms for break bulk cargo x-ray screening systems



Advanced Technology X-ray image of cargo shows possible threat areas circled by automatic detection

11

Homeland Security

Science and Technology

16.3 Tim White: Photon and Neutron Interrogation Techniques for Chemical Explosives Detection in Air Cargo: A Critical Review

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

PNNL-SA-102551

Photon and Neutron interrogation techniques for chemical-explosives detection in air cargo: A critical review

TIM WHITE

Pacific Northwest National Lab
ADSA10

U.S. DEPARTMENT OF ENERGY   DRAFT   June 6, 2014 | 1

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Summary

- Air-cargo screening for explosives with ionizing radiation is hard
  - The object is larger with a wider variety of contents
  - The task is the same
  - Cargo categories may offer tailored solutions
- Multi-mode interrogation may be needed
  - Photon-neutron radiography
  - Transmission-backscatter radiography
  - Correlated-neutron measurements, NRF
- Practical limitations
  - Innovative interrogation approaches expensive and complicated
  - Who owns the problem?

Objects

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Passenger planes carry 7,500 tons of cargo a day in storage areas under passenger cabins that also hold luggage.

Commodities (partial list)
Electronics and computer equipment
Printed material
Fresh flowers
Machine parts
Perishables, grains, animal feed
Non-metallic mineral products
Seafood and shellfish
Chemicals, alcohol, glass
Wearing apparel
Paper products (non printed)
Multiple commodities

Photon Interactions

Pacific Northwest NATIONAL LABORATORY
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"Existing data for explosives detection (FAA-conducted blind tests) indicate that the x-ray systems are not effective in the inspection of full cargo containers to detect explosives and that random selection would be equally useful."
National Academy of Sciences, 2002

Photon Interactions

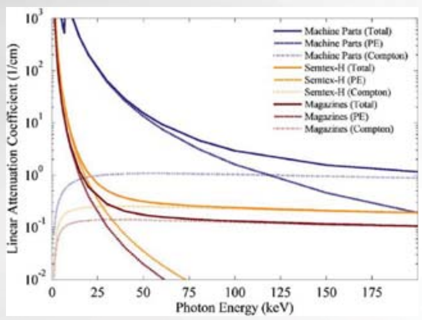
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

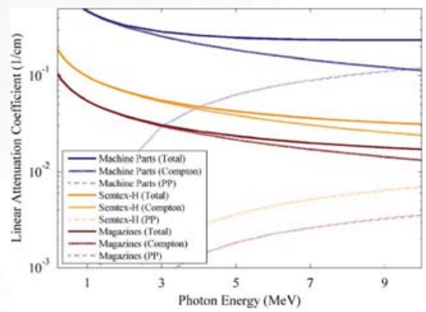
$$\mu_{pe} \propto \rho \frac{Z^4}{A} \frac{1}{E^3}$$

$$\mu_C \propto \rho \frac{Z}{A} f_{KN}(E)$$

$$\mu_C \propto \rho \frac{Z}{A} f_{KN}(E)$$

$$\mu_{pp} \propto \rho \frac{Z^2}{A} f_{pp}(E)$$





Neutron Interrogation

Pacific Northwest NATIONAL LABORATORY
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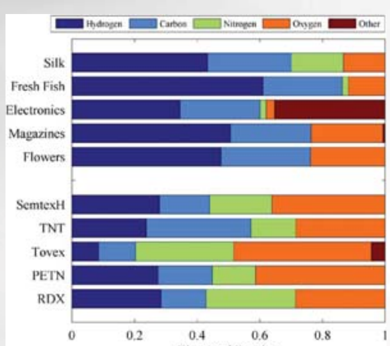
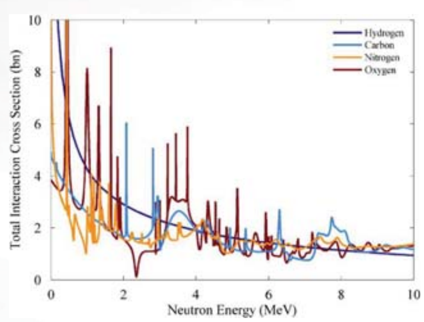
Allows access to elemental ratios
Cross section is richer
Absorption, elastic-, and inelastic-scatter measurements possible





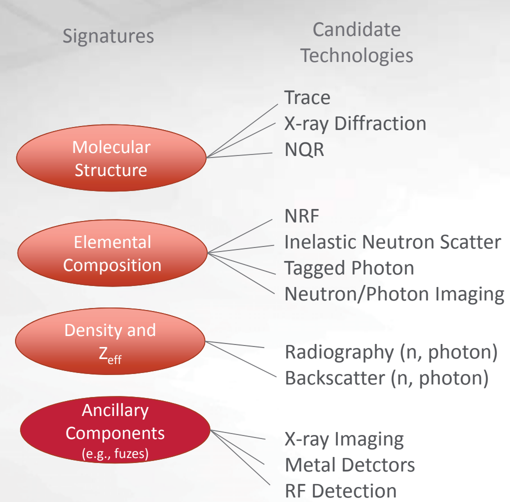
Potential Approaches

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Transmission imaging
  - **Photons**
  - **Thermal neutrons**
  - **Fast-neutron & photon radiography**
- Near subsurface
  - X-ray backscatter
  - Thermal-neutron capture
- Bulk characterization (photons)
  - PET via ^{13}N
  - Nuclear resonance absorption in ^{14}N
  - Photonuclear reactions with O and N
  - **NRF**
- Bulk characterization (neutrons)
  - **Nuclear resonance absorption with fast neutrons**
  - Fast neutron scattering analysis
  - Gamma-ray emissions via fast-neutron scattering (PFNA, API)

Signatures and Technologies

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965



Summary

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle *Since 1965*

- Air-cargo screening for explosives with ionizing radiation is hard
  - The object is larger, the task is the same
  - Cargo categories may offer tailored solutions
- Multi-mode interrogation may be needed
  - Photon-neutron radiography
  - Transmission-backscatter radiography
  - Correlated-neutron measurements
- Practical limitations
  - Innovative interrogation approaches expensive and complicated
  - Who owns the problem?

16.4 Harry Martz: What's the Problem with Neutrons for Explosive Detection

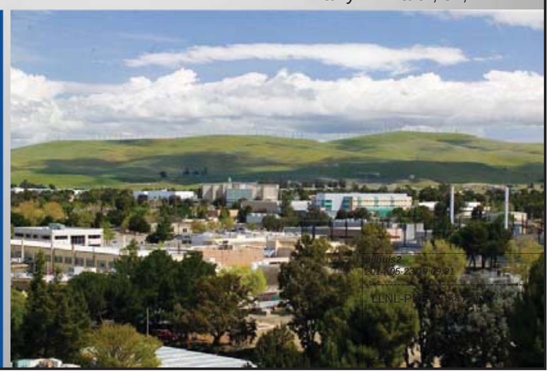
Using Neutrons to Screen Aviation Cargo for Explosives

Presented to
ADSA10
Boston, MA

on May 6, 2014

Harry E. Martz, Jr., Ph.D.

Lawrence Livermore National Laboratory



LLNL-PRES-654741

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

So What Who Cares

- Several neutron-based explosives screening systems (many of which I do not have time to discuss) have been investigated
- They have major technical limitations for aviation cargo inspection in either
  - Depth of penetration in large cargo and/or
  - Ability to detect a particular explosive class
  - High false alarm rate and low throughput
- Furthermore most have practical limitations including
  - Large size and weight for accelerator/large radiation shielding
  - Regulatory and safety issues associated with neutron-based technologies
  - Not accepted by public and workers
- Given this they have not been able to compete with X-ray-based technologies

P. Griffin, et al., Assessment of the Practicality of Pulsed Fast Neutron Analysis for Aviation Security, NAP, 2002.

Lawrence Livermore National Laboratory IM-774894_LLNL-PRES-654741

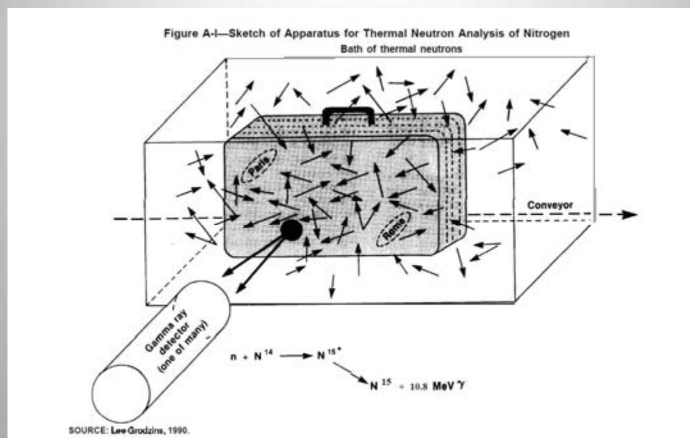
Agenda

- Summary
- Background Luggage vs Cargo
- Neutron physics and operation of
  - TNA
  - FNA
  - PFNA
- Summary

Luggage vs. Cargo

- Many of the VGs show the inspection volume for luggage
- However, the results and summary are for LD-3 and larger cargo sizes for Aviation and Eurotunnel
- Neutron interrogation methods have been applied to
  - Inspection of luggage and/or cargo for
  - Explosives and other contraband for
  - Over 30 years
  - 10's of Millions of Dollars have been spent
- But still not for prime time

Thermal Neutron Analysis—TNA Physics



TNA measures nitrogen via thermal neutron capture gamma rays

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IM-774894_LLNL-PRES-654741

Summary of SAIC TNA machine airport deployments

- Under a contract awarded to SAIC in 1985, the FAA purchased six TNA machines to detect plastic explosives
- The six TNA machines needed to be combined with X-ray unit and were called XENIS—X-ray Enhanced Neutron Interrogation System
- Four were installed at
  - JFK
  - Dulles
  - Miami
  - Gatwick

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Report to the President by the President's Commission on Aviation Security and Terrorism May 15, 1990*

- Commission began November 1989
- Charges
  - Evaluate existing aviation security systems
  - Options for handling terrorists threats
  - Treatment of families of victims of terrorists acts
  - Pan Am 103 tragedy (Dec 1988) was a point of reference
  - Findings with respect to the deployment of Thermal Neutron Analysis (TNA)
- Report completed May 1990

* http://books.google.com/books?id=PU2gl3TwFQ4C&pg=PA65&lpg=PA65&dq=Why+did+TNA+failed+to+detect+explosives+at+JFK&source=bl&ots=-3SBh9eqMi&sig=Yg13YThvRbXAZL9wud_XE4xwb5o&hl=en&sa=X&ei=cfdSUg-nI8mCygH4gYHgCw&ved=0CCsQ6AEwAA#v=onepage&q=Why%20did%20TNA%20failed%20to%20detect%20explosives%20at%20JFK&f=false

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Commission's TNA machine findings and recommendations

- Findings
  - Under a contract awarded to SAIC in 1985, the FAA purchased six TNA machines to detect plastic explosives
  - These machines by design and performance detected only amounts far greater than the weight used by terrorists
    - — For example the bomb that destroyed Pan Am 103 is believed to have weighed half or less than the amount than the TNA machine would reliably detect
  - They were not fully automated
  - The TNA/XENIS machine is massive, weighing close to 14 tons and a footprint for the TNA alone is about 12 m^2, and an additional equivalent area would be needed to add an x-ray system and baggage diverter* NAP: TNA weighted 28,000 lbs., required 41-m^2 and cost $1.4M & $0.7M operational cost/yr.
  - For threat masses of concern the false alarm rates are too high
- Recommendation
  - The program to require US airlines to purchase and deploy ~150 existing TNA machines should be deferred.
  - The FAA should create an R&D program to detect small amounts of plastic explosives.

Given the large false alarms for TNA machines other neutron based methods were explored

* http://www.skyjack.co.il/pdf/Thermal-Neutron-Analysis.pdf

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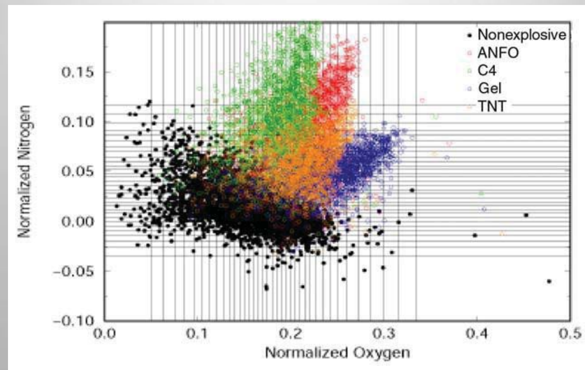
Oxygen vs. Nitrogen signatures

38,000 Pulsed Fast Neutron Transmission Spectroscopy (PFNTS) measurements from actual airline suitcases, with and without explosives

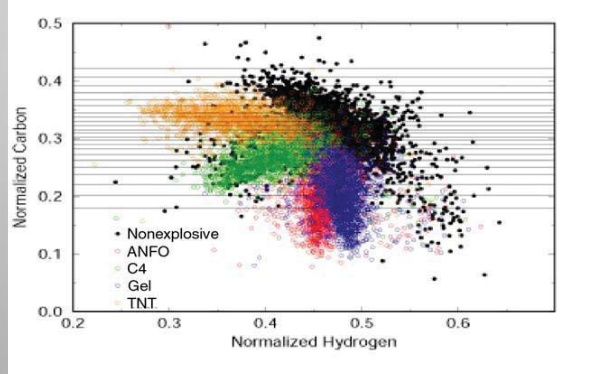


From Chmelik, et al., Analysis of Blind Tests for Explosives in Luggage Through Fast-Neutron Transmission Spectroscopy, 1997.

Lawrence Livermore National Laboratory IM-774894_LLNL-PRES-654741

Hydrogen vs. Carbon signatures

38,000 Pulsed Fast Neutron Transmission Spectroscopy (PFNTS) measurements from actual airline suitcases, with and without explosives



From Chmelik, et al., Analysis of Blind Tests for Explosives in Luggage Through Fast-Neutron Transmission Spectroscopy, 1997.

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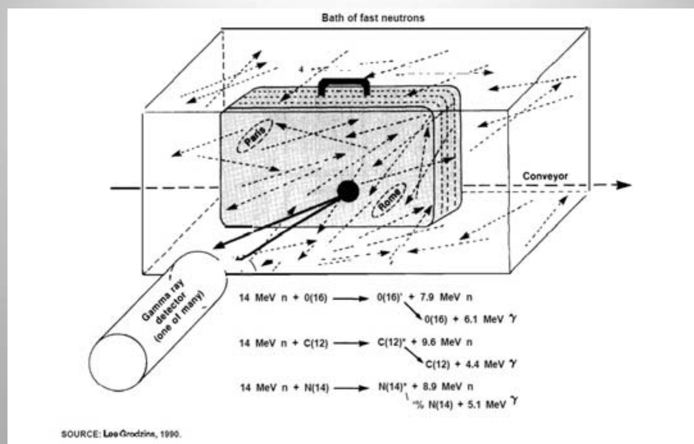
Fast Neutron Analysis–FNA Physics



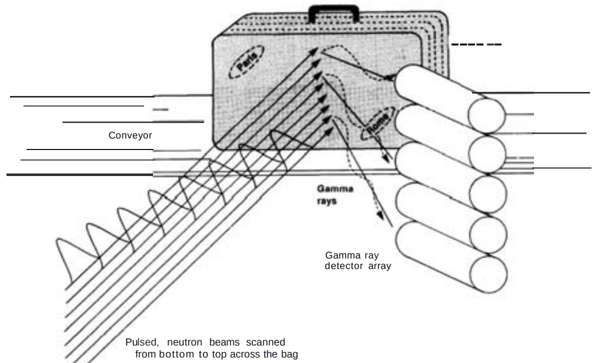
FNA measures gamma rays via fast neutrons inelastically scattered off of C, O and N

Summary of Fast Neutron Analysis—FNA

- FNA can measure more than just N so it should improve detection while reducing false alarms
- FNA is physically similar to TNA but there are significant differences in the neutron source, shielding requirements and gamma-ray detector resulting in an increase in cost size and weight
  - A fast neutron source requires an accelerator, e.g., $^{2}H(d,n)^{4}He$
  - Requires more shielding
- The fast neutrons create a lot of background in the gamma detectors
- 2D images were generated by collimation of the neutron beam
- 2D image is not good enough to sort threats from non-threats just using the atomic ratio features

Pulsed Fast Neutron Analysis-PFNA

Figure A-3-Sketch of Apparatus for Pulsed Neutron Beam Analysis



SOURCE: LseGrodzins, 1990.

Schematic of PFNA for cargo inspection

D.R. Brown, T. Gozani / Nucl. Instr. and Meth. in Phys. Res. B 99 (1995) 753–756

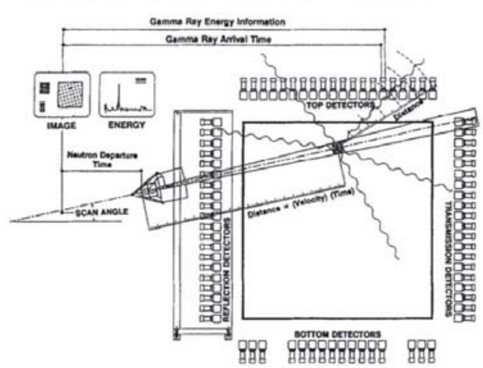


Fig. 1. Schematic view of the cargo inspection system based on PFNA.

Summary of Pulsed Fast Neutron Analysis—PFNA

- PFNA concept is similar to the FNA concept except that a focused collimated, pulsed beam of neutrons is used
- A lower energy neutron beam accelerator, $^{2}H(d,n)3He$, is used since it generates less background in gamma detectors
- The collimated neutron beam provides two-dimensional position
- Timing and image reconstruction provides the third dimension
- The 3D image provides an improvement over the FNA data but with large isotropic voxels 5 cm x 5 cm x 5 cm
- A prototype system to look at LD-3 containers was not very promising it had PD and PFA issues*:
  - Can't see zone
  - Cannot detect a particular class of explosives
- An SAIC system built to screen cargos for large threat masses in cargo
- The system is much larger than a TNA system

* C. Bell and D. Green, Pulsed Fast Neutron Analysis (PFNA) October 2000 Test Overview, viewgraphs presented to NAS PFNA study Panel, Jan, 2001

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Summary of PFNA Eurotunnel Testing

- British and French tested PFNA
- PFNA had several potential benefits
  - Detection of quantities of explosives that might be a threat to the tunnel
  - Verification of cargo contents wrt
    - Tariffs
    - Compliance with international agreements
    - Finding unauthorized hazardous commercial materials
  - Detection of large quantities of drugs illegally transported

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PFNA Eurotunnel testing was judged as a success, but*

- Was not deployed due to
  - Issues of cost both operational and initial capital investment
  - Cargo throughput
  - Value of detection
- However, they preserved the operational compatibility with future implementation if circumstances changed

* P. Griffin, et al., Assessment of the Practicality of Pulsed Fast Neutron Analysis for Aviation Security, NAP, 2002.

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So What Who Cares

- Several neutron-based explosives screening systems (many of which I do not have time to discuss) have been investigated
- They have major technical limitations for aviation cargo inspection in either
  - Depth of penetration in large cargo and/or
  - Ability to detect a particular explosive class
  - High false alarm rate and low throughput
- Furthermore most have practical limitations including
  - Large size and weight for accelerator/large radiation shielding
  - Regulatory and safety issues associated with neutron-based technologies
  - Not accepted by public and workers
- Given this they have not been able to compete with X-ray-based technologies

P. Griffin, et al., Assessment of the Practicality of Pulsed Fast Neutron Analysis for Aviation Security, NAP, 2002.

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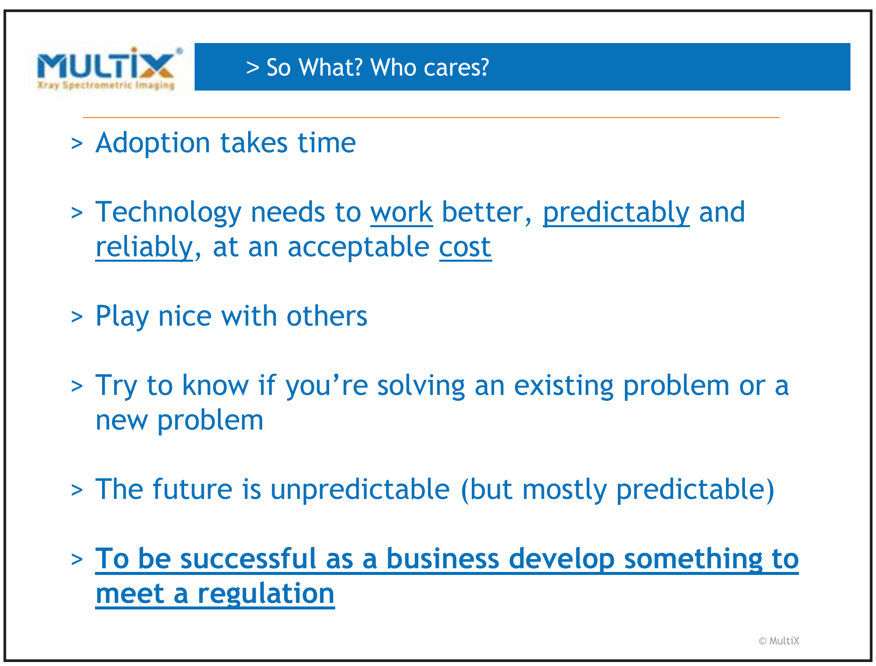
16.5 Tim Rayner: Hurdles to the Adoption of New Methods II: The Regulators Strike Back



MULTIX Xray Spectrometric Imaging

> The Security World

> **Security tends to be reactive**

- An event occurs
- Government responds and creates a requirement/regulation
- Security Developers (Academic and Commercial) develop solutions

Or…

- An ROI exists
  - Better facilitation, staff savings, reduced footprint
- Regulation adjusted to allow for facilitation
- Security Developers (Academic and Commercial) develop solutions

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> The Realities

> **Security technology is made and sold by commercial companies:**

- Development of new technology is shared between business and academia
- Development of new technology can be funded by government

> **Business will only move forward if there are sales opportunities or the perception of sales opportunities:**

- ROI

> **Nothing convinces a company board more than a regulation or a promise of regulation that requires a customer to buy your technology**

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Xray Spectrometric Imaging

> The Security Market

> **Two types of markets:**

> **Federalized (US, German, etc..)**

- Government regulates, buys and operates security equipment (HBS, Checkpoint)
- Behaviour:
  - Early adopter (usually)

> **Un-federalized (US (Cargo) EU, RoW)**

- Government regulates, airports buy and operate security equipment
- Behaviour:
  - Grudge purchase
  - ROI needs to be demonstrated

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> Case Histories (Unregulated)

> **Mouse**

- Early adoption in 1984
- Full adoption in 1995
- Introduced in 1963

> **Tablet**

- Early adoption in 2007
- Full adoption in 2010
- Introduced in in 1984

> **Internet**

- Early adoption in 1979
- Broad adoption in 1995
- Introduced in in 1969

> **Fax Machine**

- Invented in 1843

> **Internal Combustion Engine**

- Broad adoption in 1913
- Invented in 1870

> **Velcro**

- Invented in 1941

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> Case Histories (Regulated)

> **EDS**

- Early adoption in 1994
- Full adoption in 2004* (US), 2020+ (EU)
- Introduced in 1990

> **AIT**

- Early adoption in 1998
- Broad adoption in 2013(US),?(EU)
- Introduced in 1991

> **ETD**

- Early adoption in 2001
- Full adoption in 2005(US) 2014(EU)
- Introduced in 1970 (IMS)

- **LAGs Screening**
  - Partial adoption in 2014
  - Full adoption in 2015+
  - Invented in 1994

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> Good Example: Lifting of the LAGs Ban

> **LAGs ban put in place as a response to an event that happened in 2006.**

- No LAGs allowed on aircraft, only small quantities (3-1-1).

> **Ban was always temporary**

- Quad countries decided to work towards lifting the LAGs ban (2008)

> **Timeline:**

- Phase 1 Lifting of the LAGs ban failure (2011)
- Phase 1 Lifting of the LAGs ban success (2014)
- Phase 2 and 3 delayed but will treble installed base

2000+ LAGs Screening Systems Sold

Successful as selling to meet an existing regulation

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> Another Example: EDS

> **Explosive Detection System (EDS) Certification Criteria developed as a response to the Lockerbie Incident (1986)**

> **EDS Certification Process introduced in 1992**

> **Timeline**

- One company develops system that achieves regulation (1993)
  Government funds others to provide competition
- Limited deployment on selectee checked baggage only (1995) → 100 EDS Systems Sold
  1st in market nearly goes out of business
- Full Deployment on all checked baggage (2001) → 1000+ EDS Systems Sold
  Company 1st in the market sells for record amount

Successful as selling to meet an existing regulation*

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> Bad Example

> **Company identifies technology suitable to detect explosives**

> **Develops with the aid of government funding a whole series of embodiments of the technology**

> **Timeline**

- Company develops explosive detection demonstrator (1994)
- Company develops HBS systems (1998) → 5 HBS Systems Sold
- Company develops Checkpoint systems (2000)
- Another company develops a combined technology system (2005)
- Technology “moth balled”

Unsuccessful in part as no regulation exists

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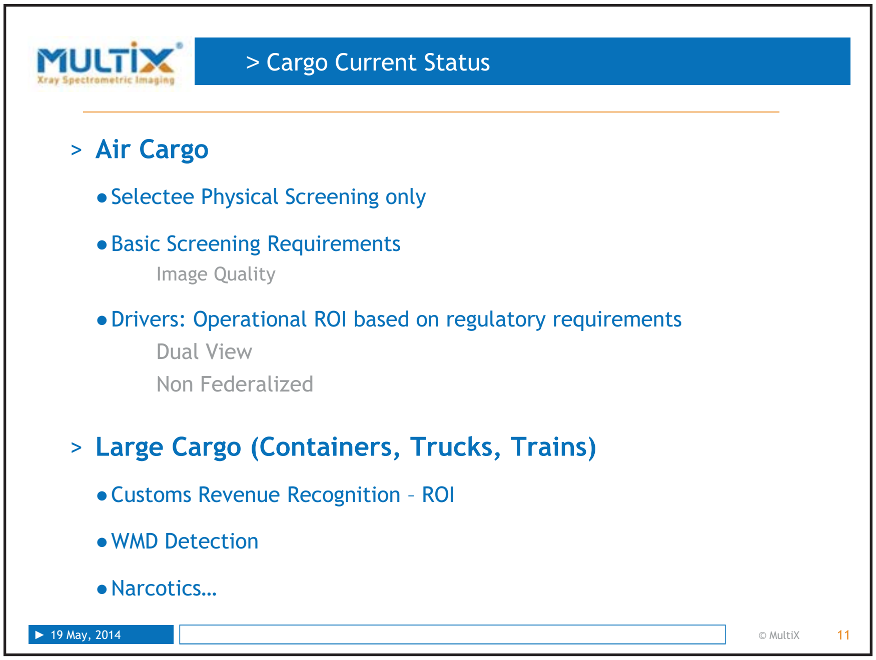
MULTIX
Xray Spectrometric Imaging
> Cargo Current Status
> Air Cargo
● Selectee Physical Screening only
● Basic Screening Requirements
Image Quality
● Drivers: Operational ROI based on regulatory requirements
Dual View
Non Federalized
> Large Cargo (Containers, Trucks, Trains)
● Customs Revenue Recognition – ROI
● WMD Detection
● Narcotics…
19 May, 2014
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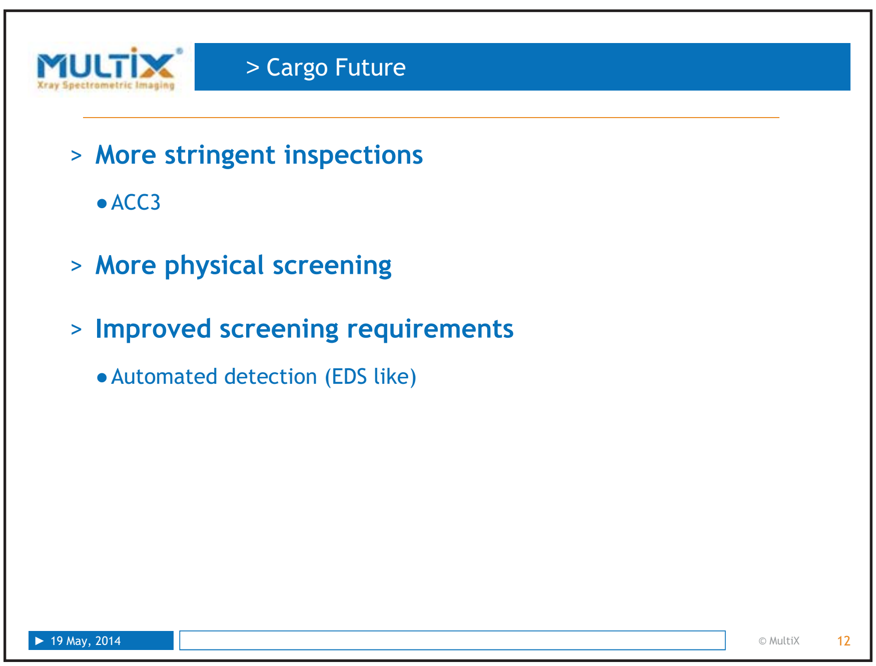
11


MULTIX
Xray Spectrometric Imaging
> Cargo Future
> More stringent inspections
● ACC3
> More physical screening
> Improved screening requirements
● Automated detection (EDS like)
19 May, 2014
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12

> Other Drivers

- > Large Company Lobbying
- > Large Airport Lobbying
- > Trade Associations Lobbying

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> Why Does technology get adopted? The 10 Reasons

- > It meets an existing regulation
- > It has an ROI
  - Facilitation, Operation, Maintenance, Replacement
- > It doesn't break
- > It works
  - Better than what was before (in both reality & perception)
  - Testable & understandable
- > It plays nice with existing systems
- > It does no harm
  - No new costs, training, expertise
  - Health, Privacy
  - Operational, in both reality & perception
- > It should work (better) in the future (platforms)
- > It meets an existing regulation
- > It works
- > It has an ROI

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> How to Succeed

- Come up with something cool!
- Understand the environment for its use
- Determine if a regulation exists or will do within the developmental timeframe
- Get the timing right (acquisition cycles)
- Have an understanding spouse
- Sell loads
- Retire and buy spouse things

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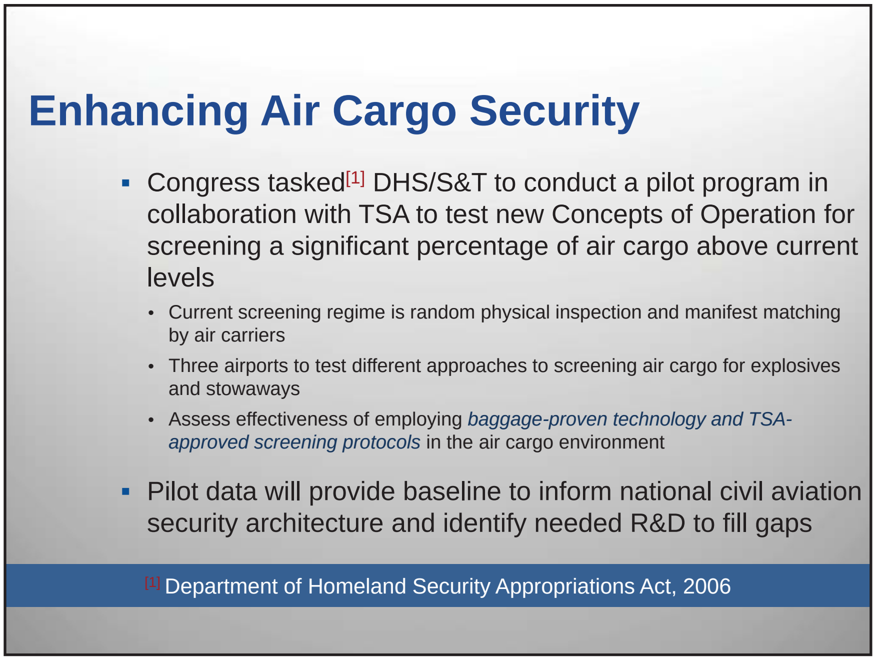
16.6 Doug Bauer: Air Cargo Explosives Detection Pilot Project - Overview



ACEDPP addressed 3 key questions

- Is it feasible to screen significantly more air cargo (i.e., at least six times more than pre-ACEDPP levels)? What resources and CONOPS are required to do so?
- What are the costs associated with increased screening levels, and how are these costs distributed over system and operational elements?
- To what degree does increased screening enhance security? How effective are technologies and protocols developed for screening passenger-checked baggage at detecting explosives in air cargo?

Technologies employed by ACEDPP were EDS, ETD and Canine

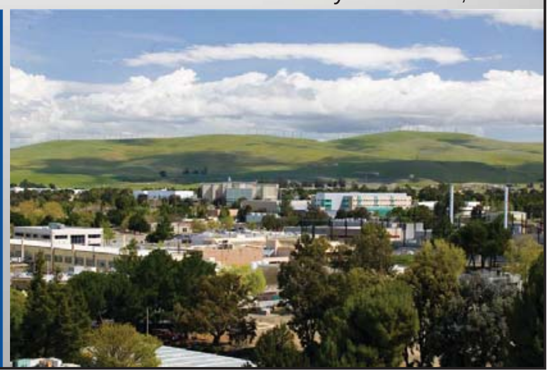
16.7 Amy Waters: Air Cargo Explosives Detection Pilot Project - Details

Air Cargo Explosives Detection Pilot Program (ACEDPP) – Observations and Lessons Learned

ADSA10 - Explosives Detection in Air Cargo
May 6, 2014
Boston, MA

Amy M. Waters, PhD

Lawrence Livermore National Laboratory



LLNL-PRES-653113
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

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ACEDPP addressed 3 key questions

- Can we screen more cargo than we do presently?
  - *Yes. However, breaking down and re-building ULD shipments for piece-level screening is very labor intensive. ULDs could be screened by air carriers using canines or another bulk screening method.*
- What would it cost?
  - *The cost of technology-based screening is on the order of $0.08-0.12 per pound, which is dominated by cargo handling and screening labor. Canine screening is much less expensive per pound – less than $0.01 per pound for the ACEDPP pilot at SEA-TAC airport.*
- How effective are present systems against threats?
  - *Limited operational efficacy assessments were conducted at SFO using explosives simulants, with positive results. Some efficacy data for ETD and canine screening have been reported elsewhere. There is still a need for system-level efficacy testing and analysis.*

Technologies employed by ACEDPP were EDS, ETD and Canine

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Recommendations and Lessons Learned

- Most urgent need is for an effective method for screening bulk cargo tendered on pallets and in ULDs.
- Further efforts needed to identify specific causes of false and nuisance alarms.
- Additional efficacy testing for cargo screening systems is needed.
- Further testing also recommended for canine explosives detection teams in live cargo environments.
- Technologies other than those used in ACEDPP should be evaluated in live cargo environment.

Additional work remains to meet 100% screening mandate

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7 Critical Scientific Questions defined data requirements

- **Q1 – *Impact***: What is the impact on air cargo commerce and security policies of increased levels of cargo screening? In particular, what is the cost of significantly enhancing screening? What information is needed to determine who should bear those costs?
- **Q2 – *System RAM***: What is the system/equipment Reliability, Availability, and Maintainability (RAM)?
- **Q3 – *Alarm Rate***: What are the sources and causes of false alarms?
- **Q4 – *Process Effectiveness***: How effective are the Concepts of Operations (ConOps) for increasing the level of air cargo security?
- **Q5 – *Baggage Equipment/Protocol Applicability***: Can cargo screening protocols largely derived from checked baggage protocols and detection systems developed for passenger and baggage applications be deployed in a cargo environment and meet specified performance objectives?
- **Q6 – *Future R&D***: What are the future Research and Development (R&D) needs for cargo management/handling and efficacious explosives detection systems as suggested by the results of the three pilots?
- **Q7 – *Data Limitations***: What are the limits of ACEDPP data in regards to scalability and extrapolation to other airports?

Data from air carrier shipping records, CIMP system, targeted data sampling, interviews

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ACEDPP data elements collected by and derived from pilot operations

Cargo Warehouse Operations Data	Cargo Load, Demand & Profile Data[a]	Screening & Effectiveness Data[b]	RAM Data	Cost Data
• Pilot operating hours • Pilot staff —no. per shift, hours spent in AC warehouse • AC cargo staff—no. of screeners, cargo handlers, supervisors per shift • Off-normal events—power outages, emergencies, VIP visits, et al. • Cargo processing stage times and rates, throughputs—unload, buildup, breakdown, transport, acceptance, et al. • Cargo volume processing stage—no. of AWBs, pieces, parcels • Staff training—per screening method, cargo-screening system operations, document processing	• Time distribution of cargo tendered (by AWBs, pieces, parcels) • Time distribution of commodity types tendered (by AWBs, pieces, parcels) • TSA exemption reasons used by shippers • Scheduled flight time • Shipments meeting scheduled flights, delayed or missed shipments • Cargo profile—weight, dimensions, no. of parcels per piece, packaging configurations & materials • Cargo destination—domestic, international, transient • Cargo service category—general, express, overnight, SPD, high-value • Cargo by aircraft size—narrow vs. widebody plane •	• Pilot test configu-ration—screening levels, numbers, and types of equipment used for primary, secondary, and tertiary screening • Screened AWBs, pieces, parcels counts by method • Cargo screened per time period; screening service times; screening throughput • Cargo screened per commodity type by method and affinity • Alarm type, mode, causes, by method • False-alarm rates by commodity and packaging types • True alarms by pieces and parcels • Screening times by method/affinity • CTX images—SP, CT, and raw data • ETD plasmagrams from alarms • Detection rates & false-alarm rates from explosives simulant testing	• Calibration times and modes per equipment item • Equipment up-time/downtime • Equipment failures—types, causes, service response time, and costs • Screening method utilization during peak/non-peak periods • Environmental factors and effects on equipment, system, and personnel performance • Equipment & system availability by peak/non-peak periods • Mean time between failures, by method • Mean time to repair, by method •	• Consumables & supplies • Cargo handling & screening systems, design, fabrication, installation, integration, parts, supplies • Labor costs—AC personnel, cargo handlers, screeners • Screening cost per parcel or lb. • On-the-job injuries • Training aides & user guides • Maintenance & repair costs • Utility costs • **Ancillary Data** • Data collected not in real time or inline with the cargo handling/screening system; these include daily logs of unusual events that disrupt operations, interviews with cargo handlers and screeners, sampling of time-in-motion events for cargo handling activities outside of pilot's cargo-handling system, et al.
	(a) in terms of number, quantity, weight, volume, percentage, as appropriate	(b) in terms of number, quantity, weight, volume, percentage, as appropriate		

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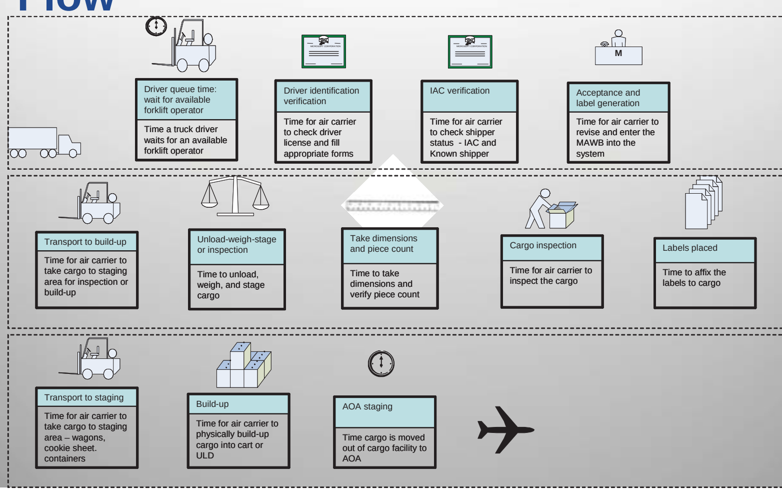
Typical Air Carrier Cargo Process Flow



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SFO pilot – commodity specific screening with dedicated technologies & personnel

- Pilot operations at 2 facilities, serving 9 airlines and handling just over half of air cargo originating at SFO
- Principle design requirement was to provide capability to screen at least 6 times more than pre-pilot
- Developed an integrated and partially automated system for cargo handling and screening
  - Systems were designed specifically for 2 facilities, based on cargo volumes, distribution of commodities, spatial constraints
- SFO and carriers also imposed requirements to minimize risk to the air carrier
  - 100% tracking and rebuild
  - No damage caused by CSS and have minimal claims
  - Robust ergonomics and safety features

ACEDPP pilot operated at SFO from September 2006 through March 2008

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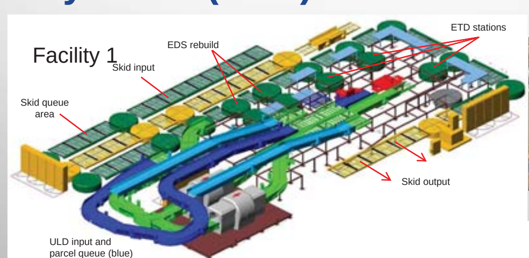
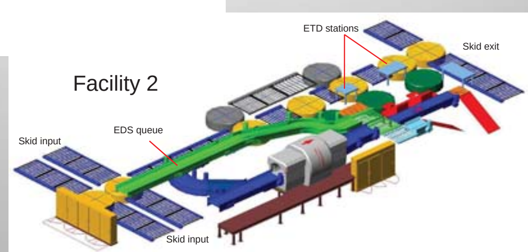
SFO Semi-Automated Cargo Handling Systems (CHS)





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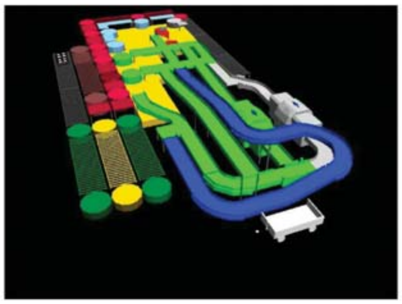
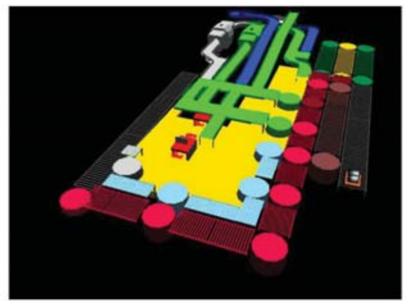
CHS included ETD or EDS screening, based on commodity type





LEFT: EDS process flow RIGHT: ETD process flow

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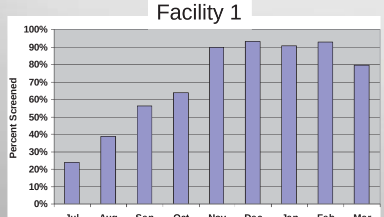
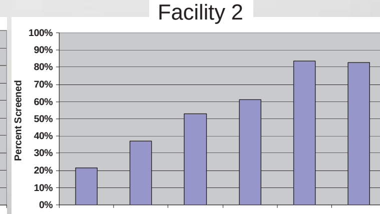
Screening at SFO was implemented in stages

Facility 1



Facility 2



Facilities were screening 15% and 5% of total volume pre-pilot (mostly due to exemptions)

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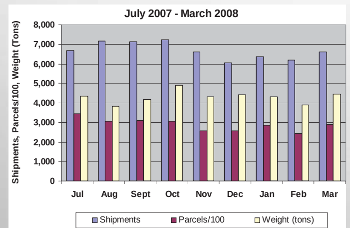
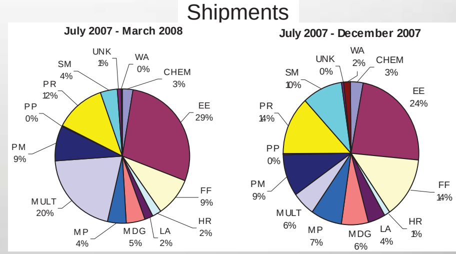
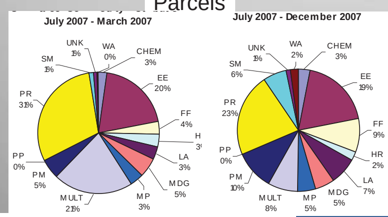
Shipments vary by commodity, by season and by airport



Shipments



Parcels



Commodity Code Key
CHEM=chemicals
EE= electronic equipment
FF=fresh flowers
HR=human remains
LA=live animals
MDG=miscellaneous durable goods
MP=machine parts
MULT=multiple commodities
PM=printed materials
PP=paper products
PR=produce
SM=seafood and meats
UNK=unknown
WA=wearing apparel

SFO - high-tech industry and agriculture

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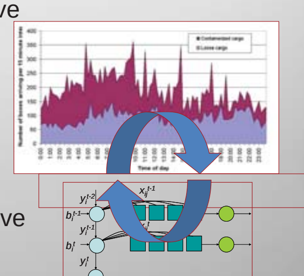
Modeling was used to evaluate a variety of topics

- Optimized system configuration (mix and number of technologies and staffing)
- Determination of costs and efficacy to drive decision making
- Determination of major cost drivers
- Calculation of system capacity
- Calculation of utilization levels
- Optimization of ConOps and policies
- Determination of critical parameters to drive requirements for data collection



ACEDPP utilized Optimization, Simulation, and Life Cycle Models

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Life-Cycle Cost Modeling

- ACEDPP developed a life-cycle cost model with three main drivers
  - Time period over which costs are incurred
  - Discount rate applied to future costs
  - Pertinent cost element
- The following assumptions were used
  - Lifecycle of cargo-handling system assumed to be 20 years
  - Cargo volume over 20-year life cycle assumed constant
  - Imputed costs included
  - Inflation accounted for in future cost of goods and services
  - Discount rate used to calculate present value

Economics Working Group (EWG) formed to identify pilot cost categories

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Pilot costs divided into 12 categories

1. Screening equipment costs (EDS, ETD, and PI)
2. Cargo handling system (CSS) costs
3. Business process modification costs including costs to expand capacity
4. Direct labor costs
5. Delay costs (given an alarm, impacts to time, labor, missed flights, et al.)
6. Performance testing costs
7. Utility costs
8. Liability (insurance) costs
9. Compliance/facility engineering costs
10. Incident costs
11. Taxes
12. Interest

All cost results presented in terms of the EWG cost components

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Total costs calculated by Life Cycle Cost Model allocated to 7 categories

1. direct-labor costs in the warehouse
2. EDS equipment capital and maintenance costs
3. ETD equipment capital and maintenance costs
4. material-handling system equipment costs
5. utility costs
6. business process modification costs
7. performance testing costs

Total Life Cycle Cost

Cumulative and net present value of as-built and as-operated pilot costs

	SFO Pilot		CVG Pilot
Cost Element	Facility 1	Facility 2	
20-year life-cycle cost	$81,402,000	$23,578,000	$33,530,402
present value of 20-year life-cycle cost	$46,821,000	$13,644,000	$18,184,601

Total Screening Cost

Screening cost comparison for SFO, CVG and SEA

	SFO Pilot		CVG Pilot
Cost Element	Facility 1	Facility 2	
$/parcel	$4.35	$5.08	$8.55
NPV $/parcel	$2.50	$2.94	$4.64
$/pound	$0.15	$0.18	$0.15
NPV $/pound	$0.09	$0.10	$0.08

At SFO and CVG, labor is the major cost driver (more than 50% of costs)

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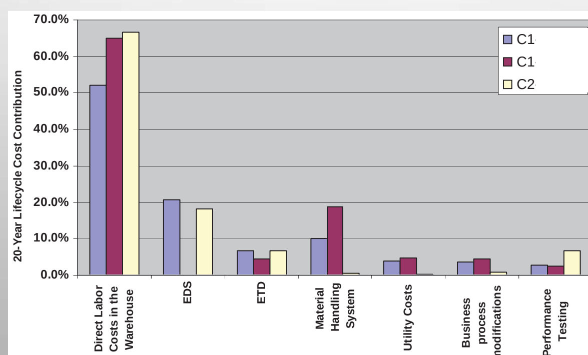
Life Cycle Cost by Category



Major drivers of cost are labor, followed by EDS

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ULDS are a significant challenge to screening operations

ULDs designated MULT commodity type

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Cargo Handling System at SFO - ULD station

The Theory……

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Unloading ULDs to conveyor extremely labor intensive

…versus reality.

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Screening at parcel level remains significant issue

- Variety of shipping configurations (e.g. ULD) require intensive labor to break down, screen and reconstitute
  - Need effective solution for screening bulk cargo configurations
- Range of cargo commodity types shipped precludes a single technology approach
- Screening systems should be designed for high-capacity with low average utilization due to shipment bunching

Bulk-screening technologies would reduce operational impact, and decrease cost

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Additional data would be useful as USG works to find optimal solution

- True sources of alarms—What specific items cause false alarms when screening air cargo?
- Oversize/heavy cargo—What is the most appropriate method for screening this type of cargo?
- Minimum number of screeners—What is the maximum throughput that can be sustained by each screener, and what is the minimum number of screeners that are required to service a given cargo volume for difference screening ConOps?
- ULD screening—On average, how much labor is required to break down, screen, and rebuild ULDs of different sizes and types?
- X-ray screening—How effective is it, and what are its cost metrics?
- RAM—What would the reliability of ACEDPP-type systems be over an extended period of operations?

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Additional data (cont.)

- Space requirements—What are the warehouse space requirements for an air-cargo screening operation as a function of cargo volume, commodity mix, and air carrier business rules?
- Industry elasticity—how would the volume of cargo shipped by air vary if the overall cost of shipping rises as the cost of increased screening is passed along to customers?
- Incident costs—What are the complete costs associated with evacuating a cargo warehouse facility in the event of a false alarm?
- Red teaming costs—what are the costs associated with establishing and maintaining the efficacy of air cargo screening?
- On-the-job injuries—What is the injury rate that can be expected for air-cargo screening operations?
- Centralized screening facilities—How well would a centralized screening approach work at airports of different sizes, and what new issues would it create? Is it cost effective?

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Acknowledgements

This work was funded and supported by the Department of Homeland Security, Science and Technology Directorate/Explosives Division.

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26
LLNL-PRES-653113

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National Laboratory

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The specific language authorizing this program in the appropriations bill (Conference Report) is:

- Based on recommendations in Science and Technology's (S&T) system engineering study of civil aviation security, the conferees direct $30,000,000 be used to conduct three cargo screening pilot programs - one at an all cargo airport facility and two at passenger cargo airports (top twenty in size) - to test different concepts of operation, as described in the House report. The conferees expect S&T to utilize TSA airport management staff to manage the oversight and day-to-day operations of these pilot programs to the greatest extent possible. One of the pilots should test whether a significant amount of cargo can be screened in the terminal using existing checked baggage security infrastructure. The conferees also expect S&T to locate these pilots at airport or airline facilities willing to contribute both physical space and other resources to this effort. The conferees direct S&T to begin all pilots in fiscal year 2006, to report on the initial results of the pilots every six months after initiation of the first pilot, and to report on the final results four months after the last pilot is completed.

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The language in the referenced House report is:

- **The Committee has provided $40,000,000 to the Science and Technology Directorate (S&T) within the explosive countermeasures appropriation to continue air cargo activities, previously funded under TSAs research and development program. Of this funding, $30,000,000 shall be used to conduct three cargo screening pilot programs - one at an all cargo airport and two at top ten passenger cargo airports. These pilots shall test different concepts of operation that TSA designs in coordination with the S&T. Testing shall consist of the following: (1) physically screening a significant percentage (e.g. six times more than today) of cargo at a passenger airport using TSA screeners during slack passenger and checked baggage screening periods; (2) physically screening a significant percentage (e.g. six times more than today) of cargo at a passenger airport using TSA or private screeners solely dedicated to cargo screening; and (3) using canine teams, supplemented as needed by technology, screening a similar percentage of cargo at an all cargo airport, specifically to detect explosives and hidden passengers. Based on results of each pilot, TSA will provide cost estimates (both non-recurring and recurring) of these different operational concepts if deployed to the top five air cargo only airports and top 10 passenger airports. The Committee expects each of these pilots to be no shorter than nine months in duration and all pilots to be completed by January 31, 2007. The Committee directs S&T to provide a comprehensive report on each pilot, two months after each is completed, and interim reports of progress and results no later than August 31, 2006.**

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Final requirements for systems at SFO

- Requirements
  - Screening system must handle skids, ULDs, and individual parcels
  - Capacity at least 6X current screening throughput
  - Sufficient equipment redundancy
  - Integrate to the airlines air waybill (AWB) software
  - Incorporate on-screen resolution (OSR) in the future
  - No delayed cargo or missed flights
  - Scalable modular design for future growth
- Optimize the system for
  - Highest automation
  - Lowest processing time per skid/parcel
  - Maximize EDS/ETD equipment utilization and screening efficacy
  - Increased airline efficiency in the cargo area – minimize labor
  - Lowest possible square-foot usage
  - Minimize capital investments for peak and average demands
  - Lowest maintenance cost

Minimize cost per parcel screened

- Minimize risk to the air carrier through
  - 100% tracking and rebuild
  - No damage caused by CSS and have minimal claims
  - Robust ergonomics and safety features

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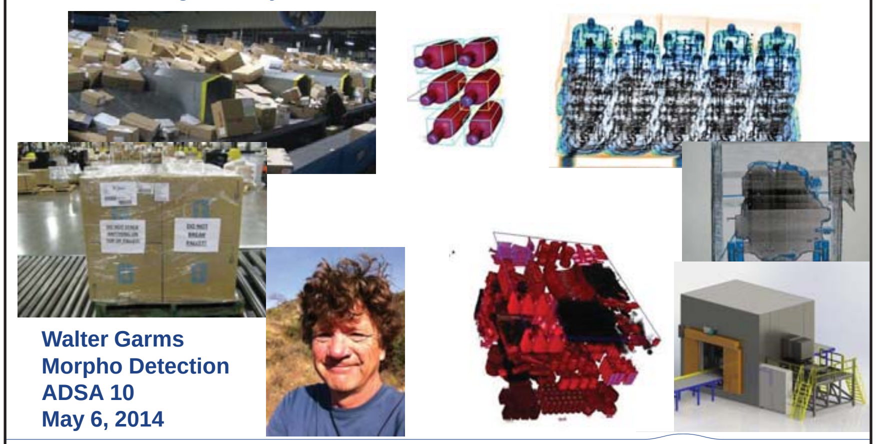
16.8 Walter Garms: SPAC: CT Scanning of Palletized Air Cargo and Security Challenges for Overnight Cargo

AIR CARGO SCANNING CHALLENGES

Achieving security at 10,000 false alarms an hour



Walter Garms
Morpho Detection
ADSA 10
May 6, 2014

SAFRAN Morpho

AIR CARGO PROBLEMS AND APPROACHES

Security study at overnight air cargo sort facility

- **Break Bulk and Palletized Cargo**
  - Intense time pressure
  - Huge variety of break-bulk items make baggage scanning seem easy
  - Large numbers of similar or identical packages
  - Customers do not want boxes opened or pallets broken down
- **Palletized cargo is even harder:**
  - Difficult to penetrate with x-rays
  - Often too cluttered to see threats in projection images
  - Customers do not want pallets broken down

Technology and approaches

- **SPAC: Full volume, high energy CT scanner for palletized cargo**
  - Need help: Scatter correction for high energy flat panels
- **Threat grouping algorithms for identifying multiple or known objects**
  - Wide open field; lots of room for creative solutions!
- **Risk based approaches**
  - (only scan boxes with real threats): Yes, go for it, but not on my time!

SAFRAN Morpho

AIR CARGO SCREENING STUDY

Study conducted at overnight cargo sort facility

- X-ray for skids (HRH-1500) 400 skids
- CT for packages (CTX-5800) 1100 boxes
- Trace for alarm resolution
  (Itemizer DX) 980 samples

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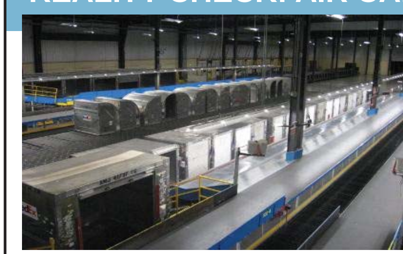
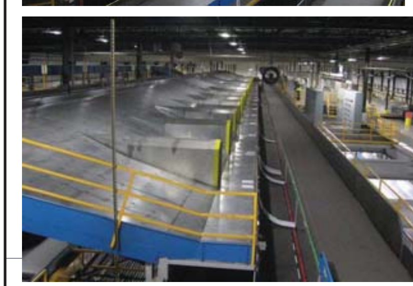
Morpho

REALITY CHECK: AIR CARGO SORT FACILITY





02:30 - 23:45
All Quiet…

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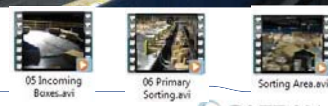
12:30AM: CONTROLLED CHAOS (SEE MOVIE CLIPS IF AVAILABLE)

12:30AM – 2:30AM

- **20,000 packages**
- **400 skids**
- **2 hours**



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FALSE ALARMS IN BREAK BULK

- **Huge variety of objects makes baggage scanning seem easy.**
- **Large numbers of similar or identical objects**
- **Contents highly dependent on season and location**

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DID I MENTION FALSE ALARMS?

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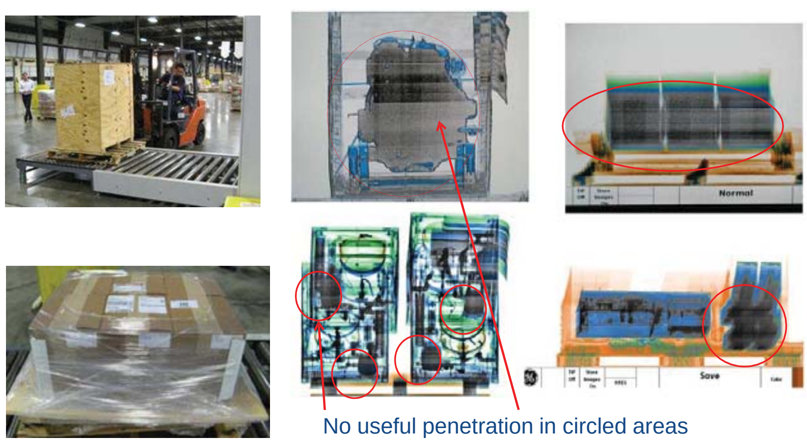
X-RAY FOR SKIDS - PENETRATION



No useful penetration in circled areas

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X-RAY FOR SKIDS – CLUTTER AND COMPLEXITY

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WHAT'S NEEDED: HIGH ENERGY, HIGH RESOLUTION CT FOR PALLETS

SPAC: Scanner for palletized air cargo

- ➔ Megavolt x-ray source to penetrate dense pallets
- ➔ Large area flat panel x-ray detectors
- ➔ High resolution Helical Computed Tomography
- ➔ Commercially viable throughput

Prototype system built by Morpho Detection in cooperation with TSA

What is the hard part?

- ➔ High energy x-ray scatter in uncollimated flat panels
- ➔ Expensive shielding
- ➔ Did I mention alarm resolution?

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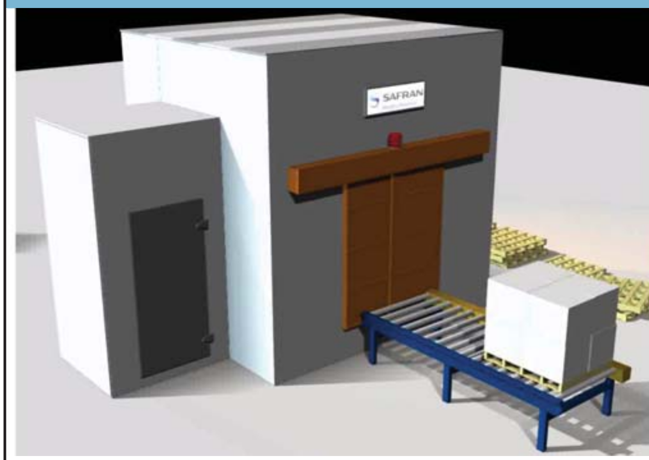
SPAC CONCEPT (SEE MOVIE CLIP IF AVAILABLE



1-SPAC
Movie.wmv

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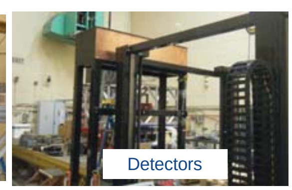
PROTOTYPE IMPLEMENTATION

Overview of SPAC system



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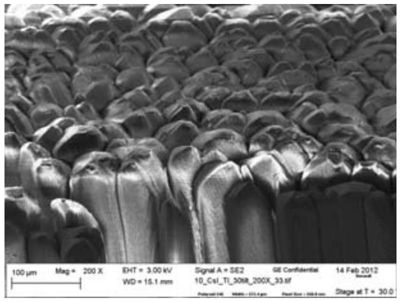
MULTIPLE FLAT PANEL X-RAY DETECTOR



Cesium Iodide scintillator needles grown on detector substrate

World's largest area CT x-ray detector?

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SCANNING TURBINE ENGINE (SEE MOVIE CLIPS)

3-Turbine Loading.MP4 4-Turbine Scanning-fast.MP4 5-Turbine unloading.MP4

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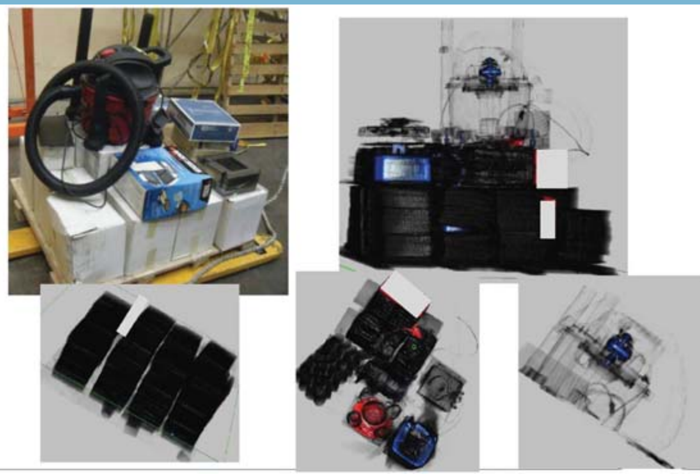
Morpho

RENDERING SECTIONS OF 3-LAYER PALLET



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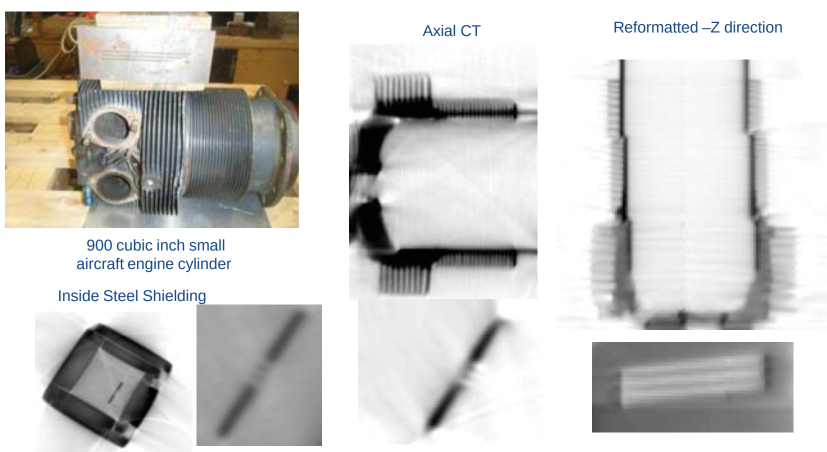
CT IMAGE RESOLUTION AND PENETRATION



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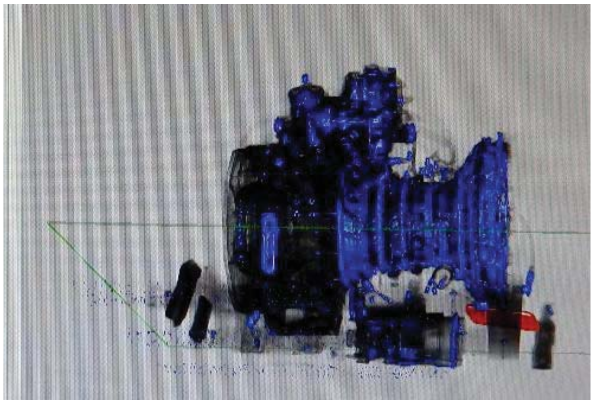
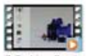
SPAC THREAT RESOLUTION INTERFACE (SEE MOVIE CLIP IF AVAILABLE)





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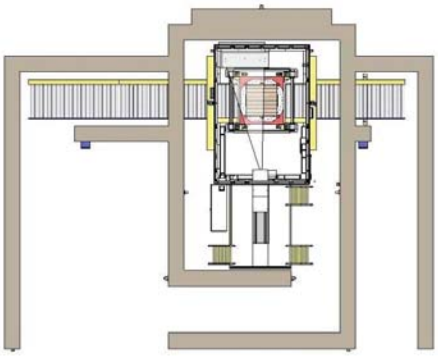
PRIMARY AND SECONDARY SHIELDING

Lead primary shield vault



Modular concrete secondary shielding (two feet thick)

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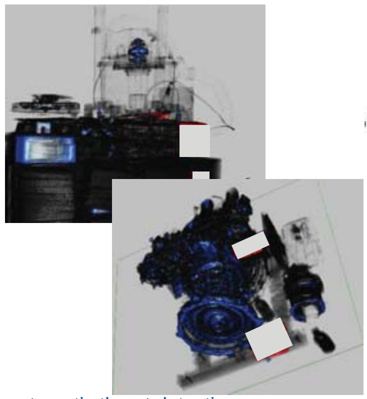
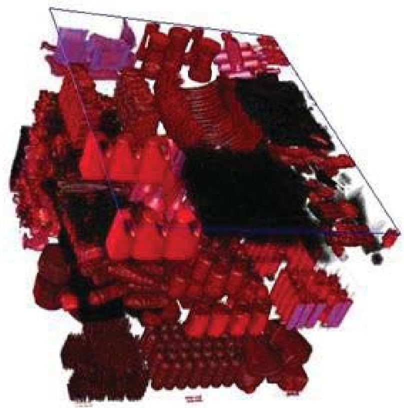
SPAC AUTOMATIC THREAT RECOGNITION



3D automatic threat detection
Detects hold baggage EDS threat quantities

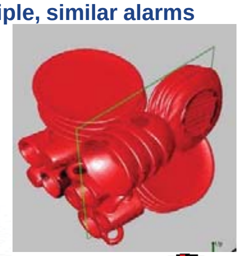
Did I mention false alarms?
Source: Megavolt CT program

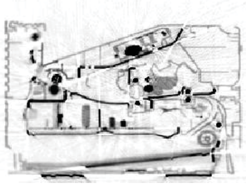


Morpho

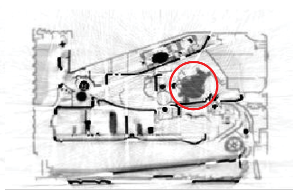
THREAT CLUSTERING/ANOMALY DETECTION

- **Problem: Pallets and packages may contain multiple, similar alarms**
- **Solution: Seen one, seen 'em all?**
  - Use ATR to detect groups of similar threat objects
  - GUI Tools to view small differences within a group
  - GUI Tools to select and clear entire groups
  - Remaining objects receive higher scrutiny





Printer with normal ink cartridge



Ink cartridge filled with explosive simulant

One coffee mug with simulant

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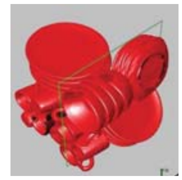
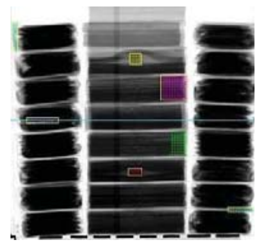
SOME IDEAS FOR CLUSTERING ALGORITHMS

- **One approach:**
  - Compute multiple features for each object
  - Apply clustering algorithms to form groups of similar objects
  - Resolve alarms on all object in a group at once.
  - Problem: When is "just a little bit different" significant?
- **Another approach**
  - Identify entire boxes in break bulk
  - Find repeating patterns in pallets to identify boxes
  - Perform global comparison to find differences
- **How about a library of known objects?**
  - Features and representative images of known objects added to library of "safe"
  - Compare currently scanned objects to library
  - Clear duplicates; highlight differences





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RESEARCH OPPORTUNITIES

Where are we now?
- Sheer volume and pace of air cargo operations stress any solution.
- CT Technology still the best for characterizing objects in air cargo
- CT scanning of entire pallets and containers now possible
- Alarm resolution is the next big hurdle

- **Where can academia help?**
  - Threat Grouping and clustering algorithms
  - Machine learning
  - High energy scatter and spectral corrections will make CT numbers more accurate, and objects easier to classify.
  - Risk assessment: When does something really need to be scanned?

- **Plenty of room for innovation here!**
  - If I had money I'd send you some for sure.

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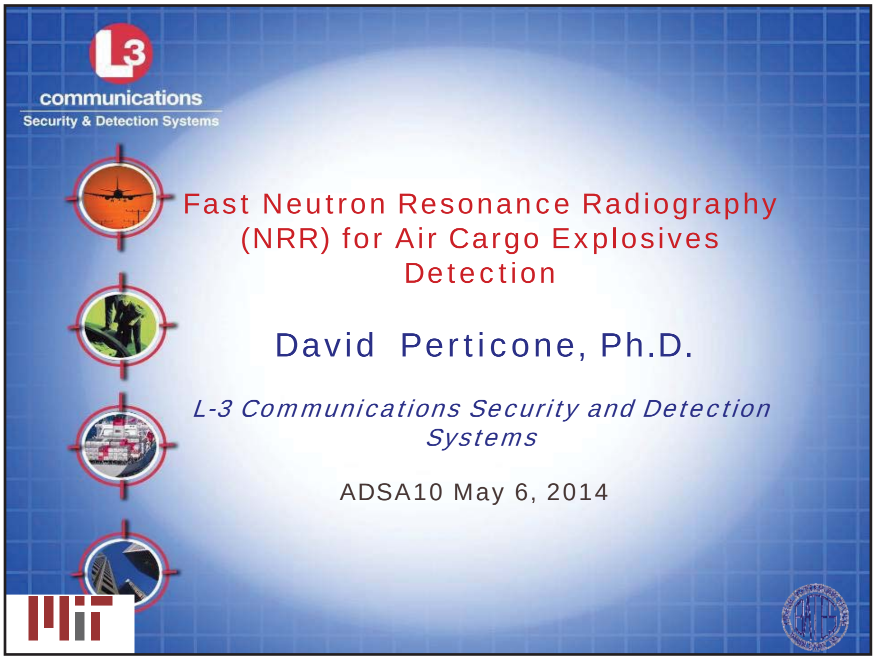
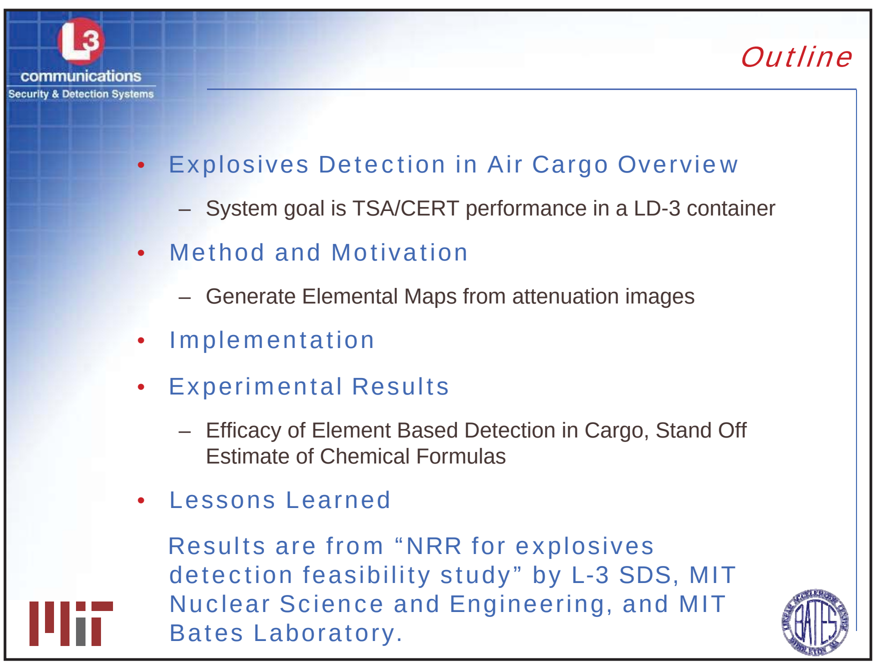
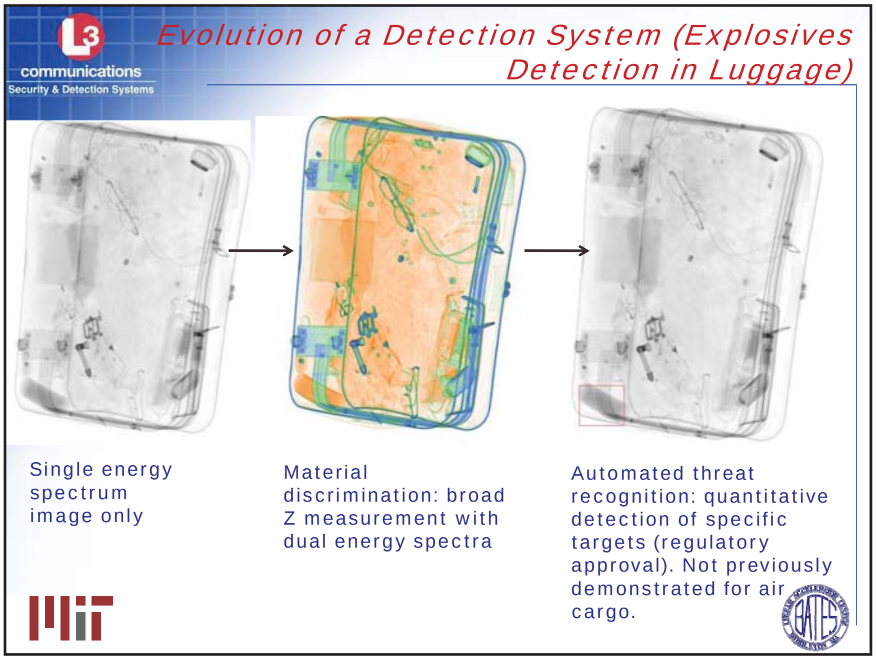
16.9 Dave Perticone: Neutron Resonance Radiography






L3 communications
Security & Detection Systems
Evolution of a Detection System (Explosives Detection in Luggage)
Single energy spectrum image only
Material discrimination: broad Z measurement with dual energy spectra
Automated threat recognition: quantitative detection of specific targets (regulatory approval). Not previously demonstrated for air cargo.


L3 communications
Security & Detection Systems
Application:
Detection of Explosives in Air Cargo
198 cm 78"
107 cm 42"
150 cm 58"
153 cm 60"
153 cm 60"
INTERNAL DIMENSIONS
B-747-400
A-340/330
LD3
HALF SIZE LOWER DECK
CONTAINER
FORKLIFTABLE
(AVE, AVN, AKE, AKN SERIES)
Rate Classification 8
Maximum Net Weight 1490 kg (3285 lb)
Tare Weight 98 kg (215 lb)
Maximum Gross Weight 1588 kg (3500 lb)
Approx. Internal Volume 4.13 m³ (146 ft³)
Floor Loading Limit 977 kg/m² (200 lbs/ft²)
Compared to luggage 4-5 X thickness and 70 X mass.
Do existing luggage EDS methods scale?

Neutron and Photon Beams are Exponentially Attenuated.

Attenuation of a neutron or photon beam I_0 by a material of thickness x:

$$I = I_0 e^{-N\sigma x}$$

N is the attenuation material atom density,

σ is the cross section.

In English: The beam is attenuated exponentially with the product of (atoms/volume)*(area/atom)*thickness

In Dimensions $(\text{atoms/cm}^3)*(\text{cm}^2/\text{atom})*\text{cm}$

The cross section (σ) is completely different for neutrons and photons. The cross section changes with attenuator Z and with probe energy.

The only options are to change probe type and energy.

Higher Energy Increases Penetration

Half-Value Layers in cm for Varying Photon Energies for Various Materials

	10 to 100 KeV	100 to 500 KeV	1 MeV
Concrete	6.56	10.83	12.05
Lead	0.03	0.50	1.31
DU	0.02	0.22	0.65
Tungsten	0.02	0.38	0.87
Steel / Iron	0.36	2.73	3.45
Tin	0.08	1.92	3.27
Aluminum	0.44	9.78	10.94
Water	23.83	26.15	28.71

HVL in centimeters for fast neutrons

Energy in MeV	1	5	10	15
Polyethylene	3.7	6.1	7.7	8.8
Water	4.3	6.9	8.8	10.1
Concrete	6.8	11	14	16
Damp soil	8.8	14.3	18.2	20.8

L3 communications
Security & Detection Systems

Standard X-ray EDS Methods at Higher Energy

- CT can work, but ~2.0m diameter bore size means highly complex system with bigger source (has been tried). Still need spatial and contrast resolution.
- Dual energy X-ray works best with one energy below 100 keV. Possible but much less effective > 5 MeV.
- Coherent scatter photons are already lower in energy and would have trouble getting out of the cargo.

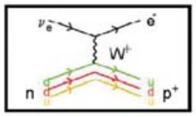
L3 communications
Security & Detection Systems

Neutrons vs. Photons.

Property	Neutrons	Photons
Discrimination	Elemental	Generic (Z_{eff} / density). Can be molecular.
Penetration	Best at High/Medium Z	Best at Low/Medium Z
Interaction	Nucleus	Electrons
Residual Radioactivity	Yes. Also can induce Fission	No
Shielding	Tricky (Borated Poly / Ricorad). Neutrons provide greater biological dose per particle.	Easy – lead.

Neutron Properties

Neutron Decay – mean lifetime 880 (sec), Q 780 keV



Primordial element formation $n + e^+ \longleftrightarrow p + \bar{\nu}_e$

$p + e^- \longleftrightarrow n + \nu_e$

$n \longrightarrow p + e^- + \bar{\nu}_e$

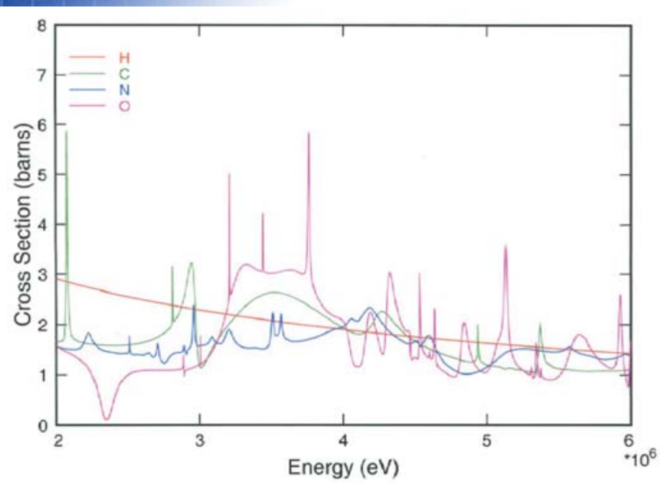
Solar cycle $p + p \longrightarrow {}^2H + e^+ + \nu_e$

$p + p + e^- \longrightarrow {}^2H + \nu_e$ etc.

Neutron star formation $p + e^- \longrightarrow n + \nu_e$

This single decay mode can be inhibited by energy conservation or by unavailable quantum states for the decay products. Thus the neutron is stable in certain atomic nuclei and neutron stars.

Neutron Cross Sections (σ) are Unique for Low Z Elements.

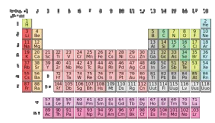


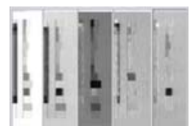
Neutron Resonance Radiography Steps

$(E_1, E_2, E_3, \ldots E_N)$

$$\begin{pmatrix} \sigma_a^1 & \sigma_b^1 & \sigma_c^1 & \sigma_d^1 \\ \sigma_a^2 & \sigma_b^2 & \sigma_c^2 & \sigma_d^2 \\ \sigma_a^3 & \sigma_b^3 & \sigma_c^3 & \sigma_d^3 \\ \sigma_a^4 & \sigma_b^4 & \sigma_c^4 & \sigma_d^4 \\ \sigma_a^5 & \sigma_b^5 & \sigma_c^5 & \sigma_d^5 \\ \sigma_a^6 & \sigma_b^6 & \sigma_c^6 & \sigma_d^6 \end{pmatrix} \cdot \begin{pmatrix} \chi_a \\ \chi_b \\ \chi_c \\ \chi_d \end{pmatrix} = \begin{pmatrix} b^1 \\ b^2 \\ b^3 \\ b^4 \\ b^5 \\ b^6 \end{pmatrix}$$

1) Take a series of neutron images at different energies
2) Do some math
3) Generate images indicating presence of basis elements – elemental maps.





Advantages Of Using Neutron Resonance Radiography

- Multiple Element (H,C,N,O +) mapping for 2-6 MeV neutrons yields many potential discriminants for explosives detection.

Name	C/O	H/N	C/N	O/N	Nitrogen (weight %)
NG	0.33	1.67	1	3	18.5
TNT	1.17	1.67	2.33	2	18.5
RDX	0.5	1	0.5	1	38.0
PETN	0.42	2	1.25	3	17.7
AN	0	2	0	1.5	35.0

- Proof Of Concept Application
  - **Separation Of Diamonds (Carbon) From Kimberlite Rock.**
- Sensitivity scales as $1/R^2$ rather than $1/R^4$
  - **TNA or PFNA detect excited gammas which adds another factor of $1/R^2$ for overall scaling of $1/R^4$**

Key NRR Challenges

- NRR requires a variable energy, effectively monochromatic neutron source. Neutron beam energy spread needs to be minimized. Accelerator production is the only option (10^8-10^10 n/sec)
- NRR requires good neutron detection and photon rejection. The overall presence of photons must be minimized as they contaminate cross section measurements.
- In order to perform NRR you must first measure neutron cross sections for all basis elements, and determine which neutron energies to use.

NRR Key Concepts - Neutron Source

- $D(d,n)^3He$ allows production of variable energy neutrons from a single deuteron beam energy into deuteron target.
- Source is accelerator based and does not use radioactive materials. In this application the accelerator energy does not change.
- The angle with respect to the incoming deuteron beam defines the neutron energy

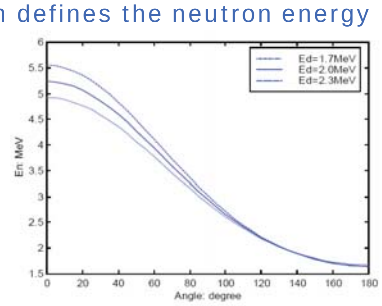
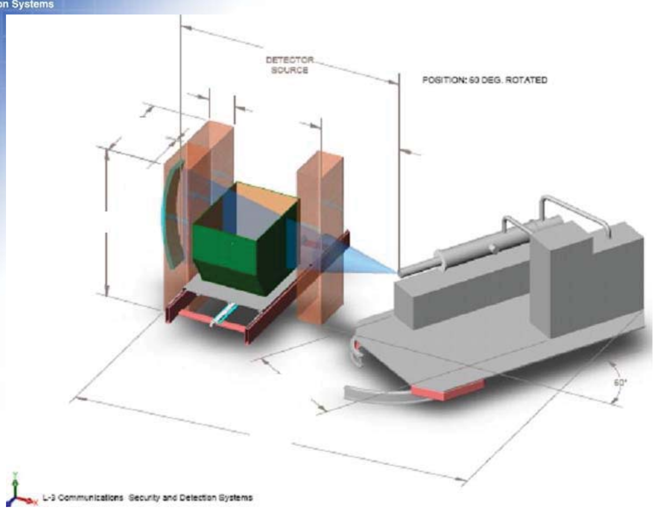


Figure 4.1 DD neutron energy as a function of angle

System Components

- Deuteron accelerator generates incoming single energy deuteron beam. Beam transport system focuses beam onto deuterium gas target to make neutrons. Commercial accelerator. MIT/LLNL gas target.
- Rotation of accelerator and adjustable collimator allows variation of neutron energies. L-3/MIT
- Neutron detection via plastic scintillator and photomultiplier tube. Commercial Detectors.
- Detector electronics / data acquisition system provides experimental control and data recording. L-3 custom electronics and DAS.
- Detection Algorithm – L-3.

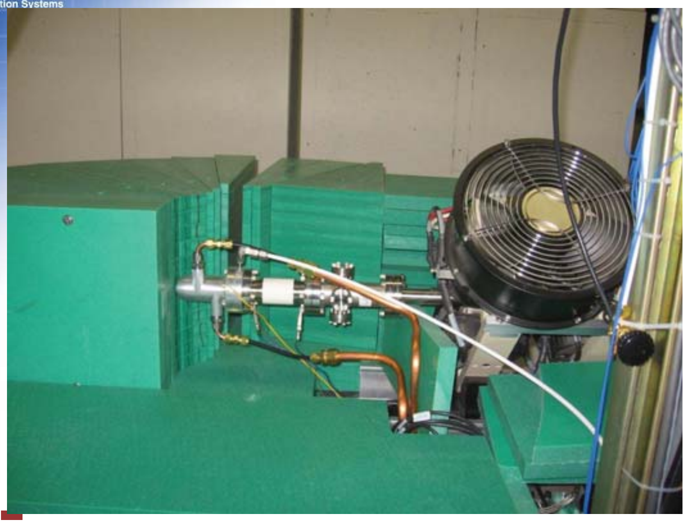
NRR Prototype Concept. Accelerator Rotates To Vary Neutron Energy




Accelerator At 90 Degrees
communications
Security & Detection Systems


Accelerator At 90 Degrees Rear View
communications
Security & Detection Systems

Deuterium Gas Target

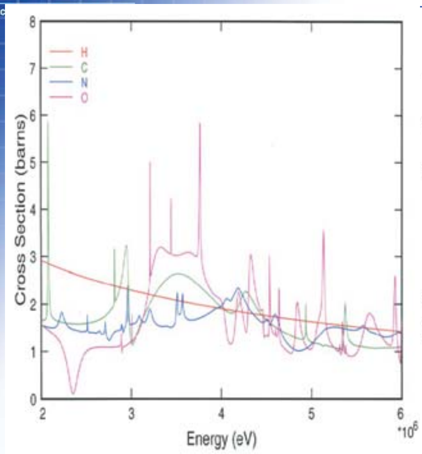


Experimental Results

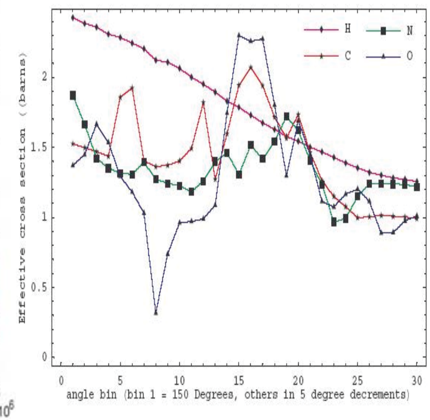
- Cross section measurements – key to project
- Elemental composition
- Elemental maps
- Results generated by taking images at 7 neutron energies and fitting for basis elements Hydrogen, Carbon, Nitrogen, Oxygen, and Silicon

communications

MCNPX Modeling Shows Impact Of Energy Resolution On Cross Section Measurements.



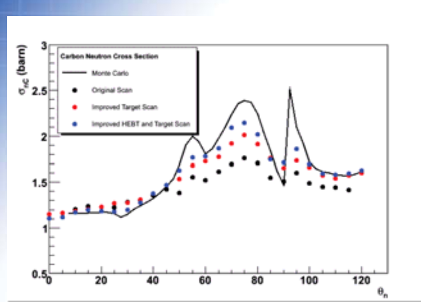
Theory



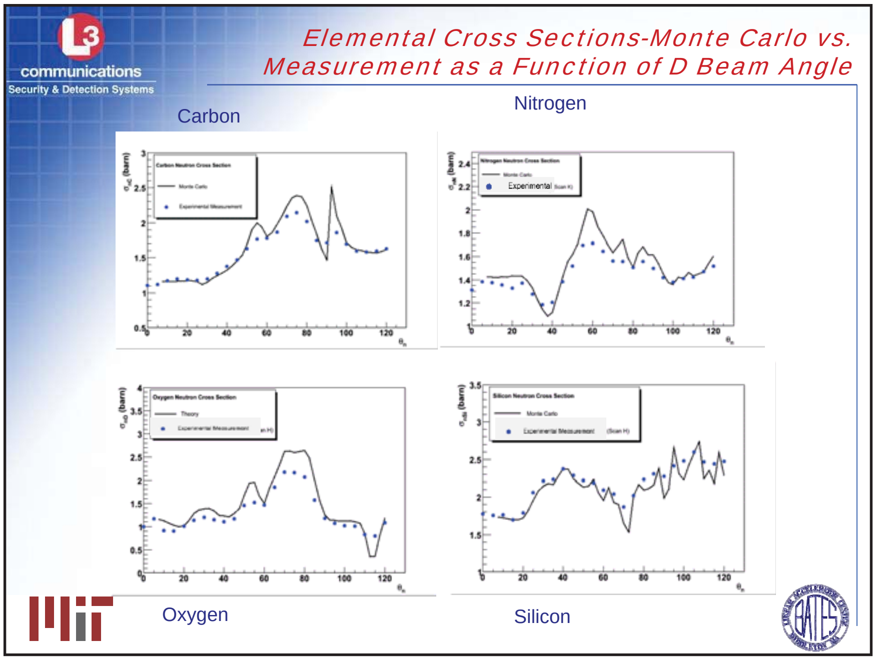
Simulation

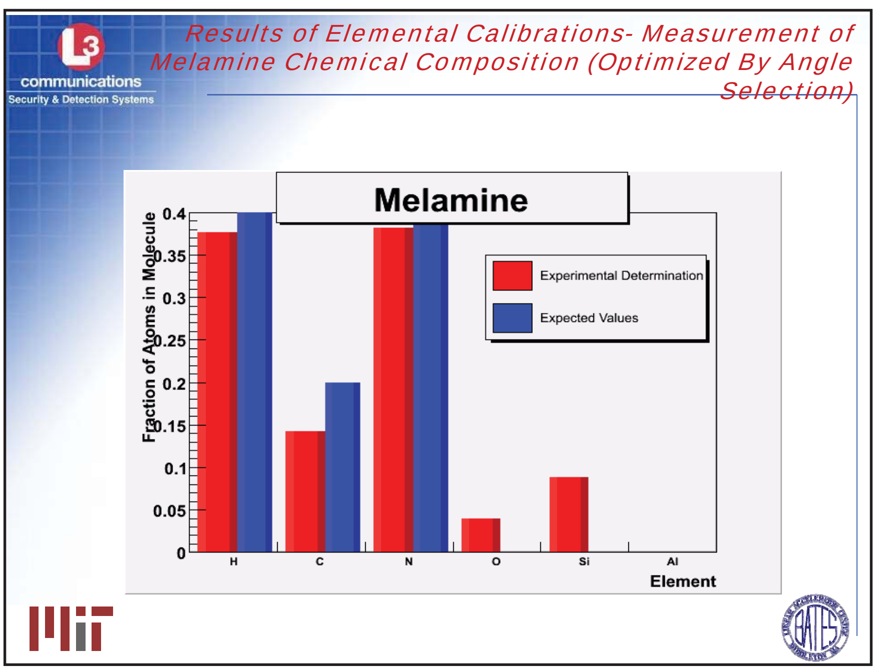
communications
Security & Detection Systems

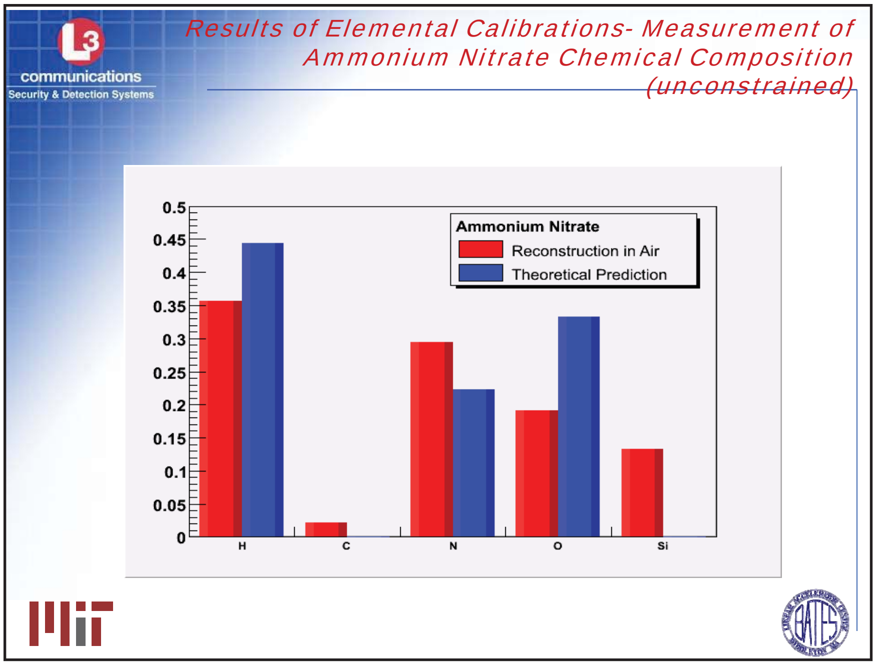
Carbon Cross Section Measurement

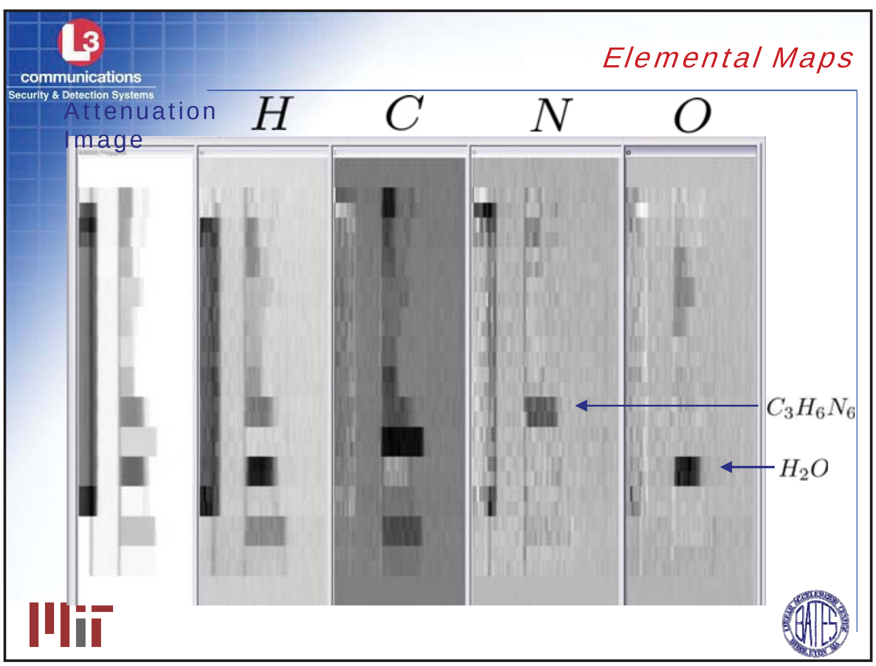


- Initial measuremnt had significantly lower cross section due to high photon background, photon-to-neutron ratio was 1.5
- Target was modified photon-to-neutron ratio was 0.6
- Beam transport modified photon-to-neutron ratio is currently 0.15

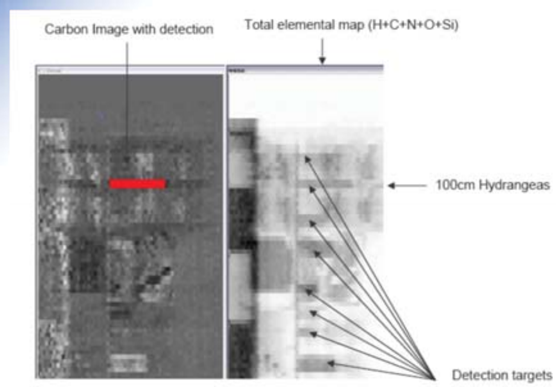

communications
Security & Detection Systems
Elemental Cross Sections-Monte Carlo vs. Measurement as a Function of D Beam Angle
Carbon
Nitrogen
Oxygen
Silicon


communications
Security & Detection Systems
Results of Elemental Calibrations- Measurement of Melamine Chemical Composition (Optimized By Angle Selection)
Melamine
Experimental Determination
Expected Values
Fraction of Atoms in Molecule
Element
H
C
N
O
Si
Al

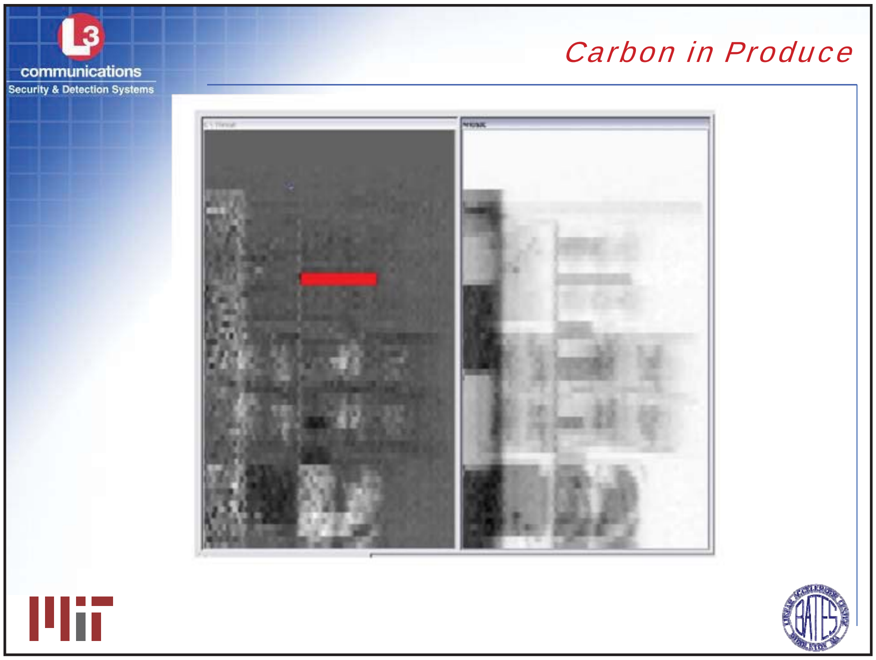

communications
Security & Detection Systems
Results of Elemental Calibrations- Measurement of Ammonium Nitrate Chemical Composition (unconstrained)
Ammonium Nitrate
Reconstruction in Air
Theoretical Prediction
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
H
C
N
O
Si

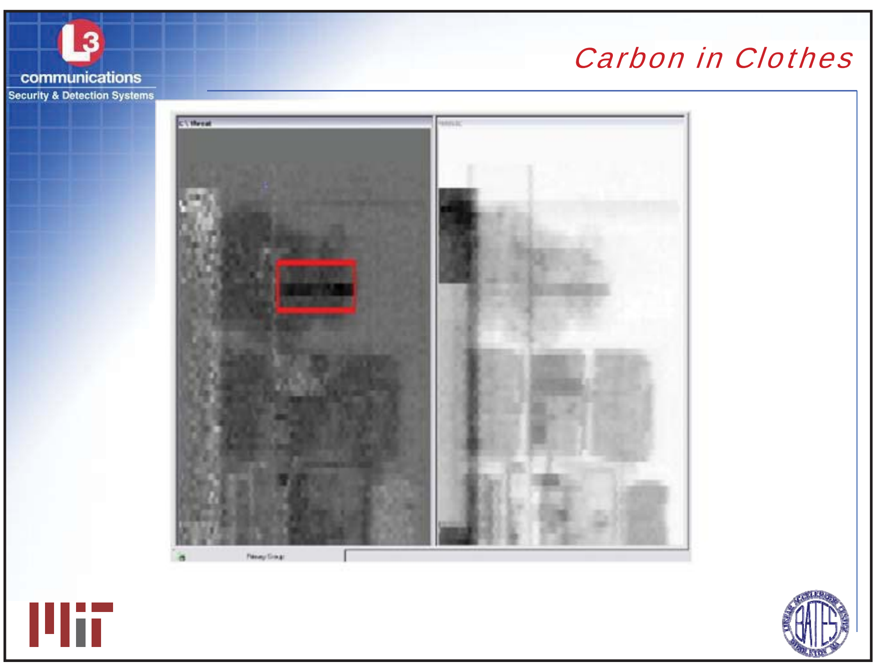

communications
Security & Detection Systems
Elemental Maps
Attenuation Image
H
C
N
O
$C_3H_6N_6$
H_2O

Carbon Detection in Flowers. Target Correctly and Automatically Detected in Typical Air Cargo Background.



Carbon Detection in Electronics. Target Correctly Detected in Typical Air Cargo Background.


L3
communications
Security & Detection Systems
Carbon in Produce


L3
communications
Security & Detection Systems
Carbon in Clothes

NRR Performance

- Detected carbon blocks in 17/22 scans in 7 cargo types with preliminary algorithm.
- Because of the short duration of the first phase of this program (2 years) we did not plan to take data at TSA Tech center in Atlantic City. TSA did not supply us with explosives or validated simulants, which made algorithm development very difficult.
- We were able to collect some explosive data at the end of the program and demonstrate explosives detection in LD-3 containers.
- The program was not extended to 5-7 years as initially planned and no further funding was forthcoming.

General Comments On Using Neutrons

- Neutrons are strongly under represented in explosive detection market as compared to photons. This makes them a tough sell to management.
- Residual radioactivity at the source can increase the mean time to repair in some circumstances.
- Shielding requires a large exclusion zone and willingness to wear badges.
- Modeling requires special purpose LANL MC code (MCNP) which DOE may or may not be willing to sell you at a high price.
  - Both models and simulants require knowledge of atom densities.
- All components (except the gas target) demonstrated to function in an airport environment.

L3 communications
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Summary

- Measurements conducted on full scale NRR prototype conclusively show multi-element discrimination possible with NRR.
- Capability to measure rough chemical formulas demonstrated.
- Automated detection based on elemental maps in air cargo sized objects demonstrated.

L3 communications
Security & Detection Systems

Acknowledgements/References

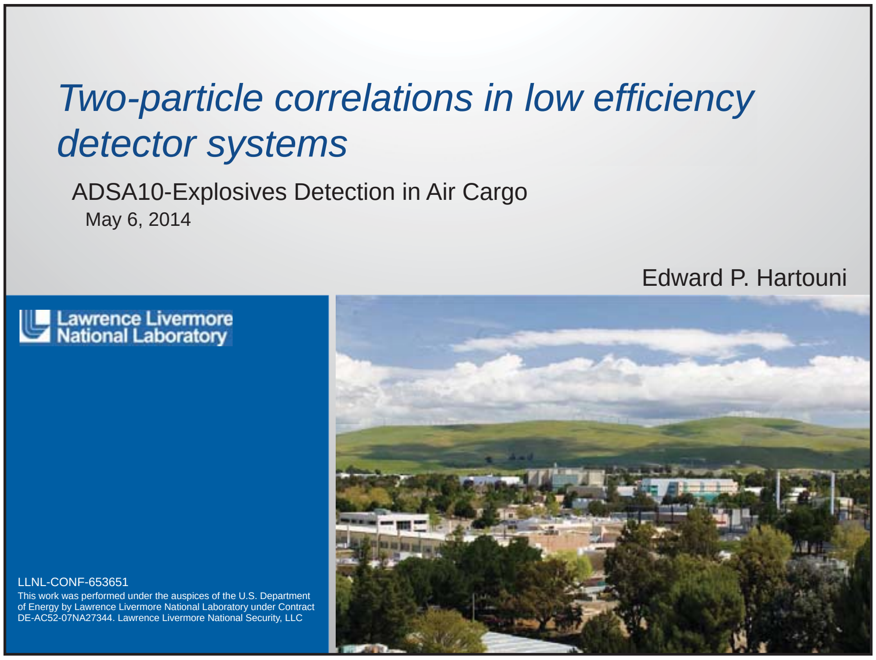
- MIT Bates Accelerator Laboratory staff
- L-3 Communications Security and Detection Systems staff
- LLNL

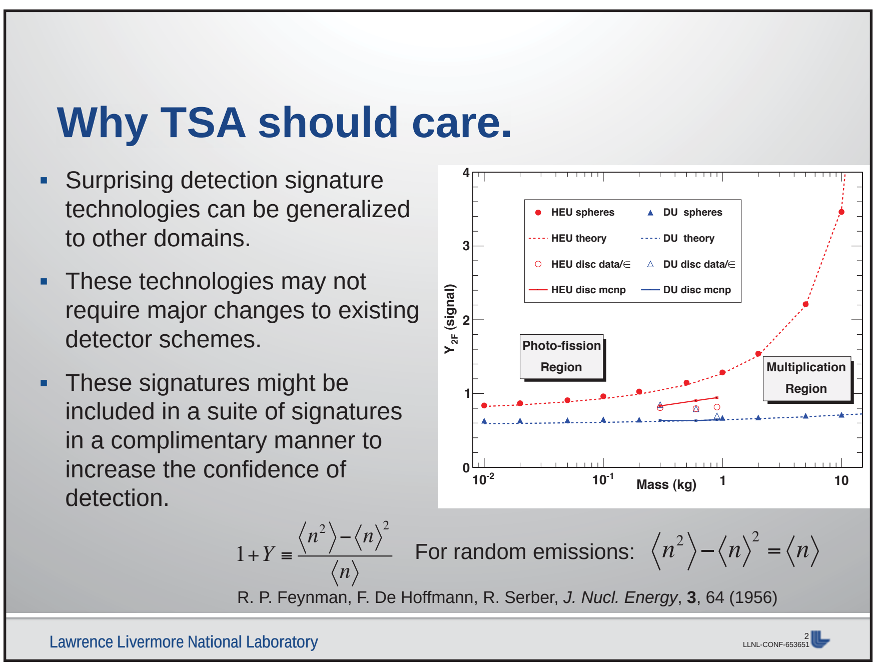
- References.....

  – D. Perticone[1,2] , B. W. Blackburn[1], G. Chen[2], W. A. Franklin[1], E. E. Ihloff[1], G. E. Kohse[1], R. C. Lanza[1], B. McAllister[1], and V. Ziskin[1,2], "Fast Neutron Resonance Radiography for Elemental Imaging: First Results (Unpublished).
  – B. W. Blackburn[1], G. Chen[2], W. A. Franklin[1], E. E. Ihloff[1], G. E. Kohse[1], R. C. Lanza[1], B. McAllister[1], D. Perticone[1,2], and V. Ziskin[1,2], "Fast Neutron Resonance Radiography (NRR) for Homeland Security", 2007 IEEE Nuclear Science Symposium – Honolulu.

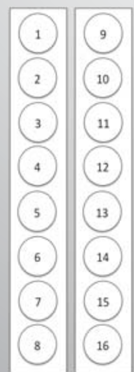
This work was supported by the US Government, Technical Support Working Group (TSWG) and by the Transportation Security Administration (TSA) through Contract HSTS04-04-C-RED953

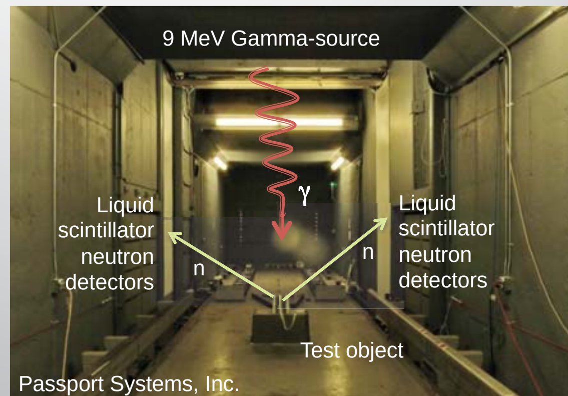
16.10 Ed Hartouni: Two Particle Correlations in Low Efficiency Detector Systems





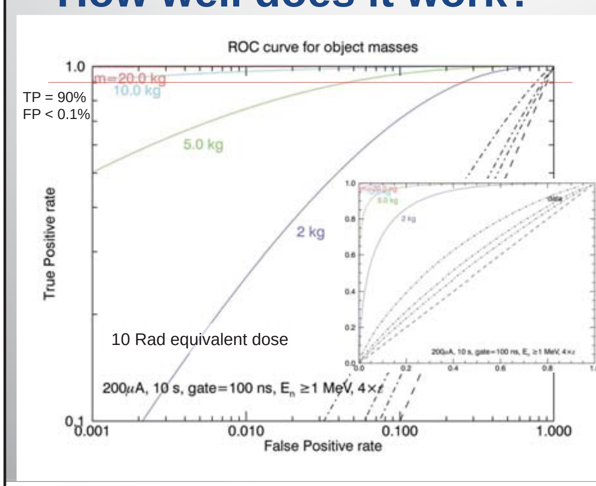
What we did: detection of fissile material using active interrogation.





Single particle efficiency ε ≈ 0.1%, two particle efficiency $\varepsilon^2 \approx 0.0001\%$
Only modification was a common time stamp for all detector channels.

How well does it work?

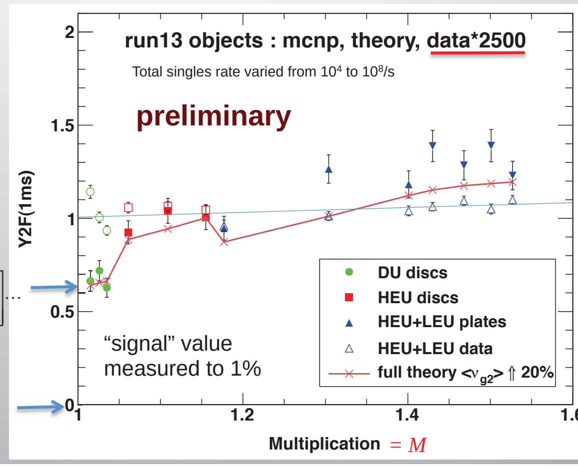


"True positives" are HEU objects.

The "false positives" are equivalent mass DU objects.

These curves are created from a combination of data, monte carlo calculation and scaling.

First fission puzzle



Unexpected:
For very small masses we have non-zero signal.

$$Y_{2F} \approx \varepsilon\left[\frac{\nu_{\gamma 2}}{\nu_\gamma} + \cancel{\left(\frac{\nu_{\gamma 2}}{\nu_\gamma}\frac{\nu-1}{\nu} + \frac{\nu_2}{\nu}\right)(M-1)}\right]\cdots$$

$M=1$

This is due to the first fission.

expected

S. Walston LLNL-TR-414245

Single fission signal

- Details of photofission are not known well enough to explain these data;
- The average neutron multiplicity is known to a few percent;
- The width of the neutron multiplicity might be the same for all fission;
- A few percent difference in the ratio $\nu_{\gamma 2}/\nu_\gamma$ between ^{235}U and ^{238}U would be distinguishable.
- 2-neutron correlation from the first fission only.

For neutron induced fission

J. Terrel, *Phys. Rev.* **108**, 783 (1957)

Conclusions and possibilities

- We have demonstrated fissile material detection in a realistic setting using 2-neutron time correlations from fissions induced by 9 MeV X-rays.
- The results indicate the possibility of very low mass detection of fissile material using the “first fission” difference of the isotopes of interest.
- Correlated 2-particle signals can be detected in active interrogation at the one part per million level in the presence of large single particle rates.

Acknowledgements

This work was conducted for DHS/DNDO

Research collaborators:

Areg Danagoulian (Passport)

Andy Glenn (LLNL)

Micah Johnson (LLNL)

Steve Korbly (Passport)

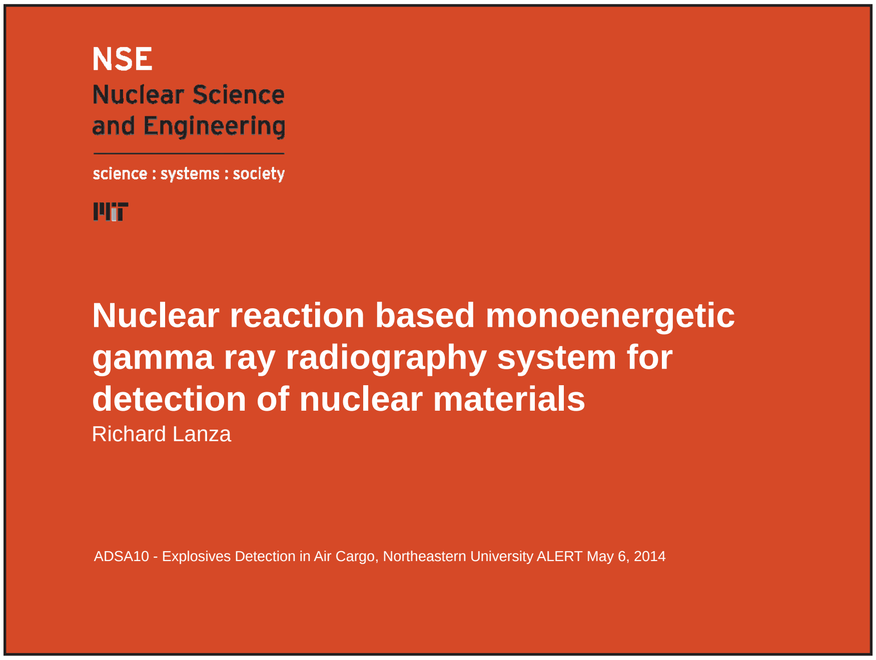
Bob Ledoux (Passport)

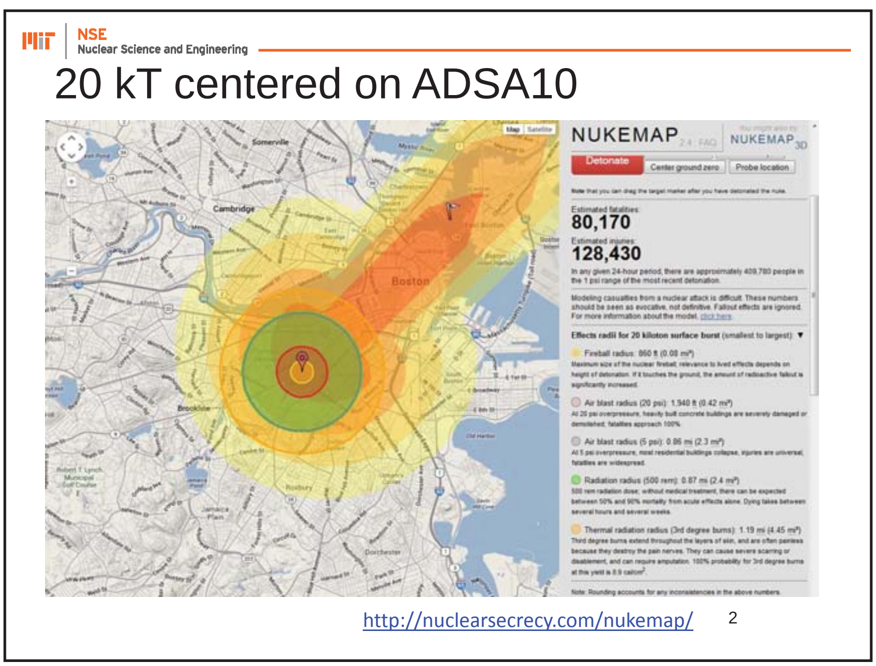
Steven Sheets (LLNL)

Ron Soltz(LLNL)


Lawrence Livermore
National Laboratory

16.11 Richard Lanza: Nuclear Reaction Based Monoenergetic Gamma Ray Radiography System for Detection of Nuclear Materials





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Overview

- What are we trying to do?
- How is this problem handled today and what are the limitations?
- What is the new approach and why will we succeed where others have failed
- Assuming success, who cares? Why does it matter and to whom?
- How long will it take? How much will it cost?

3

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US Nuclear Posture Review

Five key objectives of US nuclear weapons policies and posture:

- Preventing nuclear proliferation and nuclear terrorism;
- Reducing the role of U.S. nuclear weapons in U.S. national security strategy;
- Maintaining strategic deterrence and stability at reduced nuclear force levels;
- Strengthening regional deterrence and reassuring U.S. allies and partners; and
- Sustaining a safe, secure, and effective nuclear arsenal.

US Nuclear Posture Review April 2010

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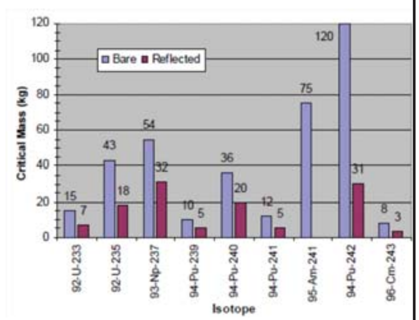
Not much material is required

- Nuclear weapons need only about 1-2 critical masses of weaponizable material
- Critical assembly must be supercritical to explode
- Chart shows the critical masses for some weapon isotopes
- Bare refers to the critical mass of a sphere of material without anything surrounding it
- Reflected refers to the critical mass when surrounded by a neutron reflector such as Iron or Tungsten
- Using a neutron reflector always reduces the critical mass
- Generally a few tens of kilograms or less of material will be involved.



5

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Size of Significant Quantities

According to the International Atomic Energy Agency (IAEA), 25 kg of HEU (about the size of a large grapefruit) or 8 kg of plutonium (about the size of a soda can) represent a “significant quantity” required to make a crude nuclear weapon.

Density for uranium and plutonium ~ 19 g/cm3.
Large Grapefruit R = 6.8 cm V =1320 cm^3 ~ 25 kg
12" Softball (3.8"ø): R = 4.8 cm, V = 463 cm^3 ~ M = 8.8 kg
Soda Can: H = 12.2 cm, R = 3.2 cm, V = 387 cm^3 ~ M = 7.4 kg

From D. Chichester, INL

6

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Basic Approach

- The fundamental approach is to generate both neutrons and monoenergetic gamma rays by means of low energy nuclear reactions. By selecting nuclear reactions with large positive Q values, small accelerators producing 3 to 10 MeV protons or deuterons can simultaneously produce fast neutrons and high energy (> 10 MeV) monoenergetic gammas.
- This multi-particle method images the SNM through shielding and also identifies it by inducing fission in the suspect material.
- Use transmission imaging to locate high-Z materials
- Use multiple energies to distinguish materials such as Pb or W from actinides
- Use photofission and/or neutron induced fission as final check
- Doses are well under 1 mrem

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Why use Monoenergetic Imaging

- an order of magnitude or more reduction in dose
- enhanced sensitivity in detection and verification
- lower requirements for shielding
- the ability to reduce the size of the source part of the system by an order of magnitude or more while still meeting requirements for detection and identification of SNM
- flexibility in detection through radiography and active probing with the same device

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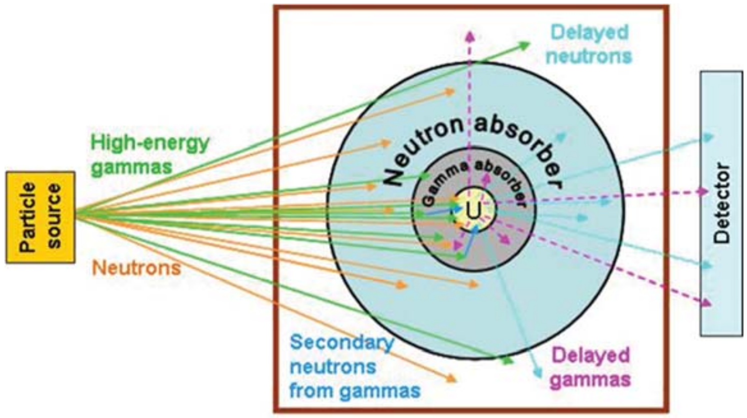
Multi-particle Probing



9

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Dose Matters!

- ANSI 43.14 standard "Radiation Safety Guidelines for Active Interrogation Systems for Security Screening of Cargo"
  - Allows as much as 5 mSv (500 mrem) to potential stowaways
  - But, principle of ALARA remains in place for all such systems
    - requires making every reasonable effort to maintain exposures to radiation as far below the regulatory dose as practical, taking into consideration the state of technology, the economics of improvements in relation to benefits to health and safety, and other societal and socioeconomic considerations
- Monoenergetic approach reduces dose to less than a mrem
- Reduced dose meets ALARA and allows for portable systems and reduced amounts of shielding

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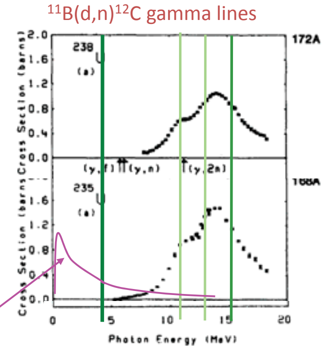
$^{11}B(d,n\gamma)^{12}C$ Produces High-Energy Neutrons And Gamma Radiation For Efficient Uranium Fission

The fission cross-section using gammas for two uranium isotopes is shown at the right.

$^{12}C^*$ gamma lines found for >2 MeV deuterons have intense high-energy-gamma lines at 4.4 and 15.1 MeV and less intense lines at 10.7 and 12.7 MeV. The neutrons have a peak around 12 MeV and a broad distribution at lower energies.

$^{11}B(d,n)^{12}C$ gamma lines



Relative Bremsstrahlung production for a 15 MeV electron beam. Lower energy gammas can be preferentially reduced by filtering but with a reduction in the overall intensity

11

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Prototype 12 MeV SC Cyclotron

12

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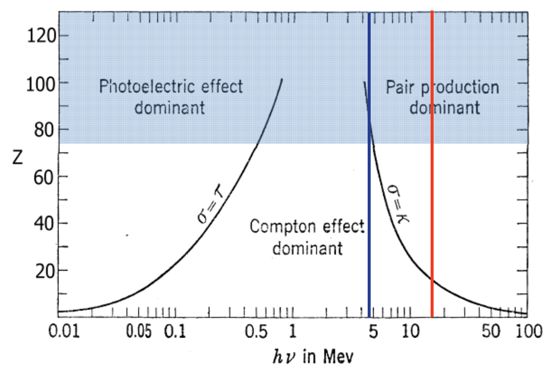
Transmission Issues



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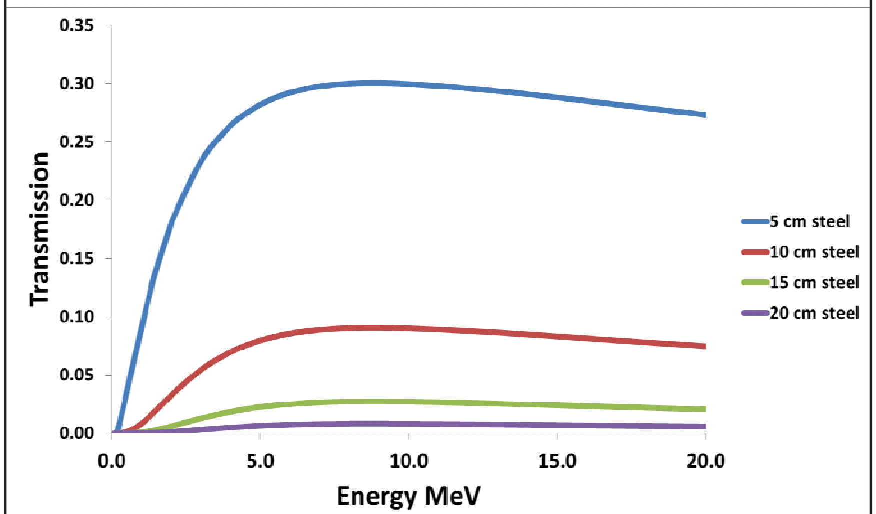
Monoenergetic Gammas



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Higher Energy increases penetration

Half-Value Layers in cm for Varying Photon Energies for Various Materials

	10 to 100 KeV	100 to 500 KeV	1 MeV
Concrete	6.56	10.83	12.05
Lead	0.03	0.50	1.31
DU	0.02	0.22	0.65
Tungsten	0.02	0.38	0.87
Steel / Iron	0.36	2.73	3.45
Tin	0.08	1.92	3.27
Aluminum	0.44	9.78	10.94
Water	23.83	26.15	28.71

HVL in centimeters for fast neutrons

Energy in MeV	1	5	10	15
Polyethylene	3.7	6.1	7.7	8.8
Water	4.3	6.9	8.8	10.1
Concrete	6.8	11	14	16
Damp soil	8.8	14.3	18.2	20.8

From D. Perticone, L-3

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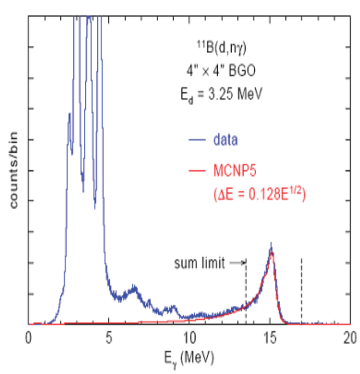
Gamma Production Rates



Gamma Energy (MeV)	Yield (gammas/s/sr)
4.4	4×10^9
10.7	2×10^7
12.7	4×10^7
15.1	6.6×10^8

LA-UR-07-2724

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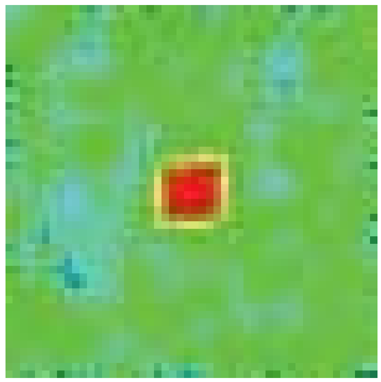
15.1 MeV Transmission Image



100 cc U cube in 40 cm Fe block imaged with 15.1 MeV gammas (MCNPX simulation)

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Identifying SNM

- Transmission measurement alone only identifies high-Z material
  - Multi-energy approach can separate actinides from materials such as Pb or W
- Use two approaches to distinguish ^{235}U by detection of fission products
  - Utilize photofission
  - Probe with low energy neutrons (< 1MeV); only ^{235}U will undergo fission

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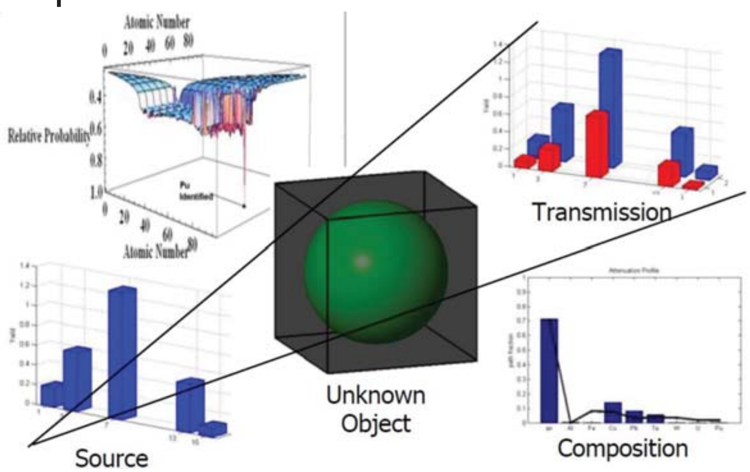
Multiple lines for material identification



From R. Sheffield, LANL

19

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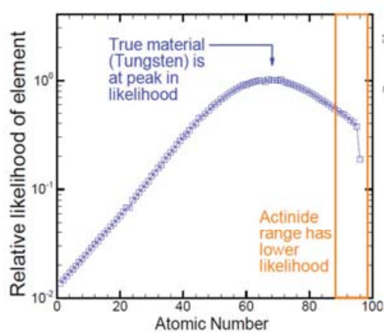
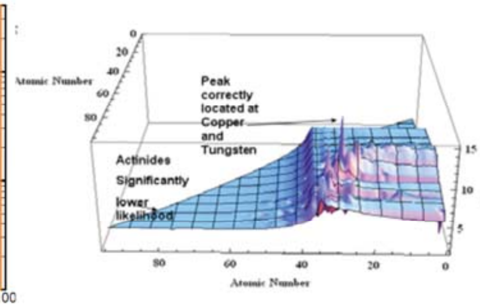
Multiple lines for material identification



Two lines separate W from actinides (experimental data)



Four lines separate Cu and W from actinides

From R. Sheffield, LANL

20

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Neutron probes

- Long term approach will use a small superconducting cyclotrons to generate both gammas and neutrons
- Some examples:
  - 9 MeV SCC
    - Generates 4.5 MeV d, or 9.0 MeV p
    - Use the 9.0 MeV p in a (p,n) reaction
    - e.g. ^{50}Cr(p,n)^{50}Mn   Q = -8.42 MeV which results in E_n < 1 MeV, *below fission threshold for ^{238}U*
  - ~20 MeV SCC.
    - ^{12}C(p,p'γ)^{12}C generates only gammas below threshold ~19.5 MeV
    - Gammas and neutrons above threshold

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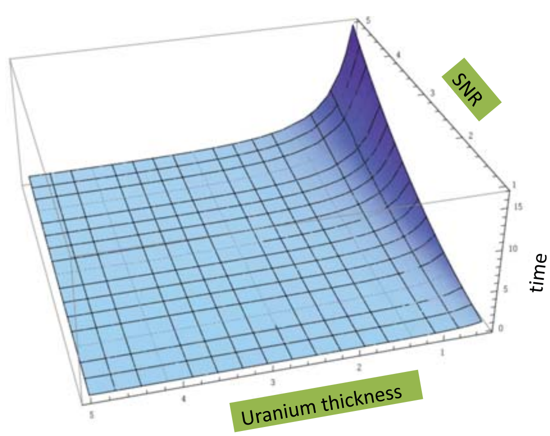
Detection Times

- Time to detect 1 cc of U in a 20 cm cube of iron with SNR from 1 to 5
- Accelerator running 90 microA d+ at 3MeV



22

Detection Times

- Time to detect 1 cc U in 20 cm Fe cube
  - 0.2 s for SNR of 1
- Increase number of lines of detectors
  - 0.01 s for 20 lines
- Increase beam current
  - 0.001 s for 900 microA
- We can scan at 1 m/s
  - Scan cargo container in 6 s

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Some Features

- Use physics defined gamma ray energies not dependent on the energy of the electron beam
  - Do not particularly need precise energy accelerator
  - accelerators are available in COTS and should be available in superconducting form soon
- Combine high resolution CdWO4 detector array (4mm pitch with our 4/15 MeV gamma detectors
  - enables us to produce an overlay of images which combine high spatial resolution and material identification
- Neutrons available for final confirmation of SNM
  - Intensities should enable rapid screening with subsequent ID
- Going to higher power or more detectors is a COTS decision for even faster scanning

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Some Conclusions

- Monoenergetic gamma transmission imaging appears practical
- Dose is *orders of magnitude lower* than alternative approaches
- Compact accelerator designs are possible
- Multi-particle approach gives both position and isotopic identification of SNM

25

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Collaborators

- Anna Erickson GT
- Paul Rose* GT
- Richard Lanza MIT
- John Fisher MIT
- Buck O'Day* MIT
- Igor Jovanovic PSU
- Zoubeida Ounaies PSU
- Cory Trivelpiece PSU
- Michael Mayer PSU
- Jason Nattress PSU
- Amira Meddeb* PSU
- Greg McKinney LANL
- Rich Sheffield LANL
- Mike Hynes MIT/RTN
- Ernie Ihloff MIT
- Joe Minervini MIT

*student

Supported by NSF/DNDO Collaborative Research ARI-LA Award ECCS-1348328

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16.12 Nelson Carey: Hardened Unit Load Device (HULD) - Research and Development History

Hardened Unit Load Device (HULD) Research and Development History

May 6, 2014

Presented To:
Advanced Development for Security Applications,
DHS Center of Excellence for Awareness and Localization
of Explosives-Related Threats (ALERT)
Northeastern University, Boston MA

Prepared By:
Nelson Carey
DHS Science and Technology Directorate
Explosives Division,
Commercial Aircraft Vulnerability & Mitigation Program

Reference herein to any specific commercial products, processes, equipment, or services does not constitute or imply its endorsement, recommendation, or favoring by the United States Government or the Department of Homeland Security (DHS), or any of its employees or contractors.

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Science and Technology

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Presentation Outline

- Commercial Aircraft Vulnerability Program Overview
  - Program Requirements
  - Program Objectives
- Commercial Aircraft Blast Mitigation/Vulnerability Reduction
  - Commercial Aircraft Internal Blast Mitigation Overview
- Hardened Unit Load Device (HULD) Development
  - Initial HULD R&D (1990-1995)
  - Initial HULD Operational Efforts (1995-1999)
  - HULD R&D Efforts (2000-Present)
- Concluding Remarks

2

Homeland Security
Science and Technology

Commercial Aircraft Vulnerability/Mitigation Program Requirements

- Milestones in aviation security that have resulted in the formation and driven the direction of DHS commercial aircraft vulnerability initiatives include:
  - (1988) Destruction of Pan Am Flight 103 over Lockerbie Scotland
  - (1990) Presidential Commission Report on Aviation Security and Terrorism
  - (1990) Public Law 101-604, Aviation Security Improvement Act (Called for EDS standards and inception of Commercial Aircraft Vulnerability Program)
  - (1996) Aviation Security Advisory Committee Domestic Security Baseline Report
  - (1997) U.S. Vice Presidential Commission Aviation Safety & Security Report
  - (2001) Public Law 107-71, Aviation and Transportation Security Act
    - PL 107-71 (Sec. 137(a)7) states: “[The TSA shall accelerate] research, development, testing, and evaluation of aircraft hardening materials, and techniques to reduce the vulnerability of aircraft to terrorist attack.”

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Program Objectives

- Validate Detection Standards in Terms of Commercial Aircraft Vulnerability. What is the Minimum Size Explosive that Must Be Detected? (Aircraft Vulnerability)
- Develop & Evaluate Techniques that Minimize the Effects of Internal Explosive Events. (Explosive Mitigation)
- Assess Other Threats to the Aircraft

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Science and Technology

L1011 Pressurized Test, Cargo Hold (1998)

5

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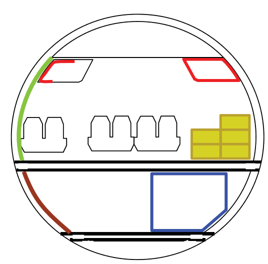
Science and Technology

Commercial Aircraft Blast Mitigation Overview

- Aircraft Internal Blast Mitigation:
  - **Hardened passenger cabin liners**
  - **Hardened overhead bin/bin liners**
  - **Hardened cargo hold liners (Narrow-Body AC)**
  - **Hardened luggage containers (Wide-Body AC)**
  - **Least Risk Bomb Location (LRBL)**
- Coordinate with FAA certification to ensure that mitigation technology conforms to existing FAA airworthiness requirements.
- Perform cost-benefit analysis of selected explosive mitigation technologies.
- Since 1990, have conducted over 150 full-scale aircraft blast mitigation tests on a variety of concepts/materials/technologies.



6

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Science and Technology

HULD Development

- HULD project initiated (1990) in response to PL 101-64 as a result of the destruction of Pam Am 103 (1988).
- HULD Objective – Protect wide-body commercial aircraft from catastrophic structural or critical system failure due to a terrorist-initiated, in-flight explosion within checked passenger luggage and/or air cargo contents.
- HULD design (internal dimensions, contour) is based upon the LD3 model of commercial aircraft lower deck baggage/cargo container.
- HULDs must meet the following requirements:
  - DHS Security – Resist/mitigate internal blast effects (shock/impulse, fragmentation, overpressure, post-blast fire).
  - FAA Airworthiness – FAA certification process ensures quality control of production units and confirms HULD is safe to install within aircraft for normal flight operations.
  - Airline – Design must meet airline user demands (operability, maintenance/repair, compatibility, etc.)

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Initial HULD Design Development (1990-1994)

- Jaycor developed and tested 5 HULD prototypes (1990-1994)
- Jaycor prototype HULD construction – continuous joint HULD body design, Spectra fiber composite construction
- Use existing LD3 design geometry as basis
- Door design – side-sliding, externally stowed.
- Prototype tare weight ranges – 680-300 pounds

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Jaycor HULD Prototype #5 Test (1994)

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SAE Participation in HULD Development (1994-1998)

Background:

- Society of Automotive Engineers (SAE) created existing LD3 industry requirements upon which the initial HULD requirements are based
- SAE HULD working group was formed consisting of FAA (Security and Certification), Air Transport Association (ATA), Airlines, Aircraft Manufacturers, and existing HULD designers

Recommendations:

- HULD requirement should address: airworthiness, ground handling (operational), and explosive resistance
- Requirement would be performance-based and use ISO 6517 (ULD design, performance and test requirements) as a baseline
- Initially pertain to use of HULD with checked passenger baggage contents only
- FAA (Security) would provide panel with research results and test data on which requirement would be based
- FAA (Certification) would confirm airworthiness compliance of HULD designs that meet explosive test criteria

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HULD Operational Evaluation Efforts (1995-1999)

- 1995 – FAA issues Phase I solicitation for limited HULD deployment/evaluation. Of 12 respondents, 4 vendors are selected for HULD prototype fabrication/testing. None of the tested designs are successful in meeting blast test requirements.
- 1997 – FAA issues Phase II solicitation. Of 8 respondents, 2 vendors are selected for HULD prototype fabrication/testing. One vendor (Galaxy Scientific) meets explosive resistance and airworthiness requirements.
- 1998-1999 – Galaxy HULD design undergoes limited operational testing.
- 1999 – Telair International HULD Generation I (GEN-I) HULD design meets blast and airworthiness requirements.

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Galaxy Scientific HULD Design (1997)

- Composition: Aluminum Frame with Glare (Glass Reinforced Fiber Metal Laminate) body panels
- Tare weight: 400 lbs.
- FAA Airworthiness Certified (TSO-C90c)
- User Acceptance Issues:
  - Impact of continued operational use on blast resistance
  - Complicated door engagement design
  - Solid/single door panel design
  - Weight/cost

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Telair International HULD Design (GEN-I) (1999)

- Composition: Aluminum Frame with Kevlar body panels
- Tare weight: 322 lbs.
- FAA Airworthiness Certified (TSO-C90c)
- User Acceptance Issues:
  - Complicated door engagement design
  - Weight/cost
- Note: Telair GEN-I design was used in subsequent HULD Pilot Program

Telair GEN-I HULD (Pre-test)

Telair GEN-I HULD (Post-test)

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HULD R&D Efforts (2000-2004)

- 2000-2002 – Limited operational testing and subsequent explosive testing on Telair GEN-I HULD prototype in cooperation with foreign government partner
- 2003 – HULD concept successfully subjected to blast test within pressurized aircraft with active aircraft cargo hold fire-suppression system
- 2003-2004 – Conducted investigation of HULD blast mitigation capability for explosive threat within air cargo contents
- 2004 – Initial cost-benefit analysis of HULD technology completed

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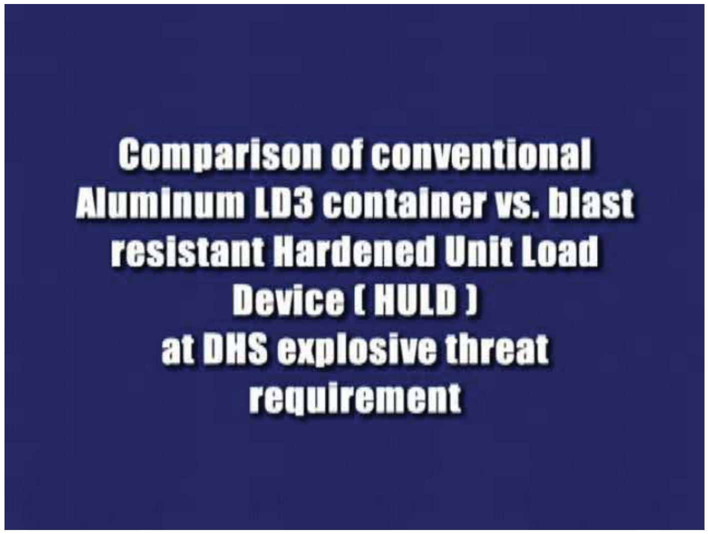
Comparison Test: Conventional LD3 vs. GEN-II HULD Checked Passenger Baggage Contents (2006)



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HULD R&D Efforts (2005-Present)

- 2005-2009 – TSA conducted HULD operational Pilot Program (operational deployment with participating US air carriers followed by explosive testing of deployed units at pre-determined operational intervals)
- 2006 – Telair GEN-II HULD prototype design (265 pound tare weight) successfully blast tested by DHS and subsequently met FAA airworthiness requirements
- 2010-2014 – Reduced cost/weight HULD (HULD-R) development effort
- 2013-2014 – Updated HULD cost-benefit assessment

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Reduced Weight HULD (HULD-R)

Background:

- In response to air carrier concerns pertaining to existing (GEN-I/II) HULD acquisition cost and weight penalties, develop and test a reduced cost/weight HULD prototype (HULD-R).

HULD-R Design Requirement Goals:

- FAA TSO approved (TSO-C90c).
- Capable of mitigating detonations from explosive devices in checked baggage and air cargo contents
- Target HULD-R acquisition cost <$10K
- Target HULD-R tare weight <220 pounds.

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Reduced Weight HULD (HULD-R)

HULD-R Project Status Summary:

- DHS S&T contract awarded to International Composites Technologies (Compton, CA) via competitive solicitation
- Successfully developed and blast tested an FAA airworthiness certified HULD-R design with tare weight (199 lbs.) in range of existing unhardened industry Unit Load Devices (180-220 lbs.) (August 2012)
- Acquire and test additional HULD-Rs to determine mitigation capability for threats in checked baggage and cargo mitigation threshold (to be completed Q4, FY14)

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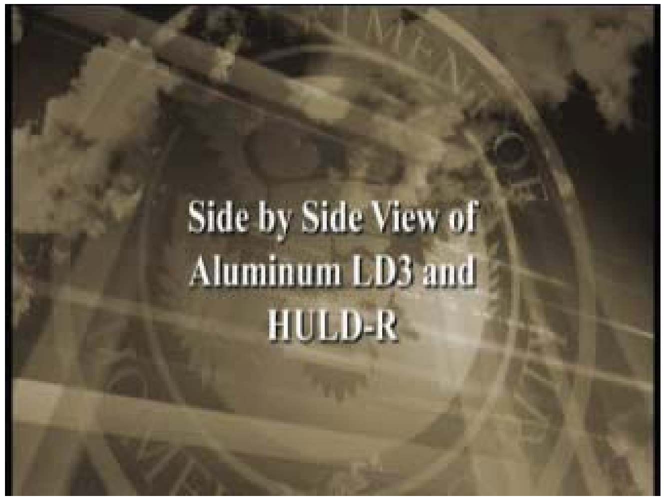
Comparison Test: Conventional LD3 vs. HULD-R, Air Cargo Contents (2011)



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Concluding Remarks

- HULD design material selection is a very small component of developing a successful HULD concept. Structural configuration and operational design aspects of the HULD (operational utility, damage/repair considerations, etc.) are paramount in successful HULD design development.
- HULD cost-benefit effort provides government with data to support policy formation, assess alternative methods of security (such as detection versus protection), and assess alternative security products in the context of a unified and layered security system.
- The HULD is but one part of a layered systems solution to aircraft/passenger protection. HULD effectiveness relative to protection of the aircraft is tied to pre-load detection technologies (HULD is not a singular solution).

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16.13 Rajiv Gupta: DHS Applications of PaX Source

DHS Applications of PaX Source

Rajiv Gupta, MD, PhD

Neuro and Cardiac Radiology
Massachusetts General Hospital
Harvard Medical School
Boston, MA

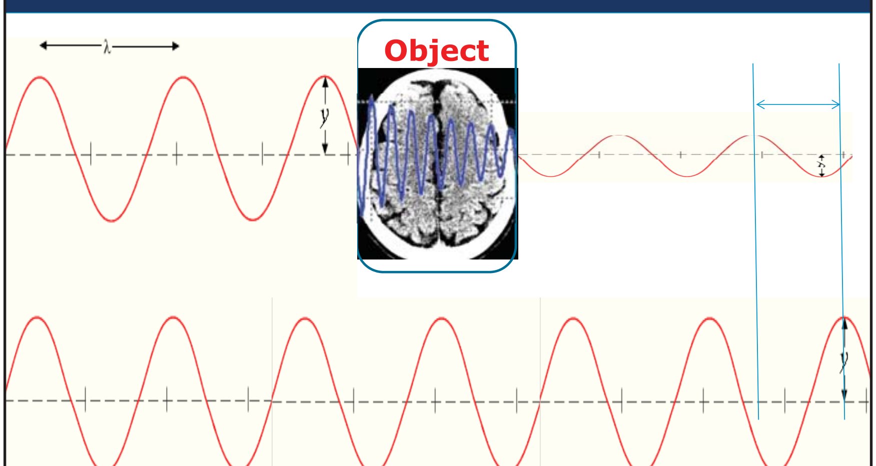
Why should DHS Care?

- X-ray phase provides an independent signature:
  - Attenuation: Eff. Z
  - Phase: Eff. ED
- Threats and stream-of-commerce may have different signatures
- MGH/MIT PaX source enables PCI

Overview

- What is Phase Contrast Imaging?
- Is there experimental demonstration?
- How can we harvest phase?
- How can we achieve coherence?
- How does PaX do PCI?

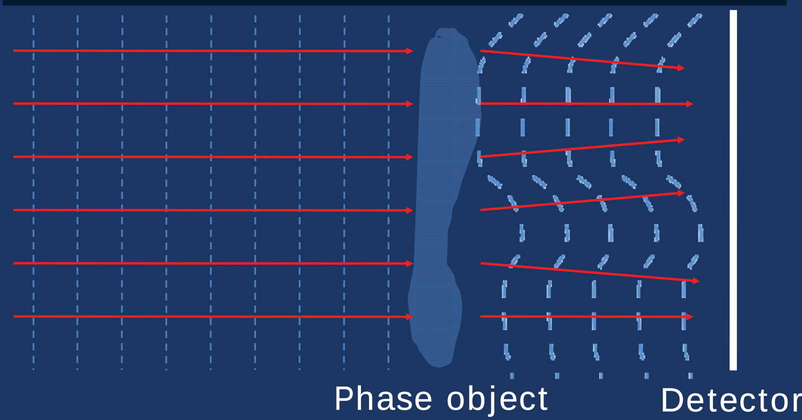
What is Phase Contrast Imaging?



X-rays Wave: Amplitude, frequency, and phase

Phase Effect on Wave front

Complex refractive index: η = 1 – δ + iβ



Contrast Mechanisms

Complex refractive index:

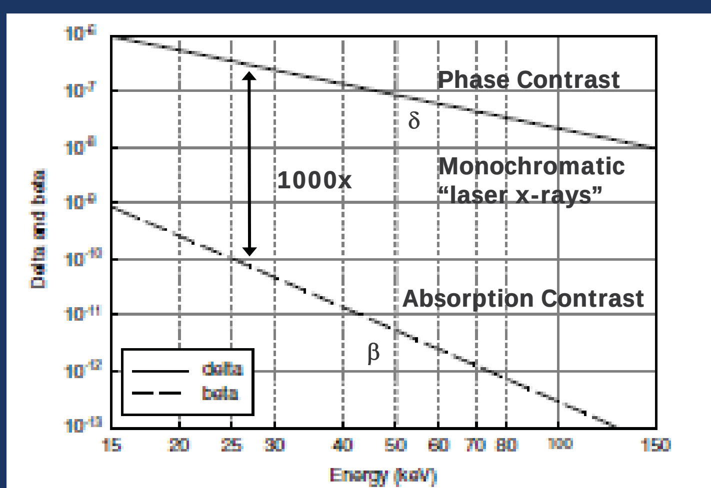
η = iβ + (1 – δ)

- Attenuation:
  - Depends on β
  - Path length
  - Photoelectric effect
  - Compton scattering
  - Depends on Z
- Phase change:
  - Depends on δ
  - Path length
  - Depends on Electron Density

Magnitude of Attenuation and Phase Contrasts

Material	μ (cm^{-1}) at 60keV	Φ (cm^{-1}) at 60keV	Ratio
H2O	0.2061	195.5	949
dH2O	0.2267	215.1	949
Ethenol	0.1582	156.6	990
Glycerin	0.2477	140.7	568
Fat	0.1793	180.7	1008
Liver	0.2174	205.2	944
Sources:			
ICRP (1975)			
Woodard and White (1986)			

Attenuation vs. Phase Contrast



Refractive index of soft tissue

Overview

What is Phase Contrast Imaging?

Is there experimental demonstration?

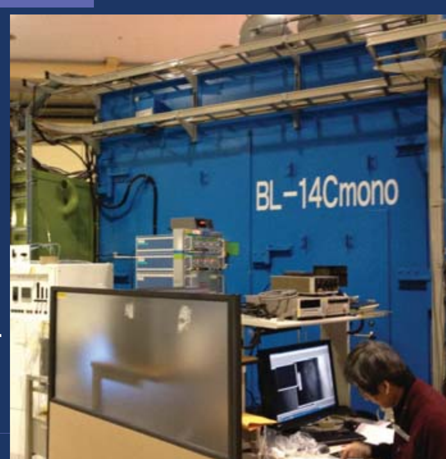
How can we harvest phase?

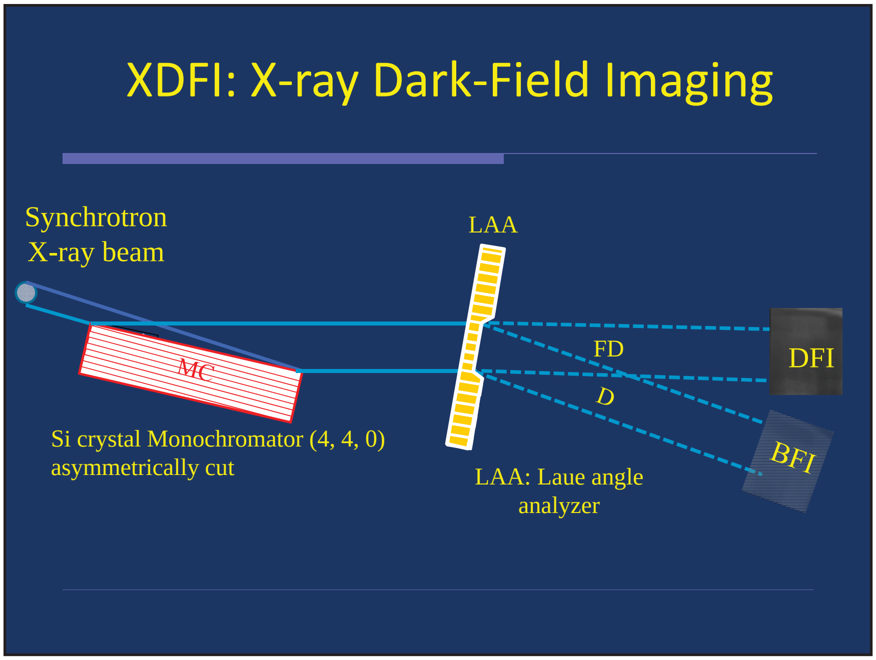
How can we achieve coherence?

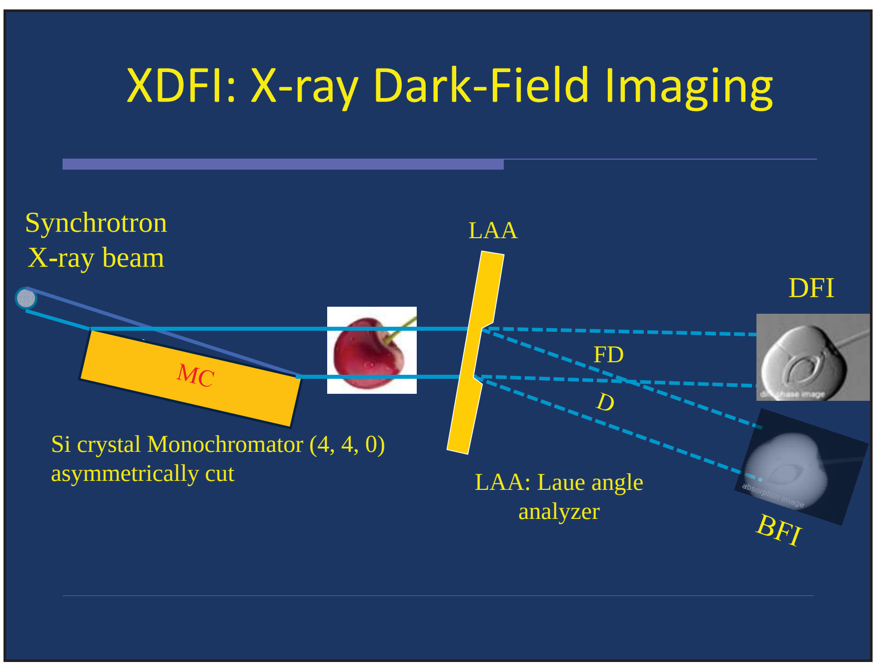
How does PaX do PCI?

PCI at Photon Factory, KEK Tsukuba

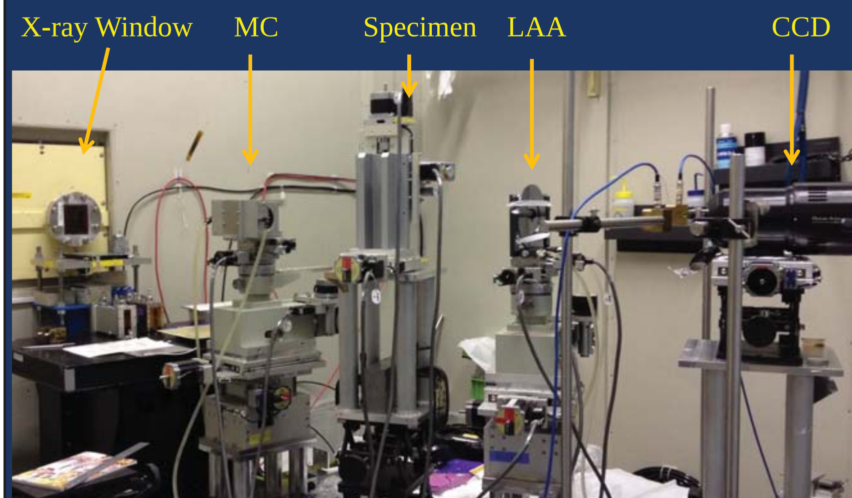
- Beam-line BL-14Cmono
- Vertically polarized 31KeV X-ray beam
- Filed-of-view: 2.5x3cm
- Rotational stage for the specimen




XDFI: X-ray Dark-Field Imaging
Synchrotron
X-ray beam
LAA
MC
FD
D
DFI
BFI
Si crystal Monochromator (4, 4, 0)
asymmetrically cut
LAA: Laue angle
analyzer


XDFI: X-ray Dark-Field Imaging
Synchrotron
X-ray beam
LAA
DFI
MC
FD
D
BFI
Si crystal Monochromator (4, 4, 0)
asymmetrically cut
LAA: Laue angle
analyzer

Experimental Setup

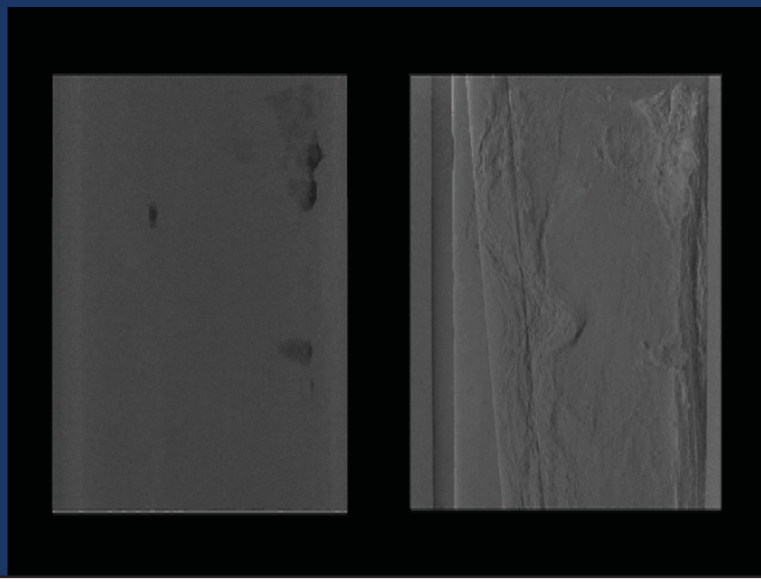


Coronary Plaque Imaging

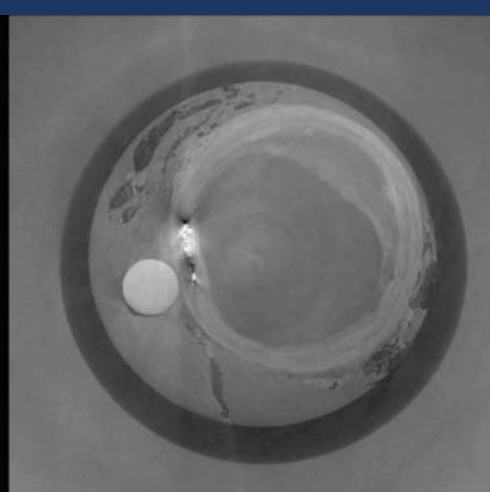
Catheter Angiography:
LAO cranial view

CT Angiography:
LAD, LCX and RCA

Plaque: Absorption and Phase



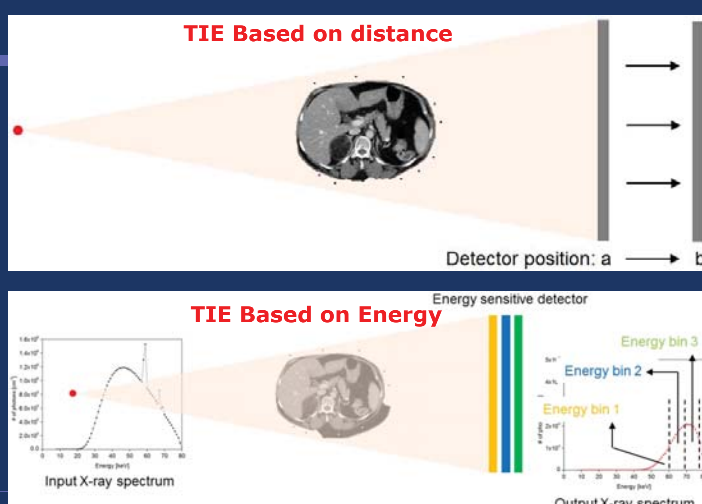
Plaque: Phase CT



Overview

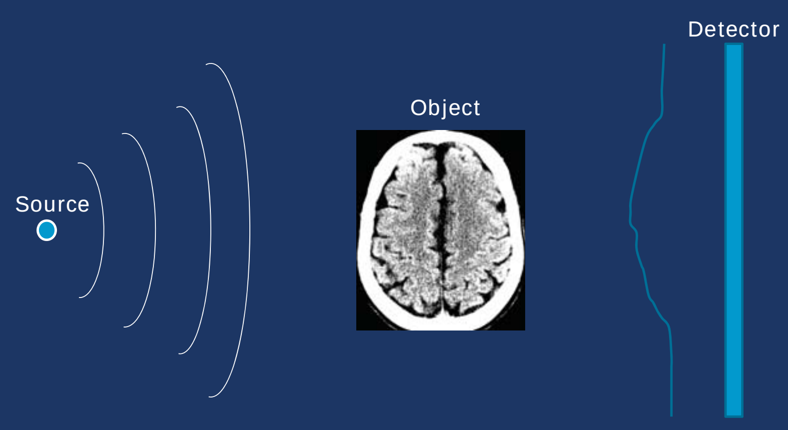
- What is Phase Contrast Imaging?
- Is there experimental demonstration?
- How can we harvest phase?
- How can we achieve coherence?
- How does PaX do PCI?

TIE-based PCI imaging



Overview
What is Phase Contrast Imaging?
Experimental demonstration of PCI
How can we harvest phase?
How can we achieve coherence?
PaX Architecture

MGH/MIT PaX Source: Basic Concept



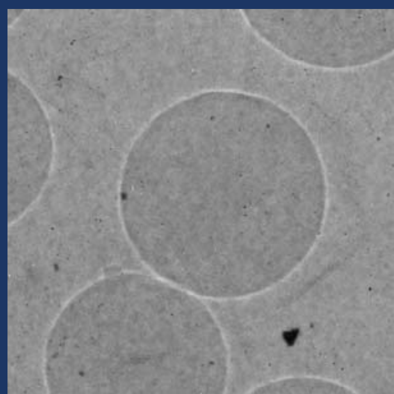
Trick 1: Use ultra-small focal spot size for x-ray

Trick 2: Keep the object far away from the source, and the detector far away from the object

Trick 3: Deduce phase from intensity images

Experimental results

Plastic microspheres (Cospheric, Inc):

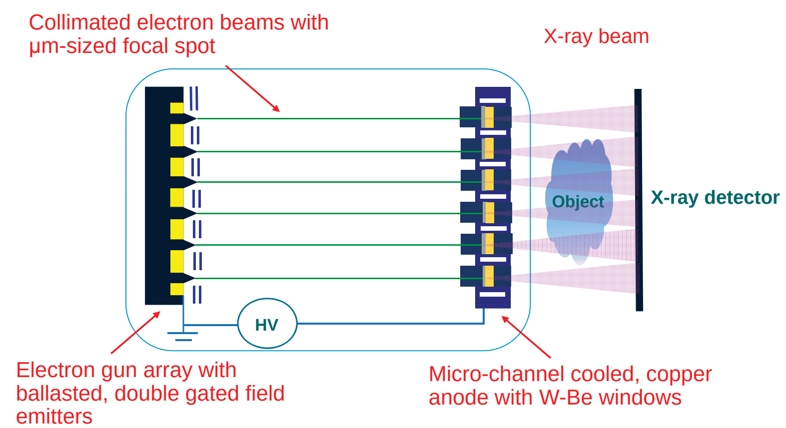


Projection image

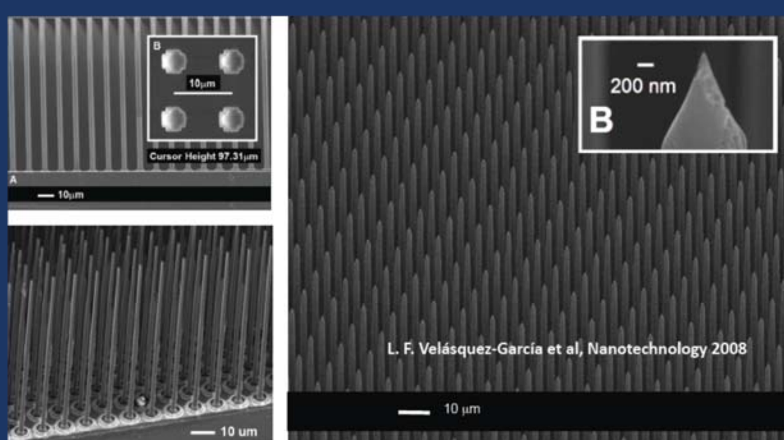
Reconstructed phase image

Overview
What is Phase Contrast Imaging?
Is there experimental demonstration?
How can we harvest phase?
How can we achieve coherence?
How does PaX do PCI?

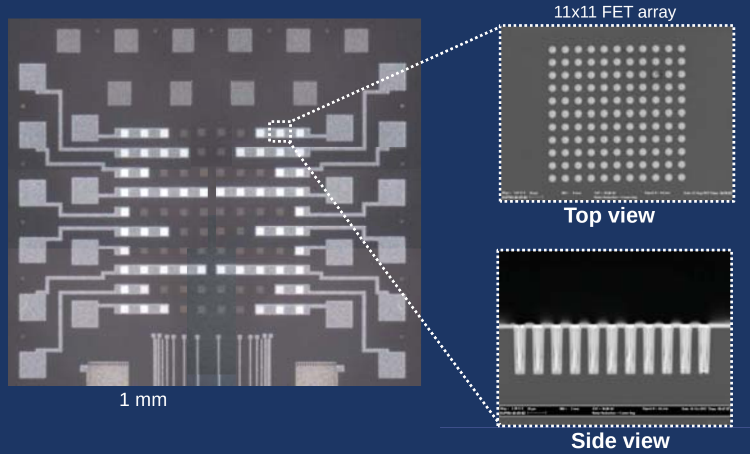
PaX Source – System Architecture



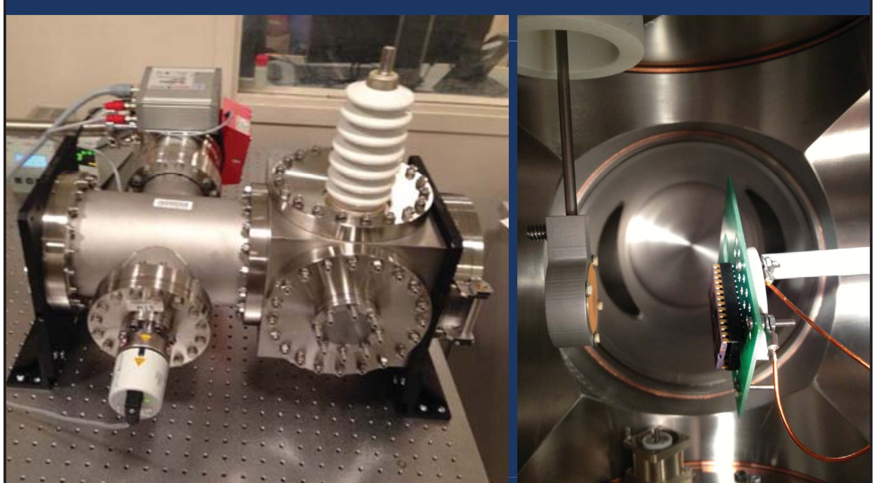
Field-emission Cathode Array



Fabricated Chip Layout



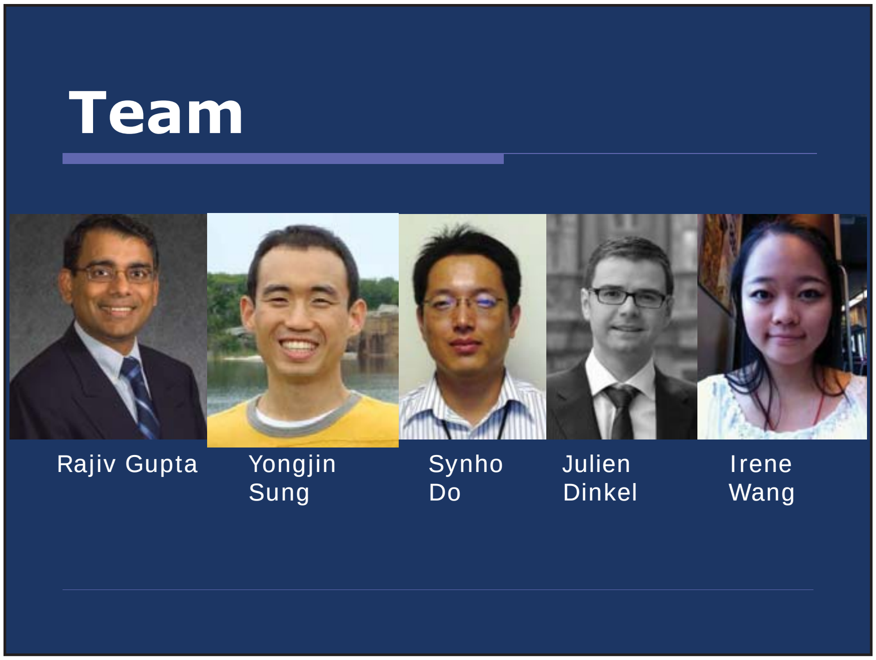
MGH/MIT PaX Source



First Image: Cadaver Wrist

Summary

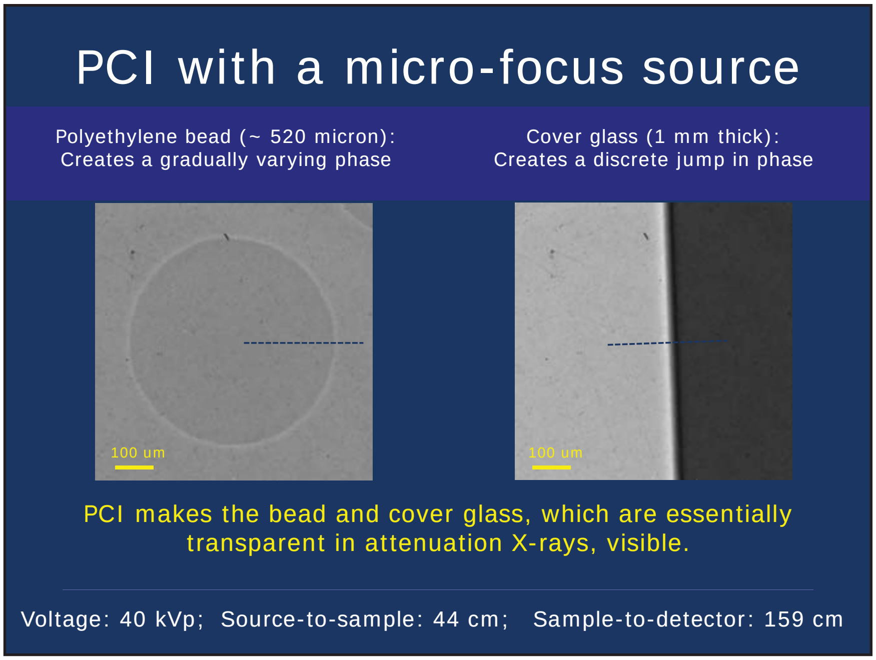
- X-ray phase represents an untapped contrast mechanism that can distinguish materials that look similar on conventional X-ray imaging
- There are ways to:
  - Make coherent X-rays
  - Deduce phase signatures

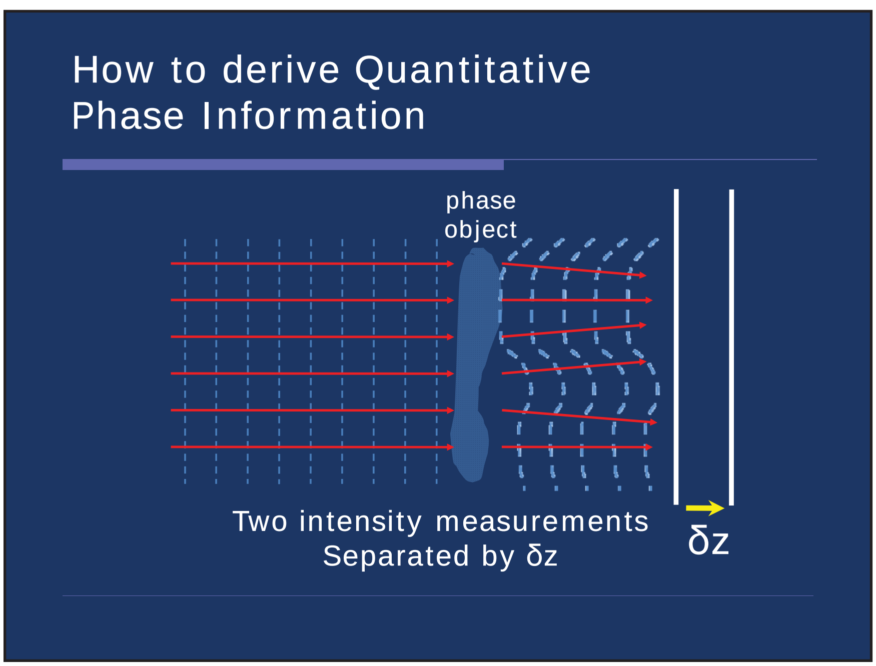

Team
Rajiv Gupta
Yongjin
Sung
Synho
Do
Julien
Dinkel
Irene
Wang


MIT
Richard Lanza
Luis Velasquez-Garcia
George Barbastathis
Jonah Jacob
SRL
Geoff Campbell
John Pasour
NRL

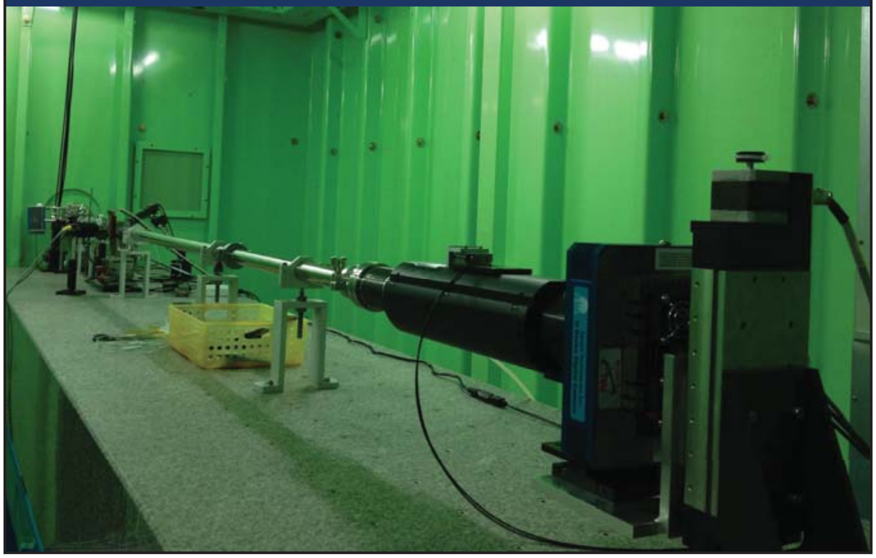
THANK YOU!

Proof that Micro-focus can do PCI

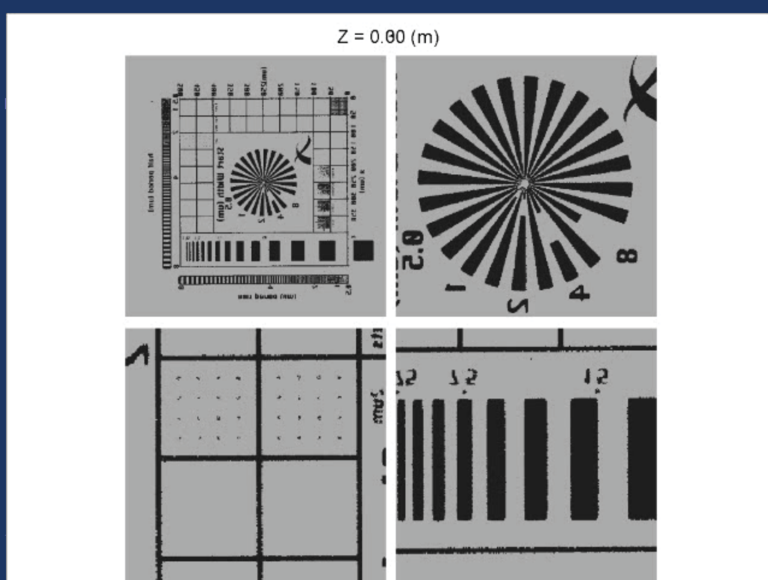

PCI with a micro-focus source
Polyethylene bead (~ 520 micron):
Creates a gradually varying phase
Cover glass (1 mm thick):
Creates a discrete jump in phase
100 um
100 um
PCI makes the bead and cover glass, which are essentially transparent in attenuation X-rays, visible.
Voltage: 40 kVp; Source-to-sample: 44 cm; Sample-to-detector: 159 cm


How to derive Quantitative
Phase Information
phase
object
Two intensity measurements
Separated by δz
δz

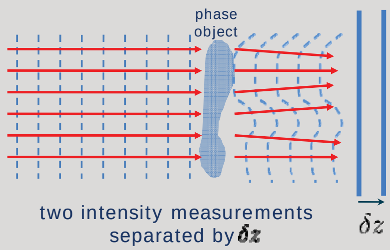
Pohang Light Source (So Korea)



Siemens Phantom at different distances



Transport of Intensity (TIE) Equation



Continuity Equation for
Intensity Transport

I: intensity $\quad \phi$: phase

$$\frac{2\pi}{\lambda}\frac{\partial I}{\partial z} = -\nabla_\perp \cdot (I \nabla_\perp \phi)$$

M. Teague,
JOSA (1983). $\quad \nabla_\perp \equiv \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}\right)$

- ‘Conservation of intensity’
- Phase recovery from intensity derivative
- Partially coherent illumination

16.14 Michelle Clark: Statistical Framework for Assessing Trace Detection Methods for Air Cargo

This project was made possible by Department of Homeland Security, Science and Technology Directorate funding

Statistical Framework for Assessing Trace Detection Methods for Air Cargo

Michelle L. Clark

May 6-7, 2014

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

This work is sponsored by Department of Homeland Security, Science and Technology Directorate under Air Force Contract #FA8721-05-C-0002. Opinions, interpretations, recommendations and conclusions are those of the authors and are not necessarily endorsed by the United States Government.

So What…Who Cares?

- Inform requirements for explosive trace detectors for cargo screening
- Estimate capabilities for specific ETD missions ***before*** technology investment decisions are made
  - Assess impact of background ETD false alarm and detection rates
- Developed a general framework to calculate idealized sensor-agnostic ROC curves for background limited scenarios
  - Based on measurements of background and threat signatures in air cargo
- Identify new CONOPs and detection strategies (correlations, etc.)
  - Instruments and algorithms that can simultaneously detect nitrate and ammonium will provide superior false alarm performance
- Current and future work focuses on measuring signatures associated with additional threats in air cargo scenarios

ALERT ADSA10 - 2
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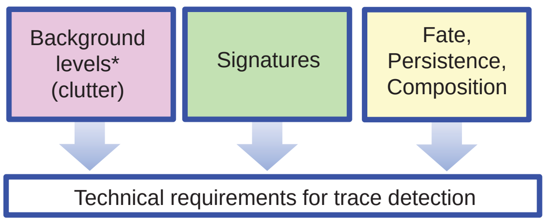
Phenomenology Overview

Measurements essential to determine if chemical sensing capabilities will be limited by the signature phenomenology



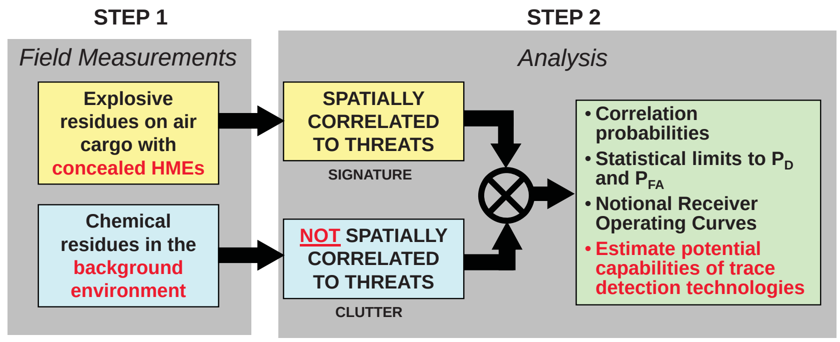
Goal: ***Project the efficacy of ETD approaches for ensuring air cargo safety***

Components of the "Signature"

SIGNATURE ATTRIBUTE	IMPACT	COMMENT
Abundance / Concentration	P_D	**Absolute Amount of Signature Chemical Present**
Form / Geometric Fill		**Optical Coupling Efficiency**
Fate, Persistence and Composition		**Length of Time Signature Available Spectral Signature / Algorithm**
Clutter	P_{FA}	**Statistics of Backgrounds and Signature**
All Listed Above	**ROC Curve**	**Upper Limit on Projected Performance**

Signature attributes directly impact P_D and P_{FA} rates of ETD technologies for detection

Approach



Use a two-step approach to project the efficacy of explosives trace detection for nitrate- and chlorate-based threats concealed in air cargo

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Outline

- **Introduction**
- **Program Overview**
  - **Measurement Campaigns**
- **Results**
  - **Distributions**
  - **Correlations**
  - **Probability of False Alarm**
- **Method for Calculating ROC curves**
- **Conclusions**

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Program Overview

- <u>Objective</u>:
  - Identify the potential performance capabilities ETD in air cargo terminals
- <u>Program Elements</u>:
  - Field measurements of background levels of AN and PC at air cargo facilities
  - Field measurements of threat levels associated with AN and PC based devices
  - Statistical data analysis to project operational impact of backgrounds
- <u>Other Related Activities at MITLL</u> :
  - Fate and persistence studies
  - Ionization reagent studies to broaden ETD system capabilities

Analysis is technology independent, but mission specific

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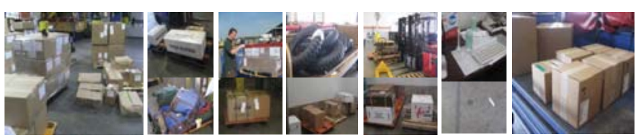
Measurement Environment

- Background surface concentrations of ammonium, nitrate, potassium and chlorate determined via surface swipes of taken at designated air cargo terminals (1254 measurements, 4 seasons)



P_{FA}

- Threat signature measurements determined from multiple threat building exercises

P_D

Notional ROC curve determined from signature measurements

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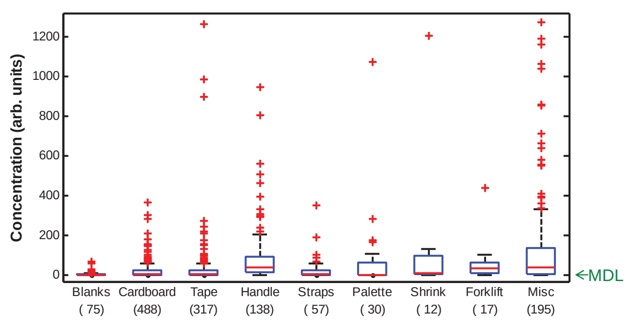
Outline

- Introduction
- Phenomenology Overview
- Program Overview
  - Measurement Campaigns
- Results
  - Distributions
  - Correlations
  - Probability of False Alarm
- Method for Calculating ROC curves
- Conclusions

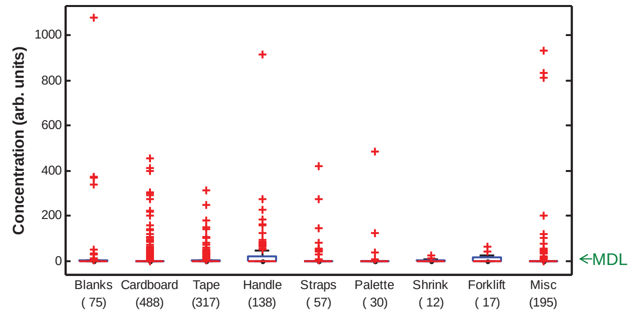
Results: Background Nitrate on Air Cargo



- Samples are sorted into nine categories
  - Most sample levels are well above method detection limits

No obvious nitrate patterns observed between sample types

Results:
Background Ammonium on Air Cargo



- Samples are sorted into nine categories
  - Median level for each category is near the minimum detectable limit of analytical method

No significant differences observed between sample types

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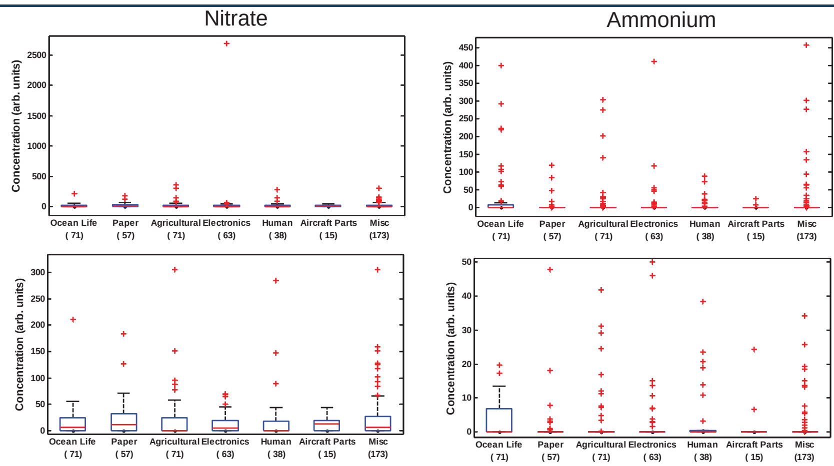
Nitrate and Ammonium Levels on Cardboard Boxes Categorized by Box Contents



Nitrate levels are independent of cargo content

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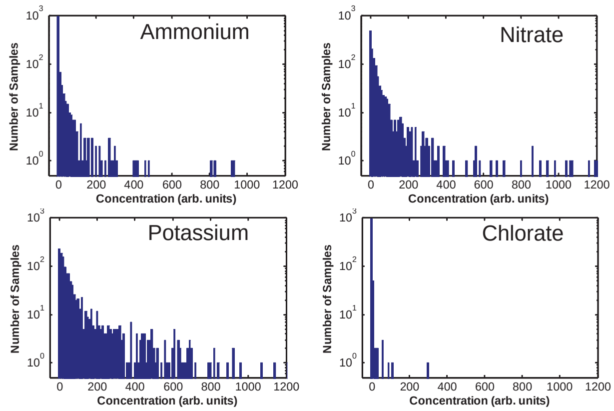
Measured Background Distributions



- Aggregate analysis of nine fieldings to date
- Significant number of samples contain nitrate (61%) and/or potassium (82%)
- Only 19% of samples contain measurable levels of ammonium
- Only 5% of samples contain measurable levels of chlorate

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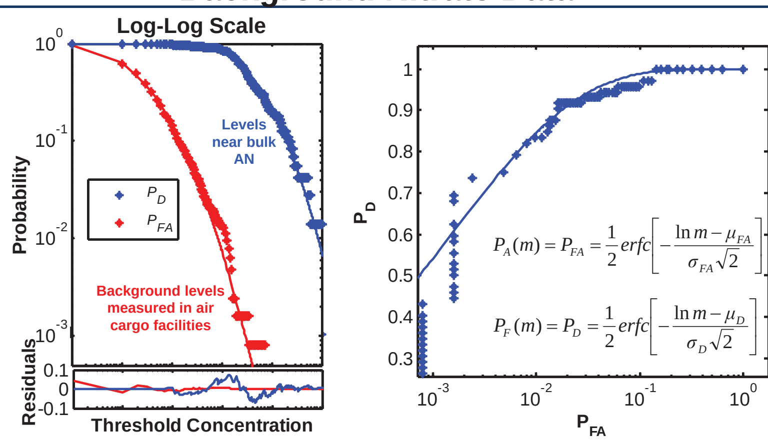
Curve Fits to the Signature and Background Nitrate Data



Nitrate background and threat distribution follows a lognormal probability distribution

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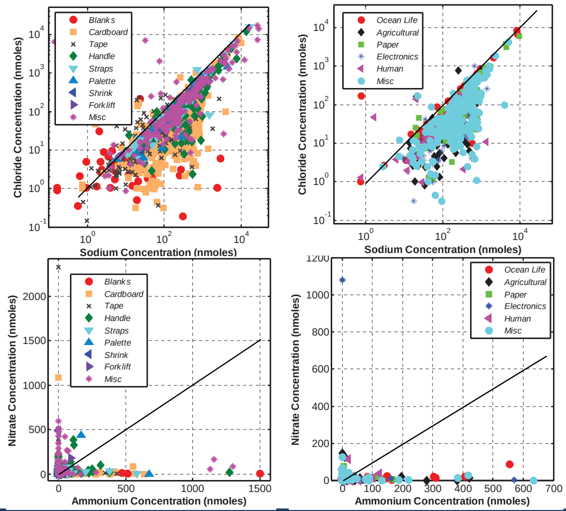
Cation/Anion Correlations in Background: Air Cargo Samples



Na$^+$ vs Cl$^-$:
Na$^+$ scales with Cl$^-$, except for cardboard, where excess Na$^+$ exists

NH_4^+ vs NO_3^-:
In the background, there is no 1:1 correlation of NH_4^+ and NO_3^- at high levels, in fact they are *anti*-correlated

Ion clusters containing both NH_4^+ *and* NO_3^- may be highly selective indicators for ANFO

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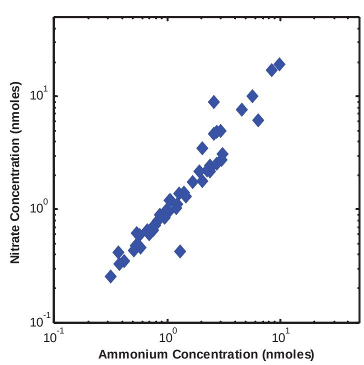
Ammonium Nitrate Fuel Oil: Correlation of Ammonium and Nitrate



- **IC analysis of nitrate and ammonium for various fingerprints of ANFO on a silicon wafer**
- **Nitrate and ammonium are correlated for ANFO samples**

Correlation of nitrate and ammonium may indicate the presence of AN despite the occurrence of elevated background levels of nitrate

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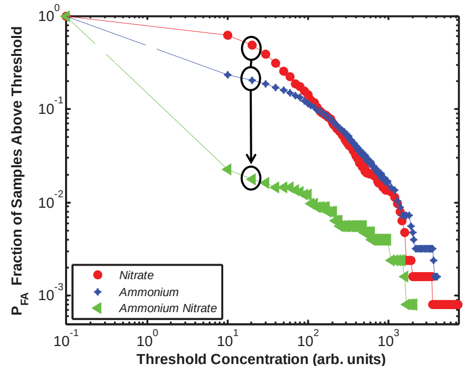
Probability of False Alarm for Ammonium Nitrate

- From the background levels on AN it is possible to determine a probability of false alarm solely due to the signature phenomenology



P_{FA} calculated by requiring Nitrate/Ammonium mole ratio for each sample to fall within a range of 0.7 to 1.3

Simultaneous detection of nitrate and ammonium lowers P_{FA} by an order of magnitude

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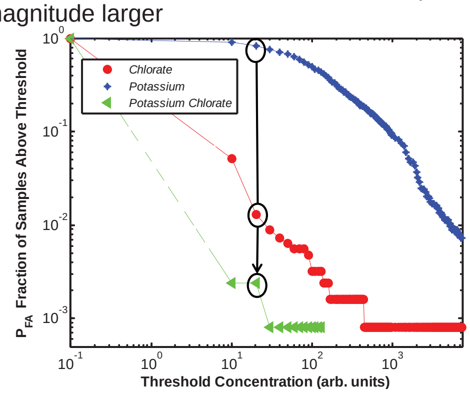
Probability of False Alarm for Potassium Chlorate

- False alarm rate for chlorate is low while potassium is orders of magnitude larger



P_{FA} calculated by requiring Chlorate /Potassium mole ratio for each sample to fall within a range of 0.7 to 1.3

Simultaneous detection of chlorate and potassium lowers P_{FA} by an order of magnitude

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Outline

- Introduction
- Program Overview
  - Measurement Campaigns
- Results
  - Distributions
  - Correlations
  - Probability of False Alarm
- Method for Calculating ROC curves
- Conclusions

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Statistical Analysis: ROC curves

- Combine background data and limited threat data set to generate ROC curve
- Background data provides estimates for P_{FA}
  - Assumes a unit (1 cm^2) sampling area, need to extend these results to larger swab area (>100 cm^2)
- Limited threat signature provides estimate for P_D
  - Additional measurements planned to get better statistics
    - Explosives expert will assemble authentic devices concealed in air cargo, made from AN and/or PC on an explosives range in South Carolina
- Develop computational framework to determine ROC curves as a function of swab area

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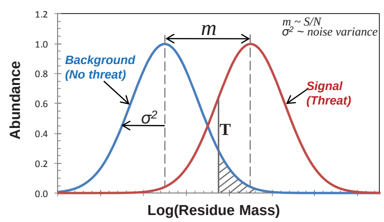
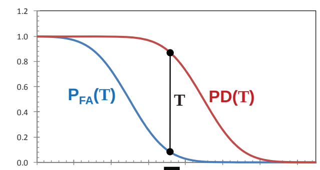
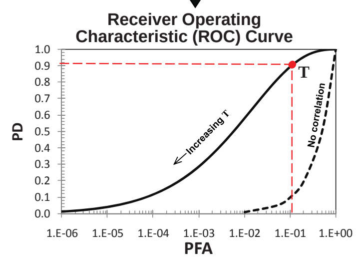
Deriving ROC Curves from Probability Distribution Functions

Response Histogram



Plotted *erfc* functions





False alarm probability:

$$PFA = \left(\frac{1}{x\sqrt{2\pi\sigma^2}}\right)\int_T^{+\infty} e^{\left(-(\ln x)^2/2\sigma^2\right)}dx = \frac{1}{2}erfc\left(\frac{\ln(T)}{\sqrt{2\sigma^2}}\right)$$

Detection probability:

$$PD = \left(\frac{1}{x\sqrt{2\pi\sigma^2}}\right)\int_T^{+\infty} e^{\left(-(\ln(x-m))^2/2\sigma^2\right)}dx = \frac{1}{2}erfc\left(\frac{\ln(T-m)}{\sqrt{2\sigma^2}}\right)$$

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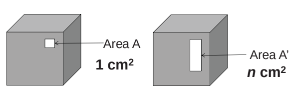
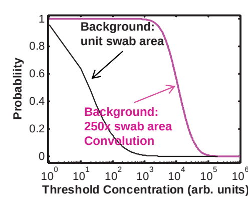
Model to Account for Different Swab Areas



For an area of *n* cm², calculate the probability that mass *m* of will exist in at least one of those *n* cm²



- **Signature data obtained for a small swab area**
- **Determine ROC curves for a larger arbitrary swab area based on convolution integrals**
- **Convolution Algorithm:**

If $X_1, X_2 \cdots X_n$ are n random variables with the same probability distribution function, and their sum is $S_n = X_1 + X_2 + \cdots + X_n$ then

$$f_{S_n}(x) = \left(f_{X_1} * f_{X_2} * \cdots * f_{X_n}\right)(x)$$

Where the definition of convolution is given by

$$(f * g)(z) = \int_{-\infty}^{+\infty} f(z-y)g(y)dy = \int_{-\infty}^{+\infty} f(z-x)g(x)dx$$

Probability of false alarm (and detection) increase as swab area increases for a given threshold

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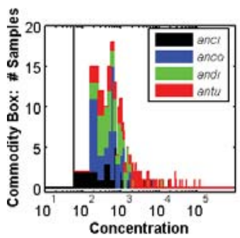
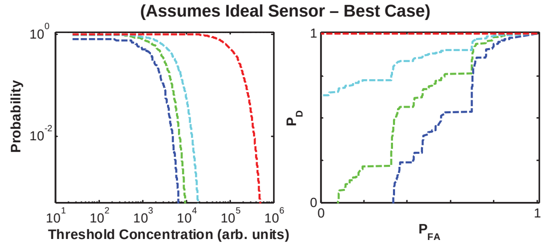
Statistical Analysis Example: Ammonium Nitrate Analysis Summary

Threat Build Results



ROC Analysis

(Assumes Ideal Sensor – Best Case)



External Commodity Box

ROC performance can be individually calculated for each sampled surface, swab area, analyte, build type, container, and correlation algorithm

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Conclusions

- **Developed a general framework to calculate idealized sensor-agnostic ROC curves for background limited scenarios**
  - **Based on measurements of background and threat signatures in air cargo**
- **Assess impact of background ETD false alarm and detection rates**
  - **Estimate capabilities for specific ETD missions *before* technology investment decisions are made**
- **Identify new CONOPs and detection strategies (correlations, etc.)**
  - **Instruments and algorithms that can simultaneously detect nitrate and ammonium will provide superior false alarm performance**
- **Inform requirements development for ETD for air cargo**
- **Current and future work focuses on measuring signatures associated with additional threats in air cargo scenarios**

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Acknowledgements

- **This work is sponsored by the Explosives Division of the Science and Technology Directorate of DHS under Air Force Contract #FA8721-05-C-0002. Opinions, interpretations, recommendations and conclusions are those of the authors and are not necessarily endorsed by the United States Government.**
- **We would like to acknowledge: Department of Homeland Security, Science and Technology Directorate, Explosives Division and Department of Homeland Security, Transportation Security Administration**

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16.15 Stefan Moser: 3D CT with Few Projections for Sea Freight Container Inspection

ALERT Workshop 2014

ADSA10 - Explosives Detection in Air Cargo

3D CT with few projections for freight container inspection

Stefan Moser
Victoria Heusinger, Siegfried Nau, Manfred Salk

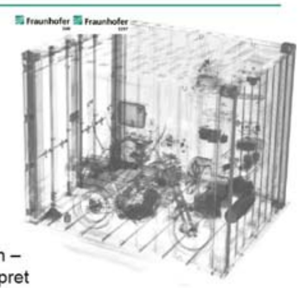
Boston
May 6th, 2014

1
Fraunhofer EMI

3D CT with few projections for cargo security

The benefit of 3D reconstructions

3D scanning (CT)



2D X-Ray images are sometimes hard to interpret.

3D volume reconstructions – even with limited resolution – allow to find threats otherwise hidden; or to help to interpret the complex 2D images (overlaps, full absorption areas).

3D is not yet used in freight scanning, because of challenges in hardware and algorithms development.

In this talk, first results of large-scale 3D freight scanning are presented.

2
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3D CT with few projections for sea freight container inspection

Talk Agenda

Content		
	Introduction	Our approach: High-Speed Computed Tomography (HSCT)
	Experiment	Experimental setup and border conditions
	Results	Comparison of reconstruction results for different projection numbers
	Summary & Outlook	Current research demand Vision for further research topics

Fraunhofer EMI

The Fraunhofer EMI

One of ~ 60 Fraunhofer institutes in Germany

Institute: 3 facilities:
Freiburg, Efringen-Kirchen, Kandern

Institute: ~ 300 employees; annual budget ~ 22 Million €
4 business segments

- Department:
  »Experimental Ballistics«; Dr. M. Salk

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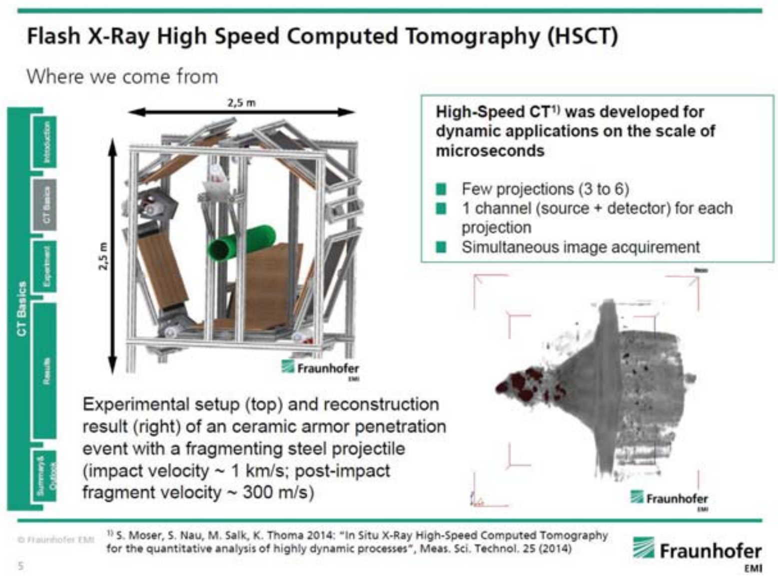
Flash X-Ray High Speed Computed Tomography (HSCT)
Where we come from
CT Basics
2,5 m
2,5 m
Fraunhofer
High-Speed CT[1] was developed for dynamic applications on the scale of microseconds
Few projections (3 to 6)
1 channel (source + detector) for each projection
Simultaneous image acquirement
Experimental setup (top) and reconstruction result (right) of an ceramic armor penetration event with a fragmenting steel projectile (impact velocity ~ 1 km/s; post-impact fragment velocity ~ 300 m/s)
Fraunhofer
1) S. Moser, S. Nau, M. Salk, K. Thoma 2014: "In Situ X-Ray High-Speed Computed Tomography for the quantitative analysis of highly dynamic processes", Meas. Sci. Technol. 25 (2014)
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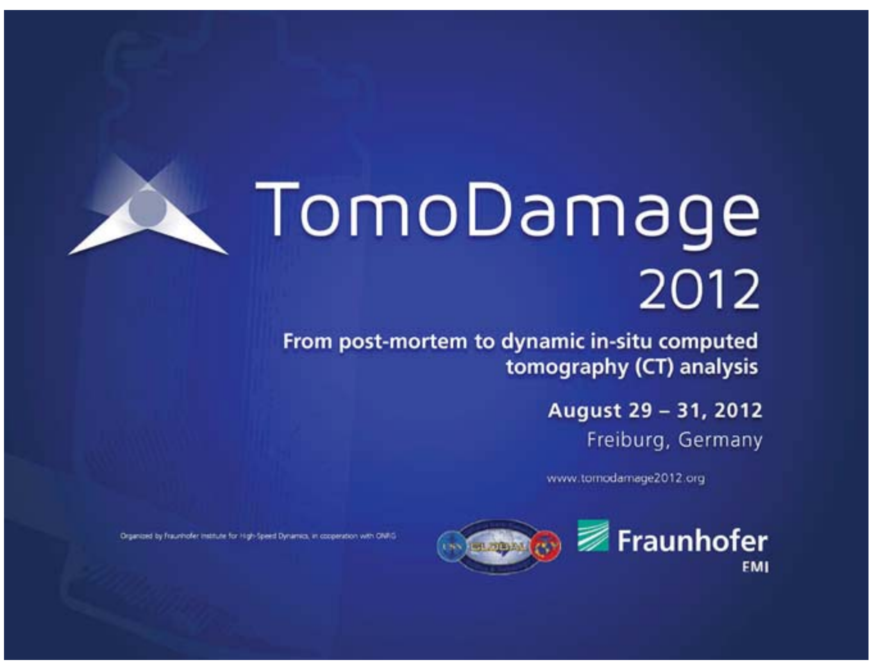
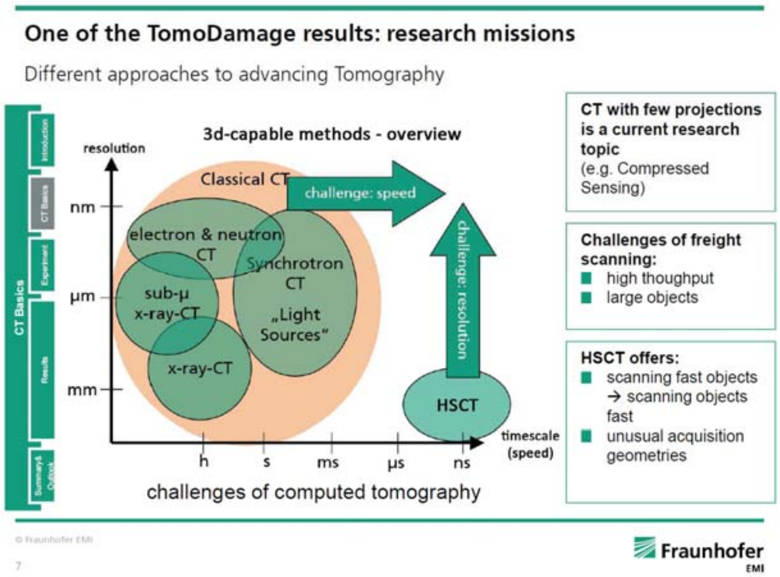
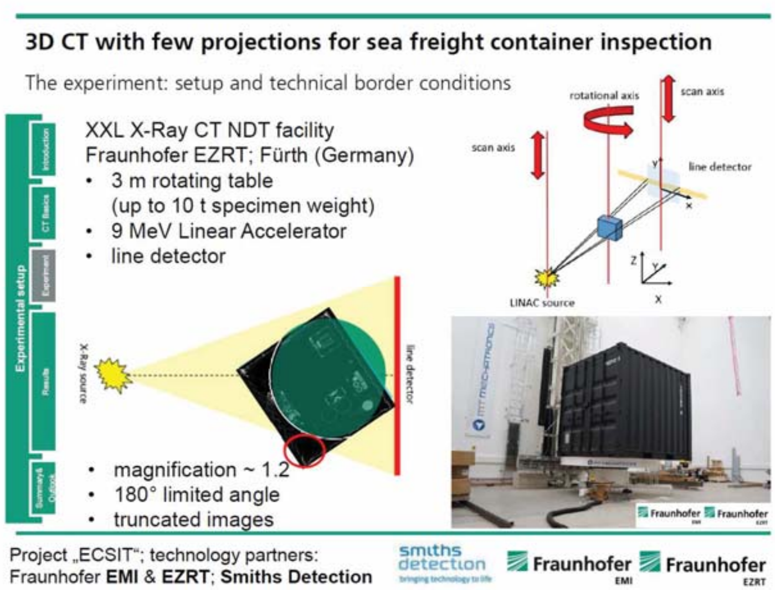

TomoDamage
2012
From post-mortem to dynamic in-situ computed tomography (CT) analysis
August 29 – 31, 2012
Freiburg, Germany
www.tomodamage2012.org
Fraunhofer
EMI


One of the TomoDamage results: research missions
Different approaches to advancing Tomography
CT Basics
Introduction
CT Basics
Experiment
Results
Summary& Outlook
3d-capable methods - overview
resolution
nm
μm
mm
Classical CT
challenge: speed
electron & neutron CT
Synchrotron CT „Light Sources“
sub-μ x-ray-CT
x-ray-CT
challenge: resolution
HSCT
h
s
ms
μs
ns
timescale (speed)
challenges of computed tomography
CT with few projections is a current research topic
(e.g. Compressed Sensing)
Challenges of freight scanning:
high thoughput
large objects
HSCT offers:
scanning fast objects → scanning objects fast
unusual acquisition geometries
Fraunhofer EMI


3D CT with few projections for sea freight container inspection
The experiment: setup and technical border conditions
Experimental setup
Introduction
CT Basics
Experiment
Results
Summary& Outlook
XXL X-Ray CT NDT facility
Fraunhofer EZRT; Fürth (Germany)
3 m rotating table (up to 10 t specimen weight)
9 MeV Linear Accelerator
line detector
rotational axis
scan axis
scan axis
line detector
LINAC source
X-Ray source
line detector
magnification ~ 1.2
180° limited angle
truncated images
Project „ECSIT“; technology partners:
Fraunhofer EMI & EZRT; Smiths Detection
smiths detection
Fraunhofer EMI
Fraunhofer EZRT

3D CT with few projections for sea freight container inspection

The experiment: Dummys representing different thread scenarios; other items

Experimental setup

The „cargo“ of the container consists of

- dummys of „dangerous items“
- large variety of cargo to conceal said dummys (e.g. motorbike, steel pipes, electronic devices (e.g. washing mashine, TV, radios …)

List of dummys hidden in the container:

high-Z scenarios:
- dirty Bomb mock-up
- high-Z Device mock-up
- high-Z material dummy

Explosives scenarios:
- pipe-bomb mock-up
- IED mock-up

Other scenarios:
- Fluids of different density
- Hidden small arms gun
- Small quantities of substances with different densities

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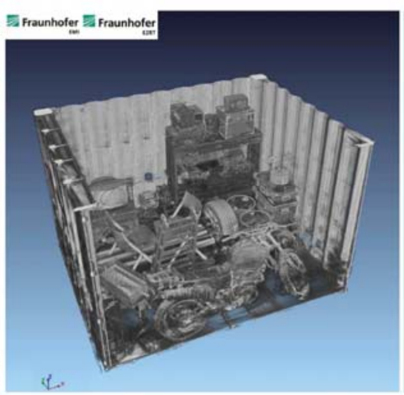
3D CT with few projections for sea freight container inspection

Results: Overview

Results



Reconstruction with 250 projections

Reconstruction parameters

Input data:
- Datasets with 25, 50, 100 and 250 projections
- Image size 1331 x 841 pixels (3 mm pixel-pitch by binning of the high-resolution line detector)

Reconstruction:
- ART with moderate regularization
- 250 iterations

Reconstruction volume:
- ~ 3 x 3 x 2.1 m
- Voxel-Size 2.5 mm (→ 1215x1215x841 voxels)

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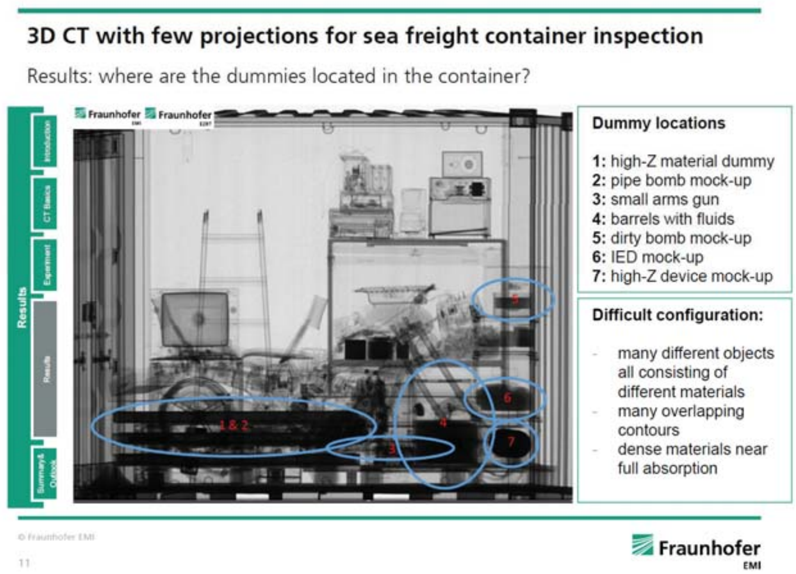
3D CT with few projections for sea freight container inspection
Results: where are the dummies located in the container?
Introduction
CT Basics
Experiment
Results
Results
Summary & Outlook
Fraunhofer
Fraunhofer
1 & 2
3
4
5
6
7
Dummy locations
1: high-Z material dummy
2: pipe bomb mock-up
3: small arms gun
4: barrels with fluids
5: dirty bomb mock-up
6: IED mock-up
7: high-Z device mock-up
Difficult configuration:
- many different objects all consisting of different materials
- many overlapping contours
- dense materials near full absorption
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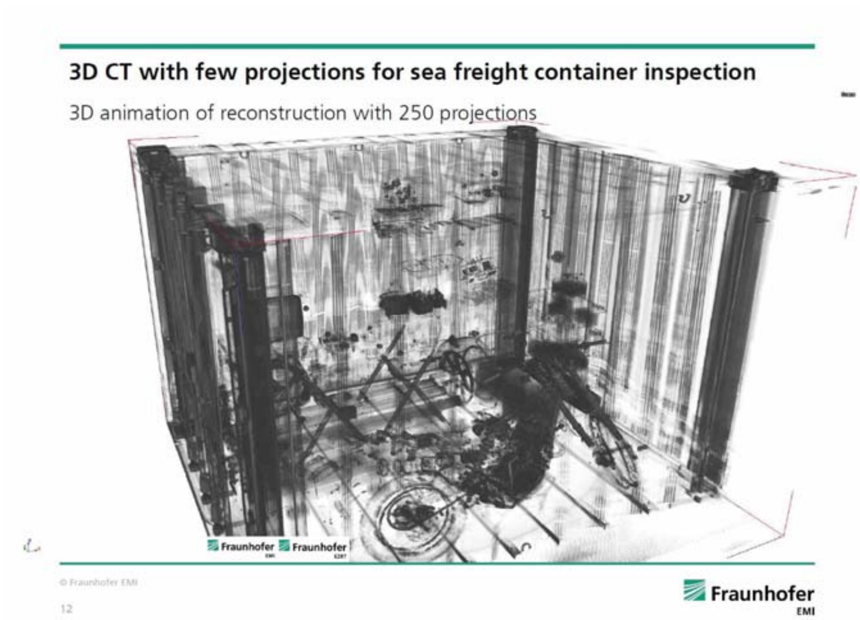
3D CT with few projections for sea freight container inspection
3D animation of reconstruction with 250 projections
Fraunhofer
Fraunhofer
© Fraunhofer EMI
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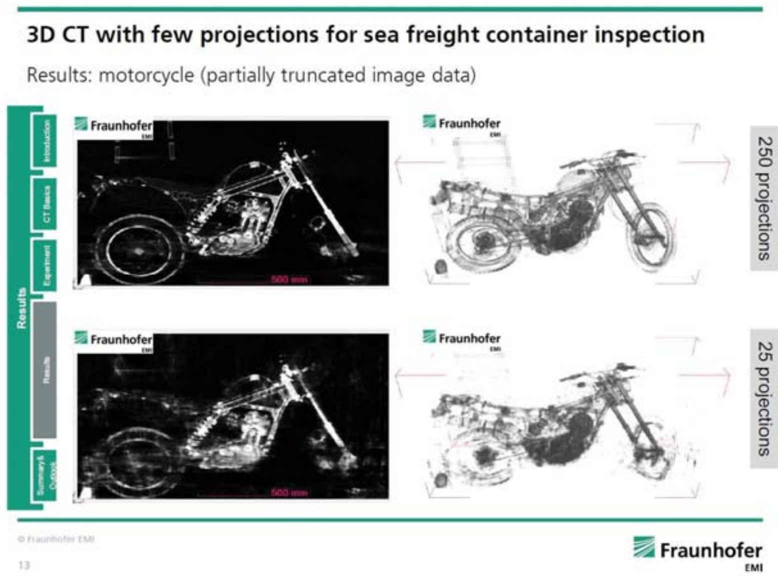
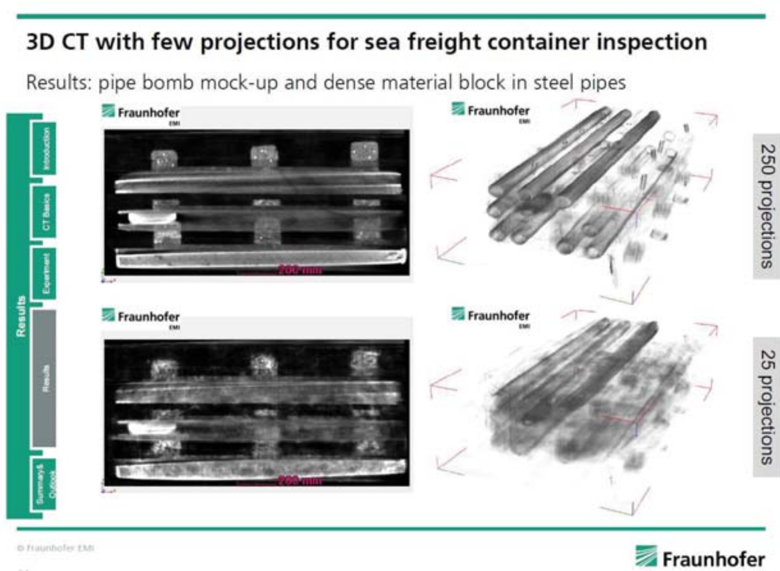
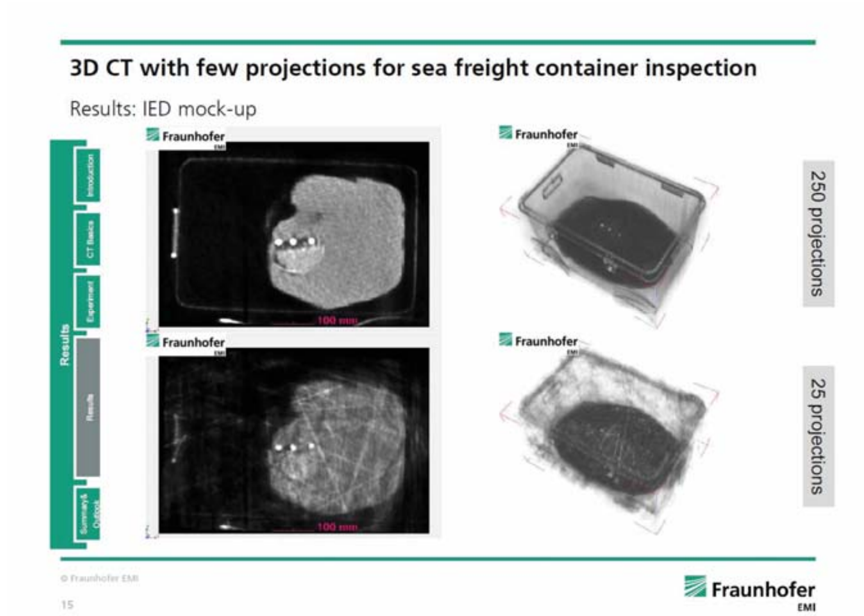
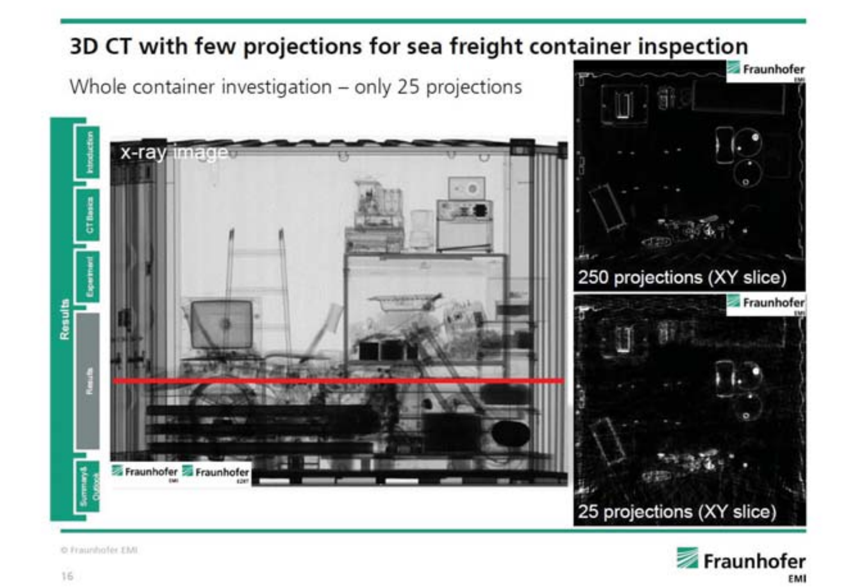

3D CT with few projections for sea freight container inspection
Results: motorcycle (partially truncated image data)
Results
Introduction
CT Basics
Experiment
Results
Summary& Outlook
Fraunhofer
500 mm
250 projections
25 projections
Fraunhofer
EMI
13


3D CT with few projections for sea freight container inspection
Results: pipe bomb mock-up and dense material block in steel pipes
Results
Introduction
CT Basics
Experiment
Results
Summary& Outlook
Fraunhofer
200 mm
250 projections
25 projections
Fraunhofer
EMI
14


3D CT with few projections for sea freight container inspection
Results: IED mock-up
Introduction
CT Basics
Experiment
Results
Results
Summary& Outlook
250 projections
25 projections
100 mm
Fraunhofer
Fraunhofer EMI
15


3D CT with few projections for sea freight container inspection
Whole container investigation – only 25 projections
Introduction
CT Basics
Experiment
Results
Results
Summary& Outlook
x-ray image
250 projections (XY slice)
25 projections (XY slice)
Fraunhofer
Fraunhofer EMI
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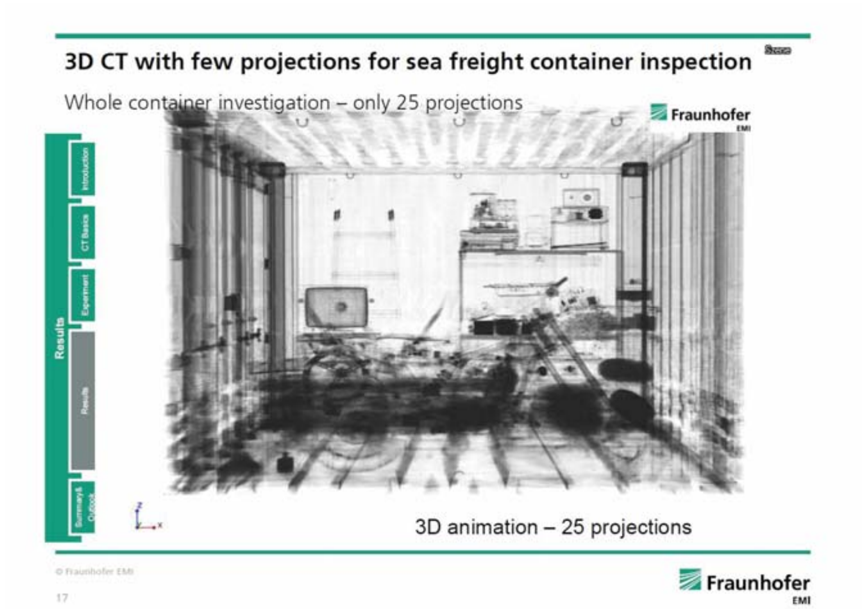
3D CT with few projections for sea freight container inspection
Whole container investigation – only 25 projections
Fraunhofer EMI
Introduction
CT Basics
Experiment
Results
Results
Summary & Outlook
3D animation – 25 projections
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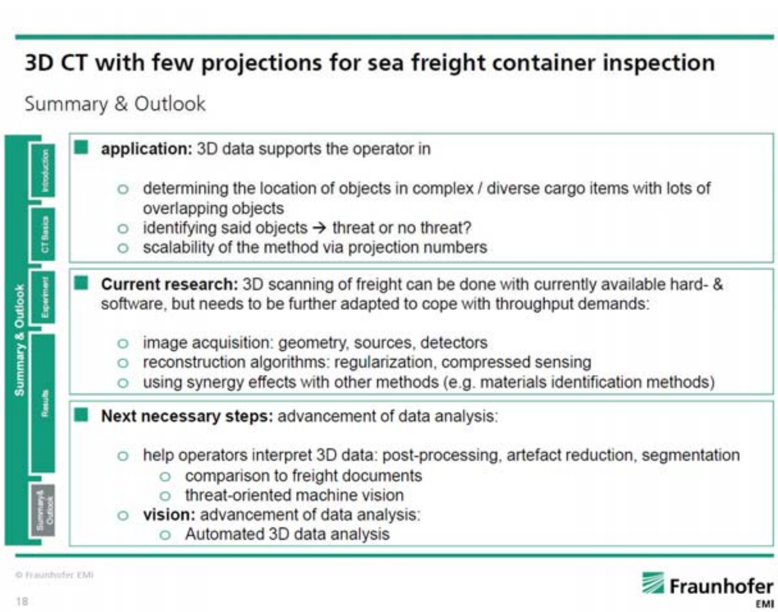
3D CT with few projections for sea freight container inspection
Summary & Outlook
Introduction
CT Basics
Experiment
Results
Summary & Outlook
Summary & Outlook
application: 3D data supports the operator in
determining the location of objects in complex / diverse cargo items with lots of overlapping objects
identifying said objects → threat or no threat?
scalability of the method via projection numbers
Current research: 3D scanning of freight can be done with currently available hard- & software, but needs to be further adapted to cope with throughput demands:
image acquisition: geometry, sources, detectors
reconstruction algorithms: regularization, compressed sensing
using synergy effects with other methods (e.g. materials identification methods)
Next necessary steps: advancement of data analysis:
help operators interpret 3D data: post-processing, artefact reduction, segmentation
comparison to freight documents
threat-oriented machine vision
vision: advancement of data analysis:
Automated 3D data analysis
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Fraunhofer EMI


Thank you for your attention!
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Tel.: +49 76 28 / 90 50 – 635
email: nau@emi.fhg.de

16.16 Kevin Cronk: DNDO's Integrated Detection Threat Platform

Domestic Nuclear Detection Office

Advanced Algorithms for Security Applications10

DNDO's Integrated Threat Detection Platform

Kevin Cronk
Program Manager
Transformational and Applied Research
Domestic Nuclear Detection Office

Homeland Security

Why is DNDO Here?

- Looking to further collaborate with DHS S&T and the non-rad/nuc detection community
- Improve rad/nuc detection capability through development of integrated multi-threat technologies
- DNDO is funding a study with a national lab to further explore the possibility/ benefit of multi-threat scanning
- Potential for future research solicitation (in conjunction with S&T or UK) for integrated approaches
- Leveraging the established and capable explosives and contraband detection scientific community to further our capability

Homeland Security

2

DNDO's Mission and Objectives

DNDO was established on April 15, 2005 with the signing of NSPD 43 / HSPD 14 for the purpose of improving the Nation's capability to detect and report unauthorized attempts to import, possess, store, develop, or transport nuclear or radiological material for use against the Nation, and to further enhance this capability over time.

- Develop the global nuclear detection and reporting architecture (GNDA)
- Develop, acquire, and support the domestic nuclear detection and reporting system
- Characterize detector system performance before deployment
- Facilitate situational awareness through information sharing and analysis
- Establish operational protocols to ensure detection leads to effective response
- Conduct a transformational research and development program
- Provide centralized planning, integration, and advancement of USG nuclear forensics programs

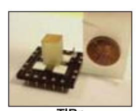
Homeland Security

3

DNDO Transformational R&D Program

Aggressive and expedited R&D programs that seek to develop break-through technologies that will have a dramatic positive impact on capabilities to detect nuclear threats.

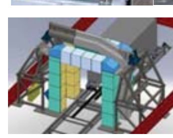
- Exploratory Research Program
  - Investigate promising concepts to show feasibility through laboratory Proof-of-Concept demonstrations
- Advanced Technology Demonstration
  - Characterize Performance Test Units in a simulated operational environment to assess technology transition potential
- Academic Research Initiative
  - Create next generation of scientists and engineers
- Small Business Innovative Research
  - Strengthen the role of innovative small business concerns with federally-funded research and development



TlBr Semiconductor

Cs_2LiYCl_6 (CLYC) Scintillator

SORDS Detector and Truck



SNAR Test Unit

Homeland Security

4

DNDO/ S&T/ UK Home Office Collaboration

- Radiation and nuclear detection development and evaluation funded and managed by DNDO
- Contraband detection requirements developed by DHS S&T BMD and the United Kingdom Home Office
- Contraband detection capability development and evaluation funded by the United Kingdom

Homeland Security

5

Nuclear and Radiological Imaging Platform

- Overall Goal: Optimize and characterize the ability of emerging technology to detect nuclear and radiological threats while clearing benign vehicles and containerized cargo regardless of the shielding level.
- Application Space
  - Ports of entry, ports of departure, and other choke point applications for vehicles
  - Lessons learned can be applied to more challenging applications
- Technical Objectives
  - Rapid clearing of cargo (short scan time and short inspection time)
  - High probability of detection of threats in cargo regardless of clutter and degree of shielding (very low false negatives)
  - Very low false alarm rates regardless of clutter (very low false positives)
  - Utility to detect other contraband is desired but not required
  - Maximize operational viability (size, footprint, radiation exposure, cost)

Homeland Security

6

Commercially Available Scanners

- Joint DNDO/ US Customs and Border Protection evaluation of two integrated radiographic/ passive detection systems installed at Pacific Northwest National Lab (PNNL)
- Systems will be utilized to set the baseline performance to benchmark developmental systems
- Data will also be collected to inform algorithms development for data fusion (passive/ radiography)
- Data analysis in progress at Lawrence Livermore National Lab currently (Martz)

SAIC IP 6500 (In Front)

Smith's Detection HCVP 6030

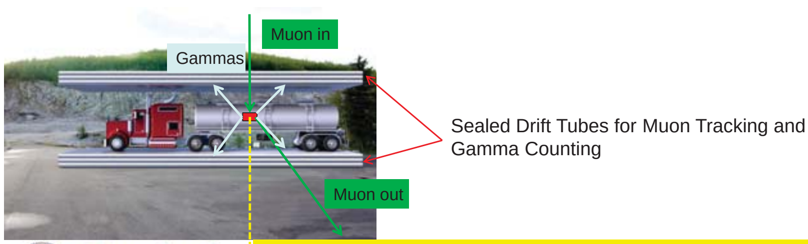
Homeland Security

7

DSIC Performance Test Unit

Cosmic-ray muon tomography takes advantage of naturally occurring cosmic ray muons to probe the scene. Muons fully traversing the inspection volume provide information via angle changes from multiple-Coulomb scattering off the nuclei of materials.

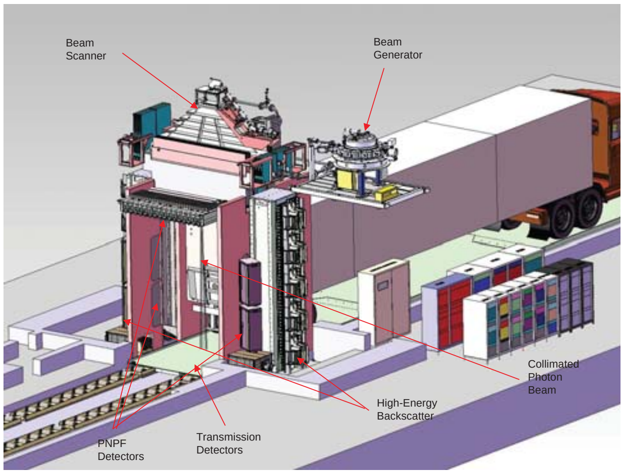
Drift tubes used for muon tracking also serve as passive gamma counters.



Average delta in angle proportional to muon energy and (density*Z^2) of target

Homeland Security

Passport Scanner Technology

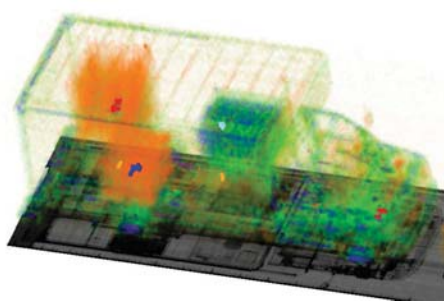


Homeland Security

Beyond Radiation and Nuclear Detection

- System originally designed to meet DNDO rad/ nuc detection requirements
- Technology shows promise for multi-threat detection

- High-Energy Backscatter
  - Effective Z
  - Density
- Nuclear resonance fluorescence
  - Elemental analysis



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10

System Build at Massport

Homeland Security

11

Joint System Evaluation

- Full government integrated system characterization
- Real-time user interaction
- Multi-threat detection evaluation
- Stream-of-commerce data collection
- Broad government evaluation
  - DNDO
  - DHS S&T
  - US CBP
  - UK Home Office
  - Atomic Weapons Establishment

Homeland Security

12

Working with DNDO

- Solicitations posted on Fed Biz Ops
  - www.fbo.gov
- Exploratory research solicitations
  - TRL 1-4
- Advanced Technology Demonstrations
  - TRL 5-7
- SBIR

Homeland Security

13

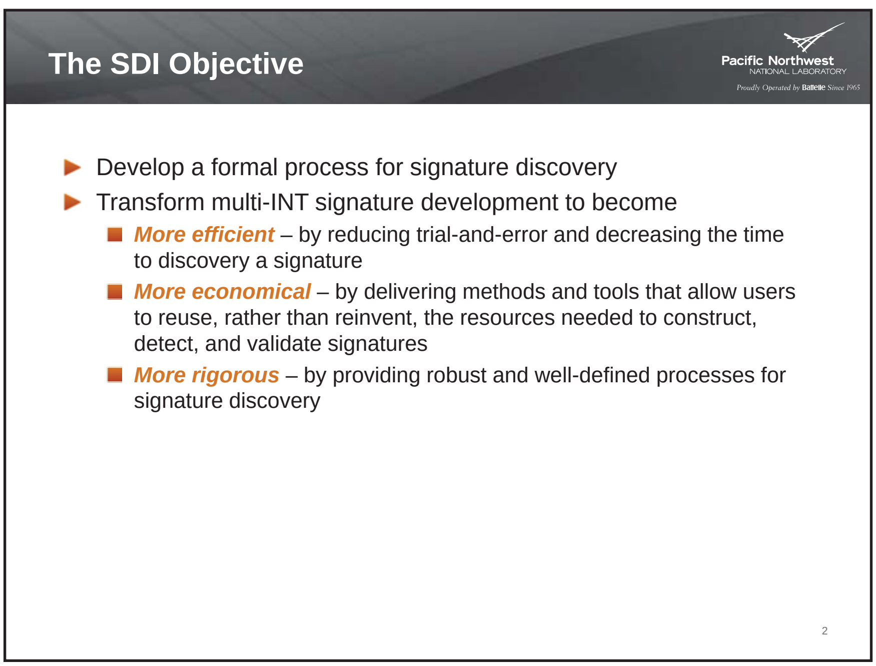
Thank you

Kevin Cronk
DNDO/ TAR
kevin.cronk@hq.dhs.gov

Homeland Security

14

16.17 Mark Tardiff: Signature Discovery Initiative



The Cargo Screening Dilemma

- Many targets with complementary or competing approaches
  - X-Ray technologies
  - Magnetics
  - Heartbeat monitoring
  - K-9 for explosives, humans
  - CO_2 monitoring
  - Ion mobility spectrometry
  - Millimeter wave imaging
  - Terahertz methods
  - Emergent passive and active interrogation techniques

3

The Cargo Screening Dilemma
Continued

- Operational constraints
  - Commerce is King
  - Time to screen
  - Time to confirm
  - Flight schedules
  - No control of when cargo arrives at the warehouse
- All in the context of extremely rare true positives – predisposed to believe that a detect is a false positive
- Containing costs is paramount because of prevalence – don't spend a lot of money on what doesn't happen

4

The Cargo Screening Dilemma
Continued

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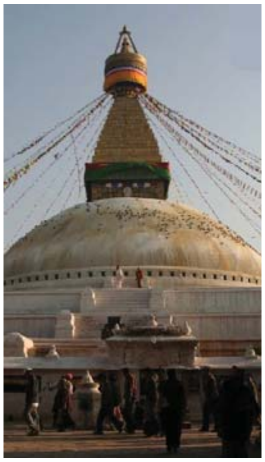

Boudhanath Stupa
Kathmandu, Nepal

5

The Cargo Screening Dilemma
Continued

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6

A Signature Centric Approach

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- To a hardware developer the cargo screening challenge is a hardware problem
- To a software developer the challenge is a software problem
- From a signature discovery perspective, cargo screening is a classifier problem

7

Introduction to Signature Discovery

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- ***Signature***: A distinguishing collection of features that *characterizes* a phenomenon of interest
- Forensic, diagnostic, prognostic
- ***Example***: gait analysis for biometrics
  - Static measurements
  - Dynamic measurements
  - Other measurements?

Feature	Measure-ment	Prob of ID
Step length	24 ± 2 in	
Step width	4.0 ± 0.5 in	
Knee angle	142 ± 5 deg	60%
Walking speed	5.2 ± 0.2 fps	
Cycle time	2.6 ± 0.1 s	80%
Acoustic power	70 dB	95%

Is this Kim Smith?

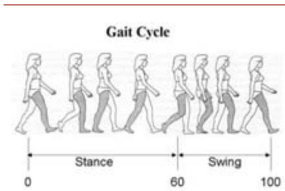
Construction
How were these features selected?

Validation
Is this a "good" signature?

?

Dynamics
What's the "shelf life" of this signature?

Detection
Can we find this signature in a crowd?



8

Open Questions in Signature Discovery

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- Challenges
  - Modern signatures often involve features from many different data types
  - Signatures are most useful when they are easily interpreted by decision-makers
- Key questions
  - How do we best select features from multiple measurement sources to construct our signature?
  - How do we detect signatures in “real world“ environments?
  - How do we assess the quality of a signature and compare different signatures?
  - How do we recognize change and adapt signatures to dynamic phenomena?
  - *Is this process generalizable across domains?*

9

Signature System

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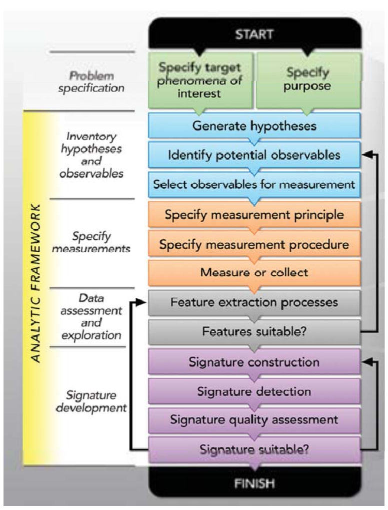

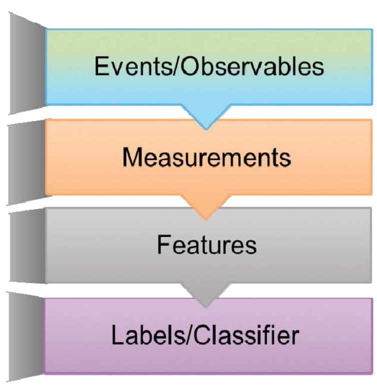

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Methodology
Gunshot Example

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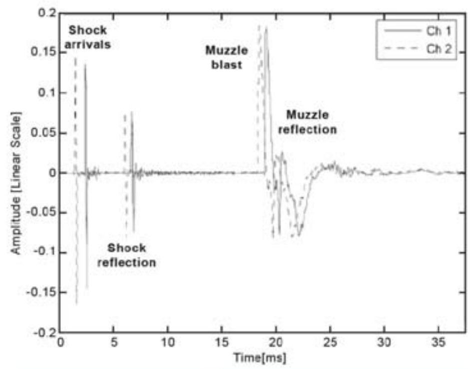
- Events/observables:
  - Gunshots
- Data
  - Sound collected over the dynamic range of the microphone
- Features
  - Frequency intervals that are related to gunshots, time intervals for gunshot duration
- Classifier
  - {Gunshot, no gunshot}



Events $\xrightarrow{\mu}$Measurements$\xrightarrow{\eta}$Features$\xrightarrow{\delta}$Labels

Generalized Form	Where
μ: $E \rightarrow M$	E = Events, $\{e_1, e_2, e_3 \ldots\}$
η: $M \rightarrow F$	M = Measurements, $\{m_1, m_2, m_3 \ldots\}$
δ: $F \rightarrow L$	F = Features, $\{f_1, f_2, f_3 \ldots\}$
	L = Labels, $\{l_1, l_2, l_3 \ldots\}$

Project Portfolio

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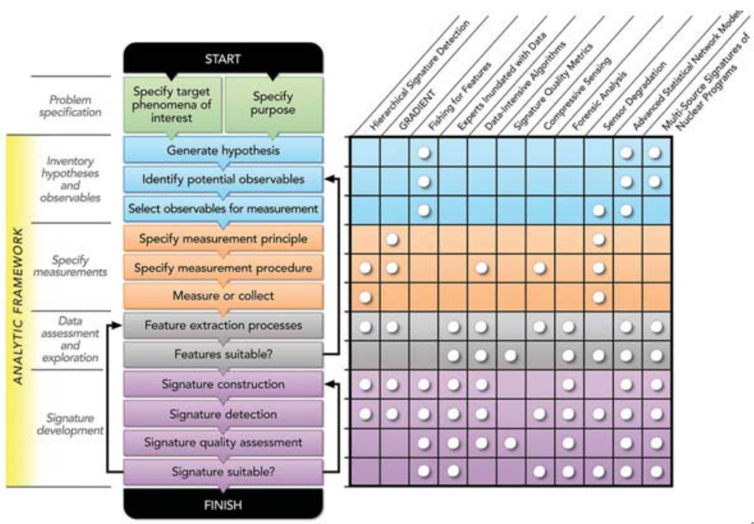
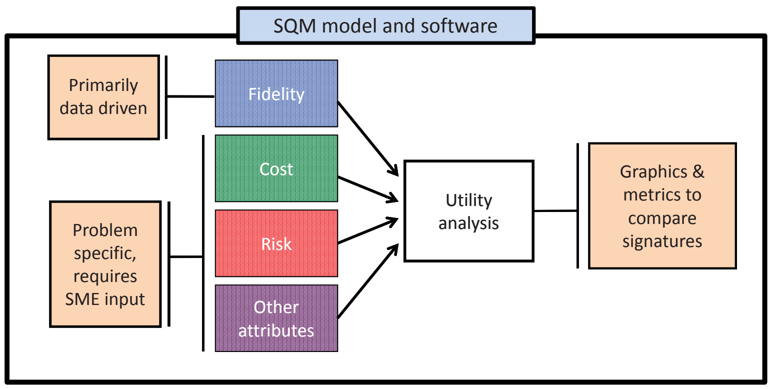


12

Signature Quality Metrics
Conceptual model



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Calculating Utility

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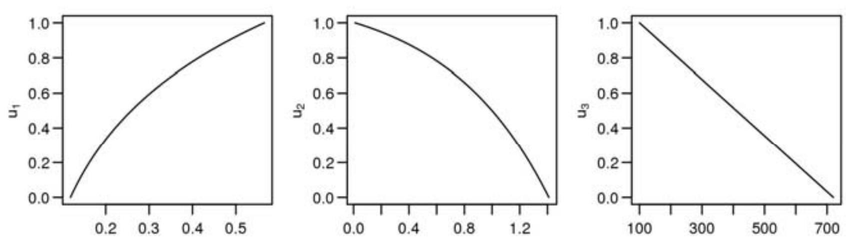

Attribute 1 - Probability of correct outcome

Attribute 2 – Dwell Time

Attribute 3 – Training cost

Additive utility function:

Utility = 0.85 u_1 (Probability of correct outcome) +
0.15 u_2 (Dwell time) +
0.05 u_3 (Training cost)

$$u(\mathbf{z}_{ij}, \theta_j, S_i(\mathbf{x}_j)) = \alpha_1 u_1(\theta_j, S_i(\mathbf{x}_j)) + \sum_{a=2}^{A} \alpha_a u_a(z_{a,ij})$$

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Calculating Expected Utility

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- Expected Utility, $E(u(S))$, can be estimated by
  - Calculating the additive utility for each observation in the test data
  - Calculating the weighted average of the resulting utilities (weighted by the likelihood of each observation)

$$\vartheta(S_i) = \iiint u(\mathbf{z}_i, \theta, S_i(\mathbf{x}))\ dF_{\mathbf{Z}|\mathbf{X}\theta} dF_{\mathbf{X}|\theta} dF_{\theta}$$

- System S_1 is preferred to S_2 if $E(u(S_1)) > E(u(S_2))$

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Pareto Frontier

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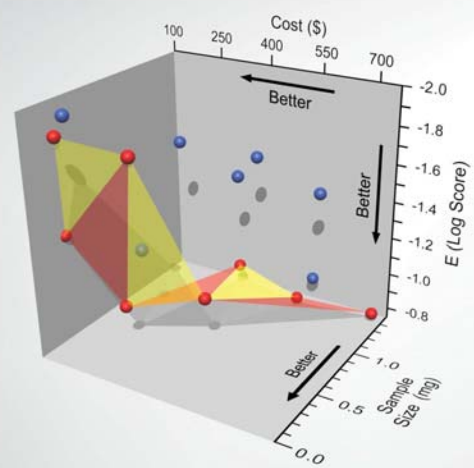

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Additional Signature Discovery Capabilities

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- Which variables in my data relate best to my target?
- Under what conditions does sensor performance fall off?
- Can we sample data as it's collected and reconstruct the original?
- How do we influence machine learning with expert opinion?
- Can we initiate data processing at the sensor and reduce I/O demands?
- Can we merge measurement and unstructured data and assign confidence to outcomes?
- How do we assess relative similarity in changing environments?
- Are there ways to graph complex data and detect changes over time?
- Can we construct a tools environment for signature discovery?
- Can we ease user access to signature discovery tools?

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Velocity

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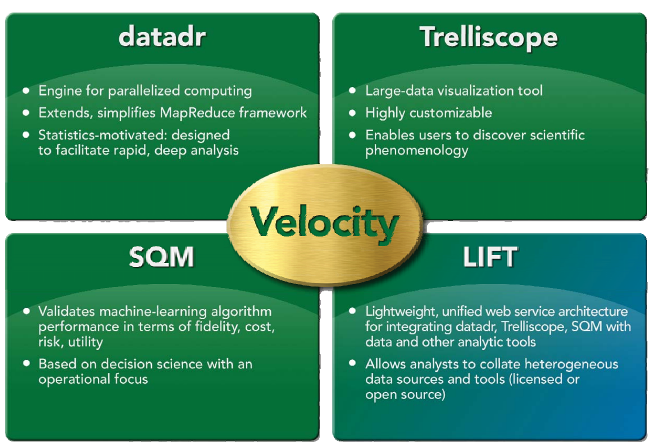

DHS, HSARPA – Steve Dennis and Meredith Lee

18

Questions

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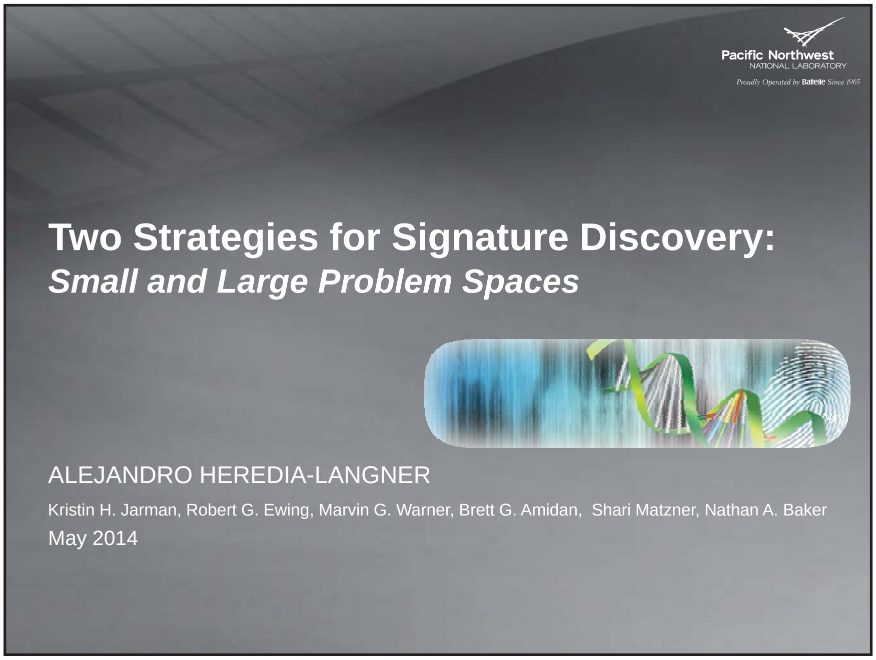
16.18 Alejandro Heredia-Langner: Two Strategies for Signature Discovery: Small and Large Data Spaces



Small Problem Spaces
Statistically Designed Experiments

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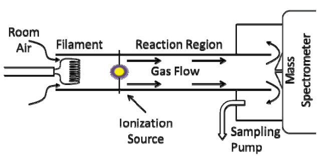
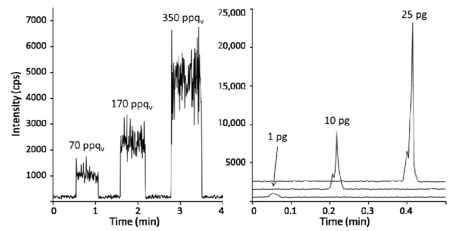
- Optimization of a signal from an atmospheric flow tube Mass Spectrometer (AFT-MS) sensor for RDX detection
- Detection of vapors from explosives is an important goal in screening
- It would allow for non-contact screening and sampling of large areas quickly
- Concentrations in air are considerably lower than saturated levels





We need to understand the effect of experimental factors

3

One of the experimental designs

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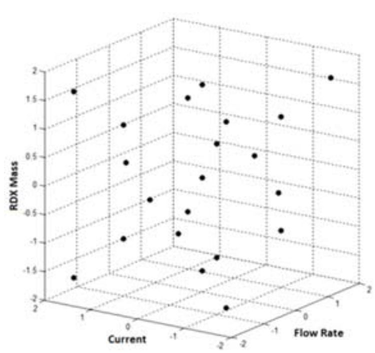
- Three relevant factors
- Seek conditions that maximize peak height



Flow Rate (L/min)	Current (A)	RDX mass (pg)	Peak Height
4.5	0.8	25	9080
3	0.56	10	1060
3	1.04	40	2100
6	1.04	10	5900
4.5	0.8	25	9200
6	0.56	40	5040
3	0.56	40	2140
3	1.04	10	3220
6	1.04	40	20880
4.5	0.8	25	10100
6	0.56	10	1180
4.5	0.8	25	5740
2	0.8	25	720
4.5	0.8	25	7480
4.5	0.8	50	24000
4.5	0.4	25	1380
4.5	0.8	0.2	0
7	0.8	25	15420
4.5	1.2	25	18200
4.5	0.8	25	10220
7	0.4	50	2980
2	0.4	50	1500
2	1.2	50	5800
7	1.2	0.2	960
2	0.4	0.2	0
2	1.2	0.2	0

4

Prediction model and results

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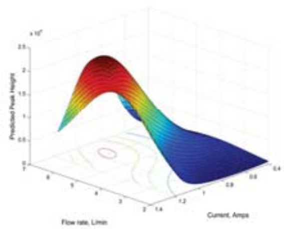

- Region of maximum signal is relatively broad and remains stable for varying RDX masses
- RDX amounts below 0.2 pg were difficult to distinguish from noise
- %RSD of signal remained 20-40%

- Air samples collected from a shipping container showing RDX concentrations in the range of 1 to 50 ppqv
- Less than 5 min sampling time

5

What if we cannot use designed experiments?

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- In many cases, we may not even know which variables to examine
- The problem space may be too large to consider optimization using highly fractionated factorial (or other types) of designs

6

Large Problem Spaces
A different approach needed

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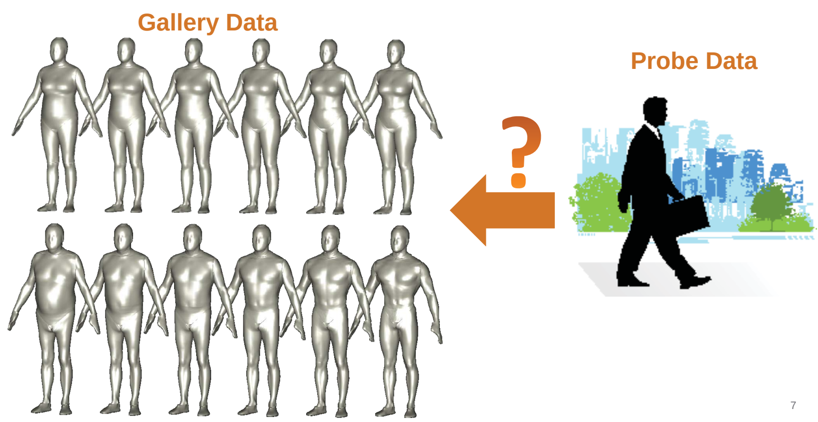
- Consider a re-identification problem: Recognizing a person (or object) previously observed, and for whom some information is available



7

Re-identification when Gallery and Probe Sets Differ

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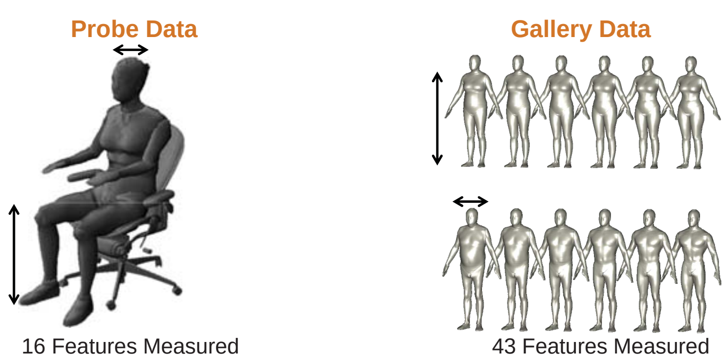
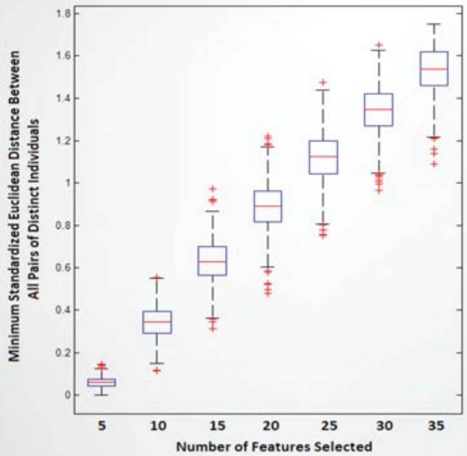
CAESAR database: 2378 individuals, data for seated & standing positions



- How do we re-identify a person in our gallery if all we have is probe set data?
- Solution usually expressed as *Rank*

8

Evidence indicates very few features are needed to unambiguously re-identify an individual if gallery set data is available and remains unchanged



9

Modeling

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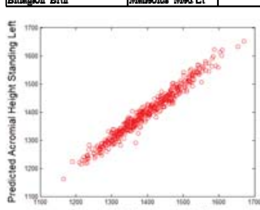
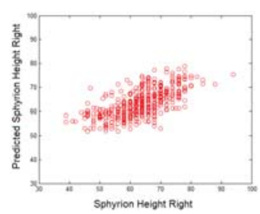
Gallery Set

Feature Name	Feature Name	Feature Name
Acromial Ht Stand Lt	Bitrochant.Brth Stand	Malleolus Med Rt
Acromial Ht Stand Rt	Bustpoint Brth	Neck Ht
Acromion-Radiale Len Lt	Cervicale Ht	Radiale-Stylion Lt
Acromion-Radiale Len Rt	Chest Ht Stand	Radiale-Stylion Rt
Ankle Ht Lt Malleolus,Lat Lateral)	Elbow Ht Stand Lt	Sellion Supramenton
Ankle Ht Rt Malleolus.Lat Lateral)	Elbow Ht Stand Rt	Sleeve Outseam Lt
Arm Inseam Lt	Foot Brth Lt	Sleeve Outseam Rt
Arm Inseam Rt	Foot Brth Rt	Sphyrion Ht Lt
Axilla Ht Lt	Infraorbitale Ht Lt Stand	Sphyrion Ht Rt
Axilla Ht Rt	Infraorbitale Ht Rt Stand	Suprasternale Ht
Biacromial Brth	Inter-pupillary Dst	Trochanterion Ht Lt
Bicristale Brth	Interaeye Dst Stand	Trochanterion Ht Rt
Bigonial Brth	Knee Ht Stand Lt	Waist Back
Bispinous Brth	Knee Ht Stand Rt	
Bitragion Brth	Malleolus Med Lt	



$f(\vec{x})$



Probe Set

Feature Name
Acromial Ht Sit Lt
Acromial Ht Sit Rt
Bi-lateral Femoral Epicondyle Brth Sit
Bi-lateral Humeral Epicondyle Brth Sit
Bitrochanteric Brth Sit
Buttock to Trochanter Lth
Femoral Epicondyle Lat to Malleolus Lat Lt
Femoral Epicondyle Lat to Malleolus Lat Rt
Infraorbitale Ht Sit Lt
Infraorbitale Ht Sit Rt
Trochanter to Femoral Epicondyle Lat Lt
Trochanter to Femoral Epicondyle Lat Rt
Trochanter to Seated Surface Lt
Trochanter to Seated Surface Rt
Elbow Ht Sit Lt
Elbow Ht Sit Rt

10

Genetic Algorithms (GA)

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- Optimization approach loosely based on Darwin's theory of evolution
- Useful to explore large problem spaces
- No guarantee of optimality, computationally expensive

Models for Gallery features, use/not use(1/0)

1	0	0	1	...	1	0	0	R^2_{th}	*train#*
$f_1(\bar{x})$	$f_2(\bar{x})$	$f_3(\dot{x})$	$f_4(\bar{x})$	$\cdots$	$f_{41}(\bar{x})$	$f_{42}(\bar{x})$	$f_{43}(\dot{x})$		

- Recombination, selection, mutation – apply until convergence
- Running algorithm multiple times is not a bad idea

11

Results

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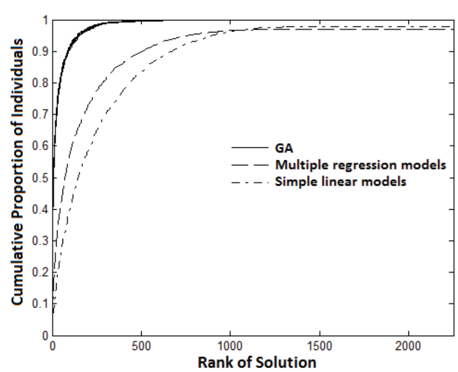
- Multiple regression: All features, all individuals
- Simple linear regression: All features, all individuals
- GA
  - R2 threshold ~0.87
  - ~300-400 individuals training set
  - ~12-20 Gallery features selected

Feature Name	Feature Name
Acromial Ht Stand Lt	Infraorbitale Ht Lt Stand
Acromial Ht Stand Rt	Infraorbitale Ht Rt Stand
Acromion-Radiale Length Lt	Knee Ht Stand Rt
Acromion-Radiale Length Rt	Sleeve Outseam Len Lt
Axilla Ht Lt	Trochanterion Ht Lt
Bitrochanteric Brth Stand	Trochanterion Ht Rt



Problem Space searched by GA has ~9×10^{12} solutions

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Final remarks

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- Designed experiments and GA both change factor levels simultaneously
- Both estimate factor effects – explicitly or implicitly
- Both guide the search to an optimal region
- Statistically Designed Experiments – Search is more systematic and thorough & allows for testing of specific hypotheses
- GA are very flexible and a good choice when deterministic methods cannot be used

13

Thank you!

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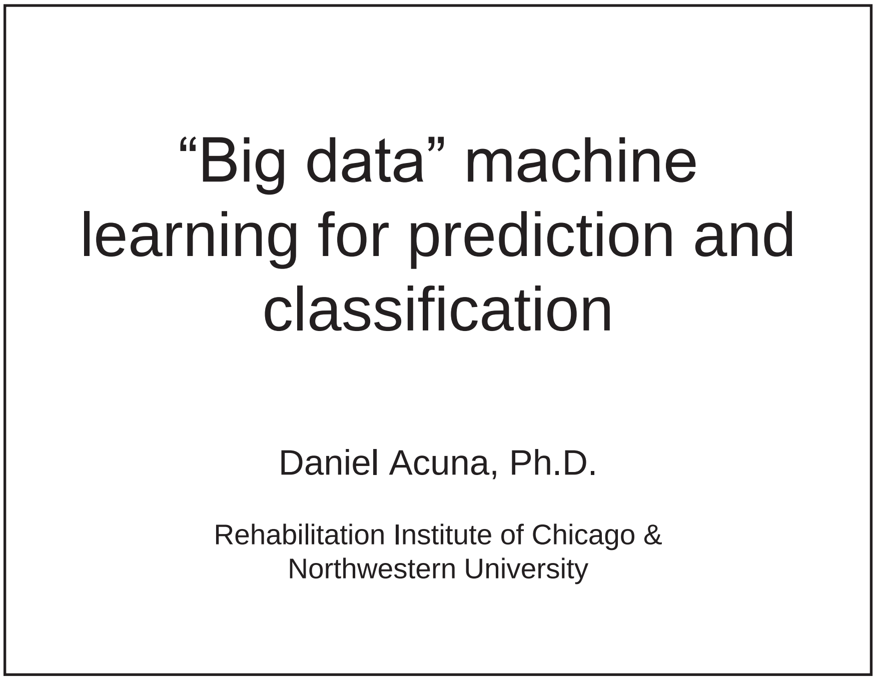
Learn more about the Signature Discovery Initiative at http://signatures.pnnl.gov
or contact Nathan Baker nathan.baker@pnnl.gov

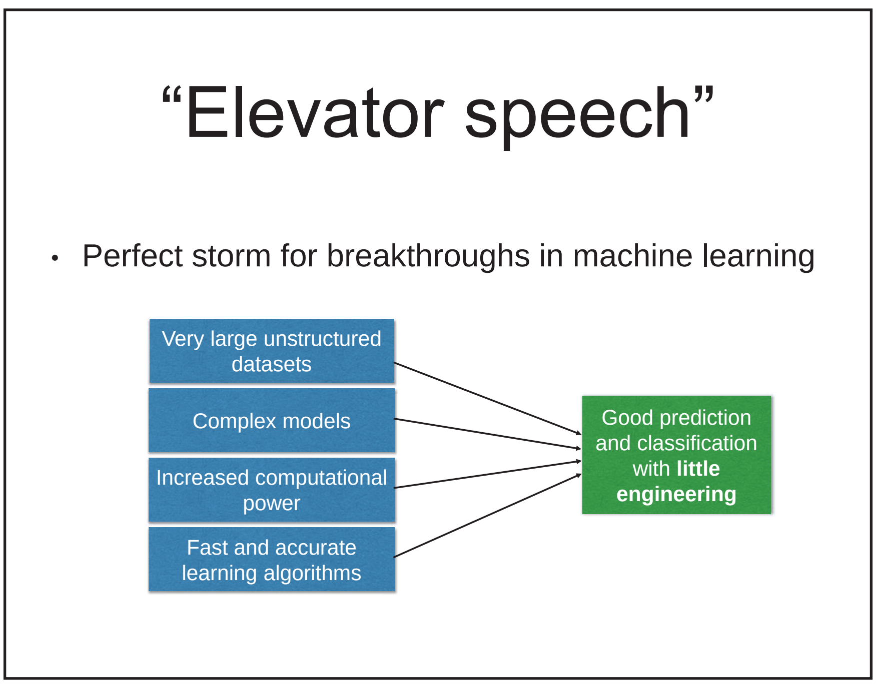
- Comments for Alejandro (Alejandro.Heredia-Langner@pnnl.gov)

The research described in this presentation is part of the Signature Discovery Initiative at Pacific Northwest National Laboratory (PNNL). It was conducted under the Laboratory Directed Research and Development Program at PNNL, a multi-program national laboratory operated by Battelle for the U.S. Department of Energy.

14

16.19 Daniel Acuna: "Big Data" Machine Learning for Prediction and Classification



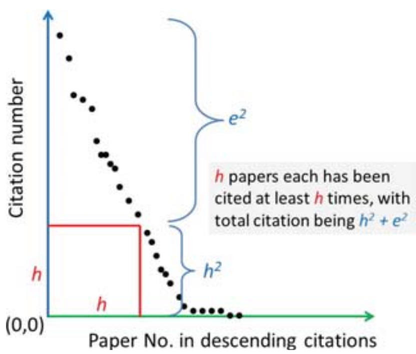


Predicting scientific success

- Typically done by a committee of experts based on education, awards, experience, publications, and funding.

Quantitative measure of scientific "success"

- h-index: Measure of scientific "success"

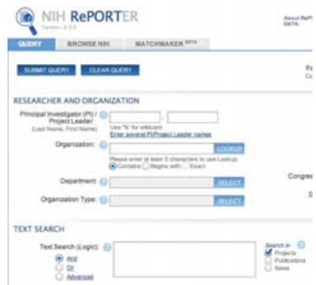


Index of success using "big data"?

- Combining large datasets from heterogenous sources

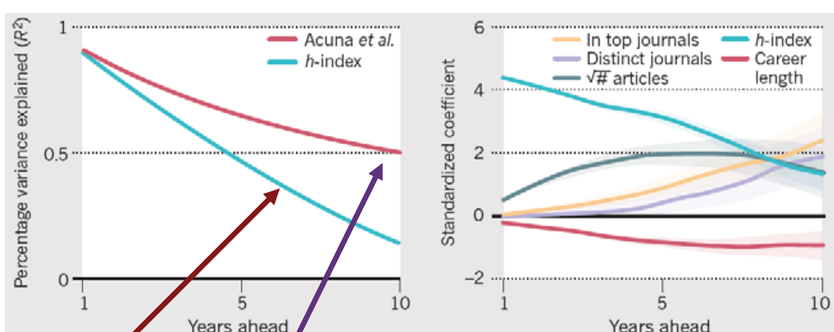
Publications

Funding



Collaboration

Predicting scientific "success"

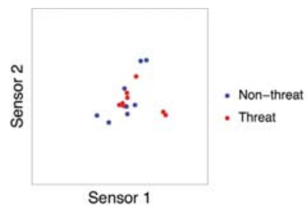


"small data"

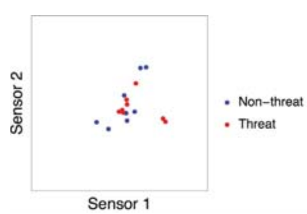
"big data"

Acuna et al., Nature, 2012

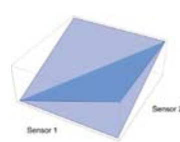
Why "big data" works?



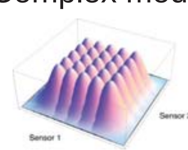
Why "big data" works?



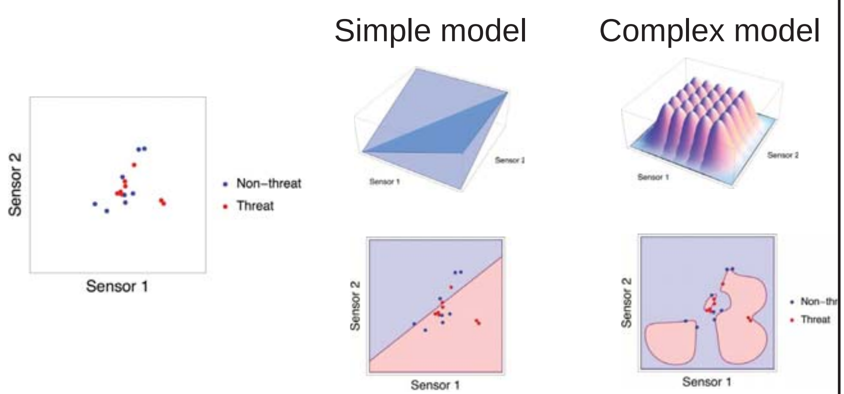
Simple model



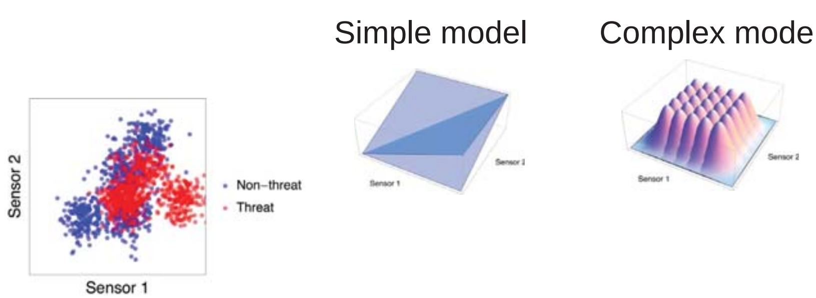
Complex model



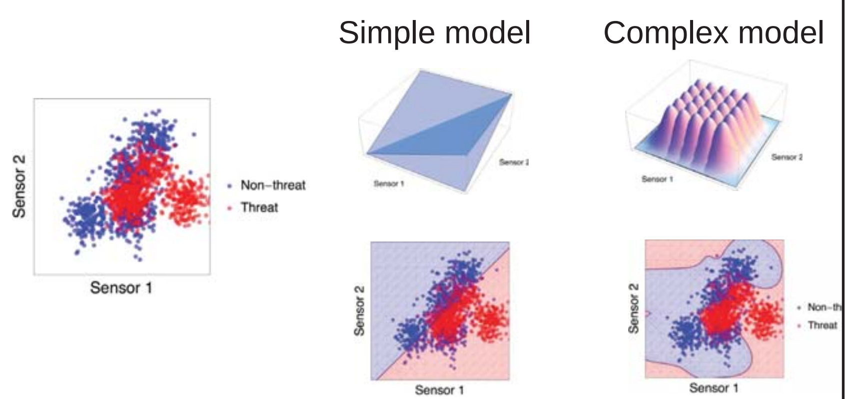
Why "big data" works?



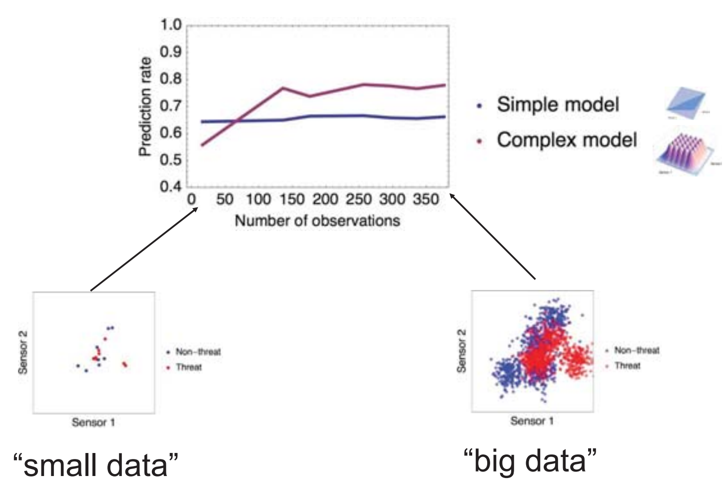
Why "big data" works?



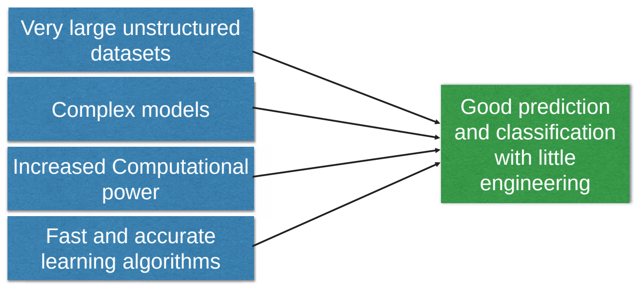
Why “big data” works?



Why “big data” works?



“Big data” machine learning for prediction and classification



Daniel Acuna, Ph.D.

Rehabilitation Institute of Chicago &
Northwestern University

16.20 Carl Crawford: Call to Order/ADSA11

Tenth Advanced Development for Security Applications Workshop (ADSA10):

Explosives Detection in Air Cargo

Call To Order
Day 2

Carl R. Crawford
Csuptwo, LLC

1

Reminders

- Fill out questionnaire on Survey Monkey
- End at 4:00 PM today
  - Please stay to end if possible
- Comments welcome after conclusion

2

ATR Project (Task Order 4)

- Status meeting today at 4:30 at Stearns 431
- All are welcome

3

ADSA11 Possible Topics

- Cargo II – Screening v. scanning
  - Risk based, ATR, manifest, canine, cost models, deterrence
- Computer simulations
  - X-ray transmission, back-scatter, diffraction, MMW, neutrons
  - Standardized phantoms
- Application of micro-CT
  - Training/testing
  - Scanner transfer functions
- Improving statistical significance of testing
- Video analytics
- Risk-based screening & gaming theory

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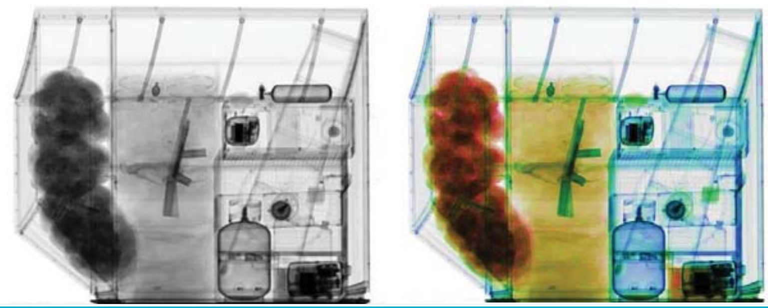
16.21 Nick Cutmore: Cargo Scanning with X-Rays and Neutrons and the Challenge of Effective Detection



Cargo scanning with X-rays and neutrons and the challenge of effective detection

Dr Nick Cutmore, Dr James Tickner & Dr Yi Liu
CSIRO **MDU Flagship**

ADSA10 – Explosive Detection in Air cargo, Northeastern University, Boston, May 6-7, 2014

MINERALS DOWN UNDER FLAGSHIP
www.csiro.au

CSIRO

Air Cargo Scanning

- Only a small fraction of global air cargo is currently examined *physically*
- Cargo volume and levels of scrutiny are expected to increase
- Wide range of potential threats – explosives, weapons, narcotics, prohibited materials, etc
- CSIRO and Nuctech have developed a fast-neutron/X-ray scanner to address the problem

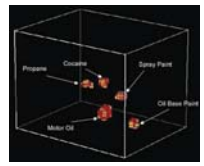
Major challenges

- Scanner - footprint, speed, reliability
- Imaging – small objects in large cargo
- People – effective process

2 |

CSIRO

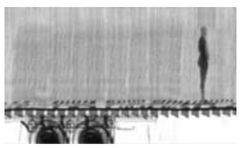
Technology comparisons



3D 'voxel' techniques
Complex, large systems
3D material discrimination

Add parallel neutron source and detectors to X-ray scanner

Neutron radiography
Commercially available
3D material discrimination possible with advanced software tools

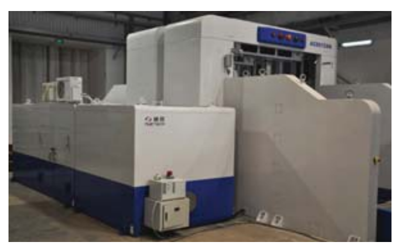


Conventional X-ray
Wide-spread deployment
Little or no material discrimination

High-power accelerator neutron source
Large gamma-ray detection system

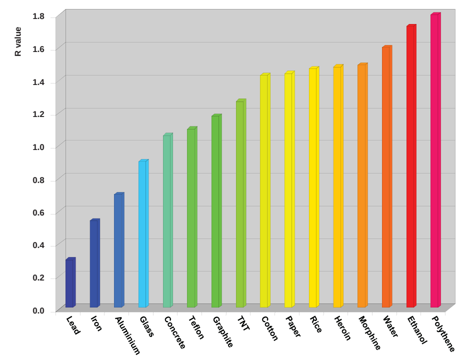
AC6015XN Air Cargo Scanner

- Incorporates 6 MV X-ray LINAC and 14 MeV neutron source
- Scanning speed up to 6 m/min (10 cm/sec)
- Small commercial neutron generator ($5x10^8$ n/s)
- Modular construction for rapid assembly on airport site



4 |

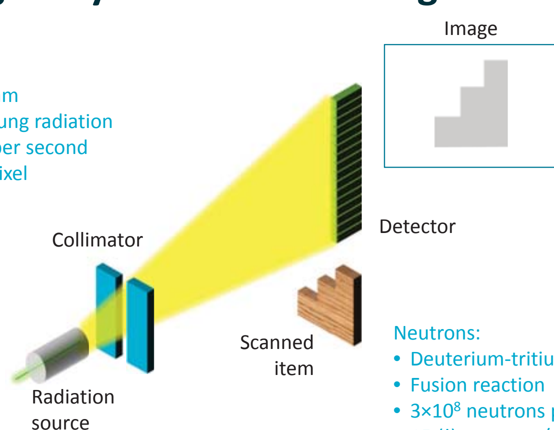
Combined X-ray/neutron imaging



5 |

Collecting X-ray and neutron images

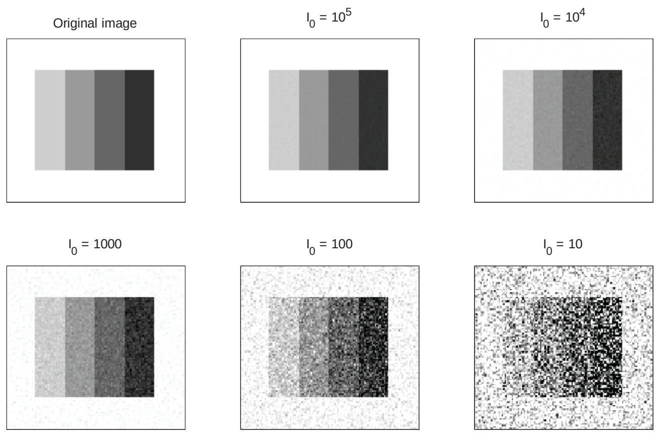
X-rays:
- Electron beam
- Bremsstrahlung radiation
- 10^{13} X-rays per second
- 10^{5} X-rays/pixel



Neutrons:
- Deuterium-tritium beam
- Fusion reaction
- 3×10^{8} neutrons per sec
- 15 (!) neutrons/pixel

6 |

Statistics and image quality



7 |

Solution (1) – improved neutron detectors

- Major technology development over past decade
- Basic detector element comprises plastic-scintillator, solid-state photodetector, discriminators and counting electronics
- Main drivers - Increased efficiency, reduced form-factor/power consumption/cost, automated calibration and fault-finding

Prototype	Mark 1+2	Mark 3
1 column	4 columns	6 columns
<10% efficiency	10% efficiency	30% efficiency
	×4 overall gain	×20 overall gain

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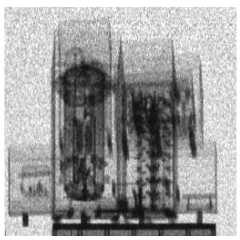
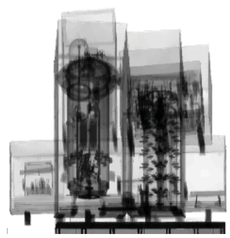
Solution (2) – Image Filtering

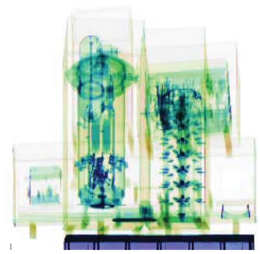
- Problem – low SNR makes it impossible to discriminate real features from noise
- Images of real objects exhibit a high degree of spatial coherence
- Solution – custom image filtering using both neutron and X-ray data



Raw neutron image



Filtered neutron image



Combined image

9 |

Effective detection

Scanner

Distinctively shaped items need:

- High-resolution images
- Good penetration

→ **Driven by X-ray performance**

Quantitative materials detection needs:

- Good image filtering
- Accurate R-value determination
- Tools to handle overlapping materials

Process

Agreed image analysis process that optimises detection :

- “Hardwired” image assessment process?
- Adequate training

Efficient targeting and handling strategy for bulk cargo

- Customised to client logistics
- Speed important at cargo hubs

10 |

Conclusions

Fast-neutron/X-ray radiography proven for air cargo assessment.

- Scanner footprint being optimised for differing applications
- Reliability of systems optimised
- Imaging quality – enhanced through new filtering approaches
- Effective detection – further work progressing with clients

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Thank you

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Theme Leader
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16.22 Jens Gregor: Quantitative and Qualitative Approaches to Neutron Imaging

Summary and Conclusions

- Neutron imaging and X-ray CT similar/complementary
- Presence of fissile material can be quantified using non-traditional / low resolution imaging geometry
- Standard tomographic techniques allow quantitative high-resolution imaging of hydrogeneous material
- Coded source based data acquisition facilitates higher resolution imaging without loss of much needed flux
- Can be combined with X-ray CT, SPECT (not shown)

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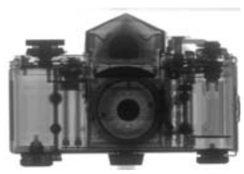
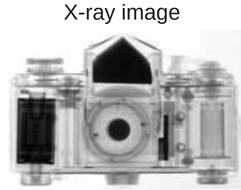
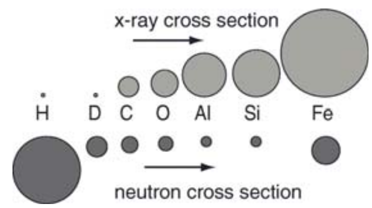
Neutron vs X-ray Imaging


X-ray image


Neutron image

http://www.psi.ch/niag/what-is-neutron-imaging



Macroscopic cross-section, Beer's Law:

$$\Sigma = N\ N_A/M\ \rho\ [cm^{-1}]$$

$$I_1 = I_0 \exp(-\textstyle\int_L dl\ \Sigma)$$

N: atomic number, N_A: Avagadro's number
M: molar mass, ρ: material density

APNEA 1: Fissile Material

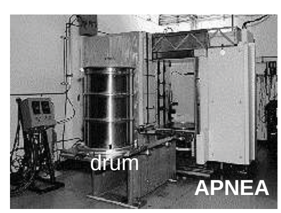
D.C. Hensley, ORNL/NorthWest Nuclear LLC

- Non-destructive assay, examination of waste drums
- Passive: single (α,n) reactions, correlated events
- Active: pulsed thermal neutrons, differential dieaway

- Imaging equations: y = E m

Single: $y_{d\theta} = \Sigma_v\ e_{d\theta v}\ m_v$
Corr.: $y_{d\theta} = \Sigma_v\ e_{\theta v}\ e_{d\theta v}\ m_v$
Active: $y_{d\theta} = \Sigma_v\ e_{d\theta v}\ f_{\theta vt}\ m_v + h_{dt}$

y=yield, e=detector efficiency, m=mass, f=flux
d=detector pack, v=voxel, θ=rotation angle, t=time



APNEA 2: Least Squares Formulation

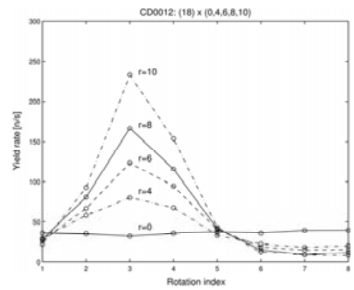
- LSQR used to solve penalized least squares problem

$$m = \text{argmin} \mid E\,m - y \mid^2 + \Sigma\, \beta_i \mid H_i\, m - z_i \mid^2$$

- Concentrated vs uniformly distributed source material
- Drum model (image)

Segments

Core
Wedges



APNEA 3: Example Results

- ^{252}Cf point source embedded in soil: true rate 9,555 n/s

Location: r=0" (core)

Total activity = 9478.1
Min, max levels = 0.0 9345.0

HEIGHT	0	6	12	18	24	30		TOTAL
CORE	0	0	0	986*	0	0	=	986
AZ 1	0	0	0	0	0	0	=	0
AZ 2	0	0	0	0	0	0	=	0
AZ 3	0	0	0	0	0	0	=	0
AZ 4	0	0	0	0	0	0	=	0
AZ 5	0	0	0	10	0	0	=	10
AZ 6	0	0	0	0	0	0	=	0
AZ 7	0	0	0	2	1	1	=	4
AZ 8	0	0	0	0	0	0	=	0
AZ SUM	0	0	0	12	1	1		
TOTAL	0	0	0	998	1	1		

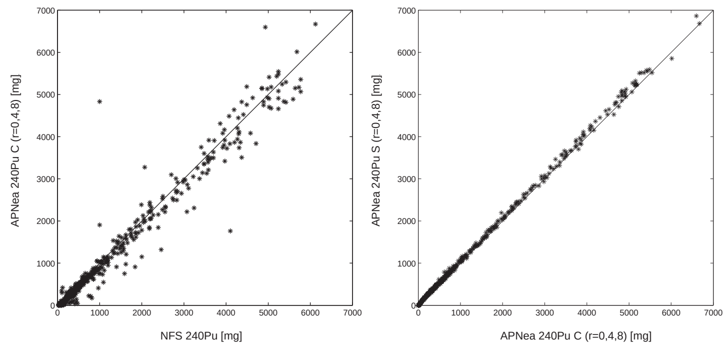
Location: r=6" vs 0,8" for model

Total activity = 8210.0
Min, max levels = 0.0 5962.4

HEIGHT	0	6	12	18	24	30		TOTAL
CORE	0	0	0	0	0	0	=	0
AZ 1	0	0	0	0	0	0	=	0
AZ 2	0	0	1	9	0	0	=	10
AZ 3	1	0	12	12	0	0	=	25
AZ 4	0	0	0	20	4	0	=	24
AZ 5	0	0	0	0	0	0	=	0
AZ 6	0	0	41	44	0	0	=	85
AZ 7	0	0	32	726*	57	0	=	815
AZ 8	0	0	0	0	25	16	=	41
AZ SUM	1	0	86	811	86	16		
TOTAL	1	0	86	811	86	16		

APNEA 4: Example Results

- D&D waste from Nuclear Fuel Services (Erwin, TN)
- ^{240}Pu embedded in soil – sample size of 528 drums



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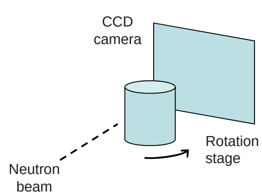
HFIR 1: Tomographic Imaging

T. Toops and C. Finney, ORNL / NTRC

- CG-1D beamline at High-Flux Isotope Reactor (HFIR)
- High-resolution cone beam tomography (proj. based)
- SIRT used to solve weighted least squares problem

$$x = \operatorname{argmin} | A x - b |_w^2 + \beta | x |^2$$



CCD array:	2048 x 2048
Angular incr.:	< 1º
Exposure time:	30-240s
Angular range:	180º + fan
Image resolution:	40 um

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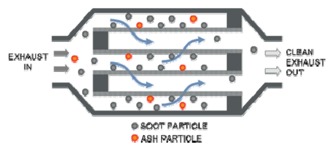
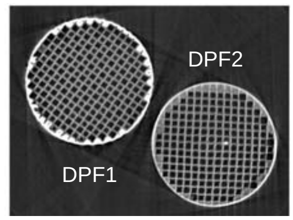
HFIR 2: Diesel Particulate Filter

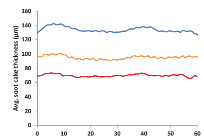
- Diesel particulate filter (DPF) traps soot, particulate matter
- Quantify deposit / regeneration



- Differences in inlet and outlet channel open areas correlate with average deposit build-up

Cross-sectional image





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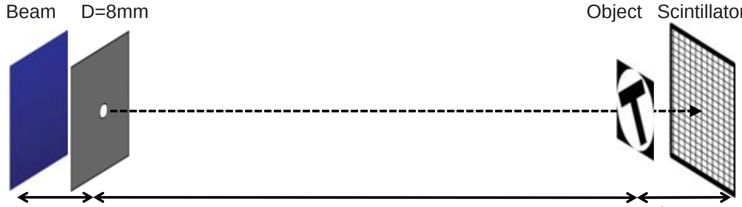
Coded Source 1: Improved Resolution

P. Bingham and H. Santos-Villalobos, ORNL

- HFIR guide set-up leads to near-parallel neutron beam
- System design trade-off: flux α D, resolution α L/D, 1/d



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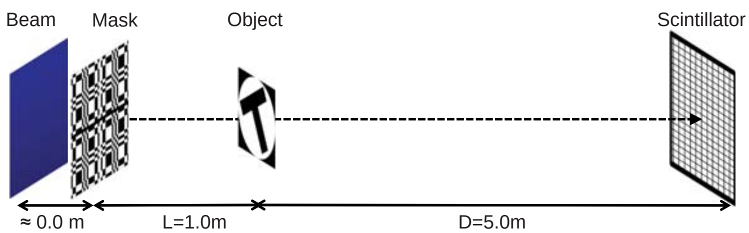
Coded Source 2: Mask Aperture

- Detector resolution limit overcome thru magnification
- Small pinhole = resolution, many pinholes = more flux
- Overlapped projections ➔ radiographic reconstruction



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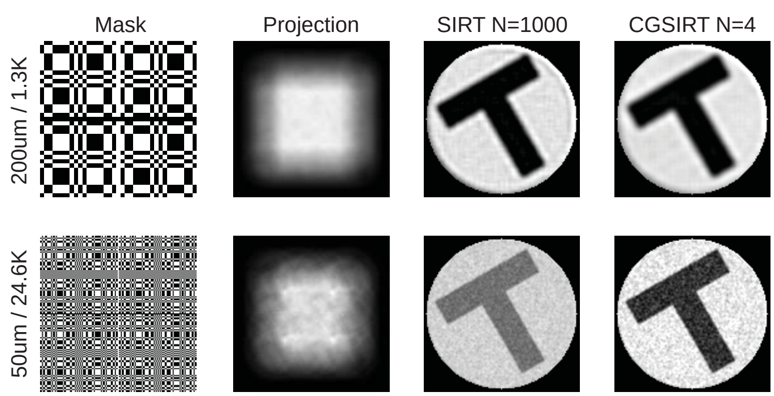
Coded Source 3: Example Results



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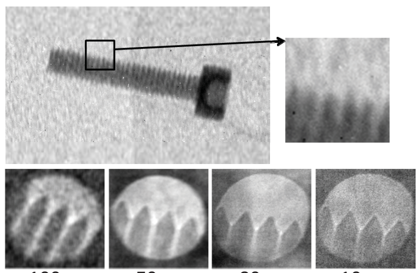
Code Source 4: Example Results

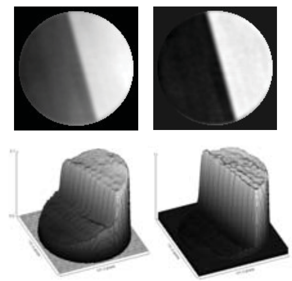
- Convolution reconstruction of metal screw: HFIR data
- Iterative reconstruction of wedge: simulated

Direct imaging at top. Coded source at bottom.



100um 50um 20um 10um

SIRT N=100 CGSIRT N=4



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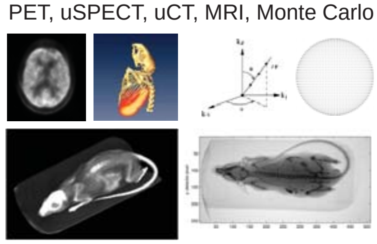
Related Imaging Research Examples

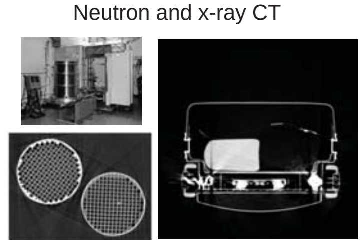
Medical, preclinical imaging

PET, uSPECT, uCT, MRI, Monte Carlo



Industrial, security imaging

Neutron and x-ray CT



- Statistical, algebraic reconstruction algorithms and Feldkamp
- Academic proof-of-principle and commercial/production code
- Participant: ALERT T03 Iterative Recon, T04 ATR Development

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16.23 Dan Strellis: From Steady State to Pulsed: A Review of Neutron Interrogation Techniques for Explosives Detection

Rapiscan systems
An OSI Systems Company

ONE COMPANY - TOTAL SECURITY

From Steady State to Pulsed: A Review of Neutron Interrogation Techniques for Explosives Detection

Dan Strellis

Rapiscan Laboratories

for

ADSA10

Boston, MA

May 2014

Rapiscan Systems Ltd. Cargo Division

So what? Who cares?

- Screening air cargo is difficult (adequately covered yesterday by Crawford, White, Garms, et al.)
- Neutron-based techniques offer a measurement of material specificity of the cargo that widely-deployed systems today cannot provide (examples also provided by Perticone, Cutmore, Gregor)
- Using neutrons faces many hurdles, even for situations when technology is demonstrated to work (ref. Martz): regulations, end-user acceptance, technology maturation
- Review of neutron techniques Rapiscan (or predecessors) has tried (and deployed in some instances) for air cargo screening

2

Rapiscan systems

Using Neutrons - Sources

Steady state ← | → *Pulsed*

Cf-252 spontaneous fission source

No timing

μs timing

dT 14MeV or 2.5MeV sources

Time-of-Flight (TOF) ns timing

dT – Associate particle imaging source

TOF ns timing

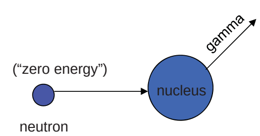
Van de Graff accelerators dD ~8MeV source

3 Rapiscan systems

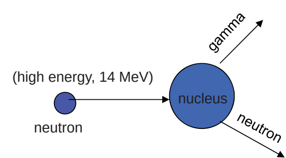
Using Neutrons – Basic Physics Principles

Two Primary Reactions Involved

- TNA **Thermal Neutron Analysis**
  - **"Room temperature" neutrons completely absorbed by material**
  - **Characteristic gamma ray identifies element**
- FNA **Fast Neutron Analysis**
  - **High energy (e.g. 14 MeV) neutrons "bounce" off material**
  - **Characteristic gamma ray identifies element**



Thermal neutron absorption reaction

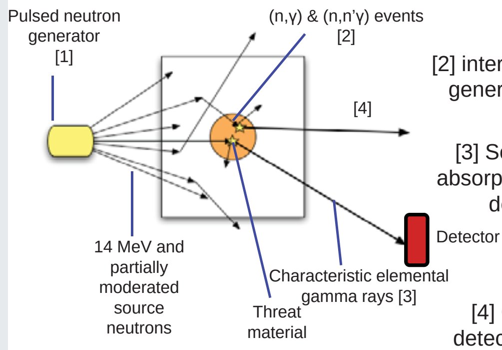


Inelastic scattering reaction

4 Rapiscan systems

Neutron-based Interrogation

[1] Source neutrons generated during the pulse. Some are partially moderated in the source spectrum tailoring system. These and the uncollided source neutrons can either interact in the cargo materials as fast neutrons, or thermalize and be absorbed in the cargo, leak out, or…



[2] interact with the threat elements and generate characteristic gamma-rays

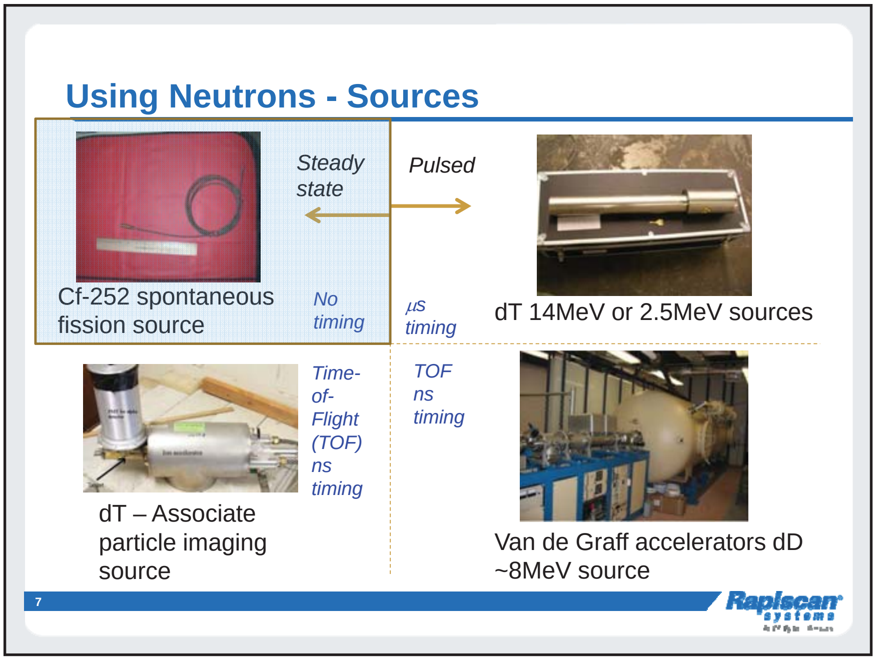
[3] Some of the gamma-rays escape absorption in the threat or cargo and are detected by system detectors

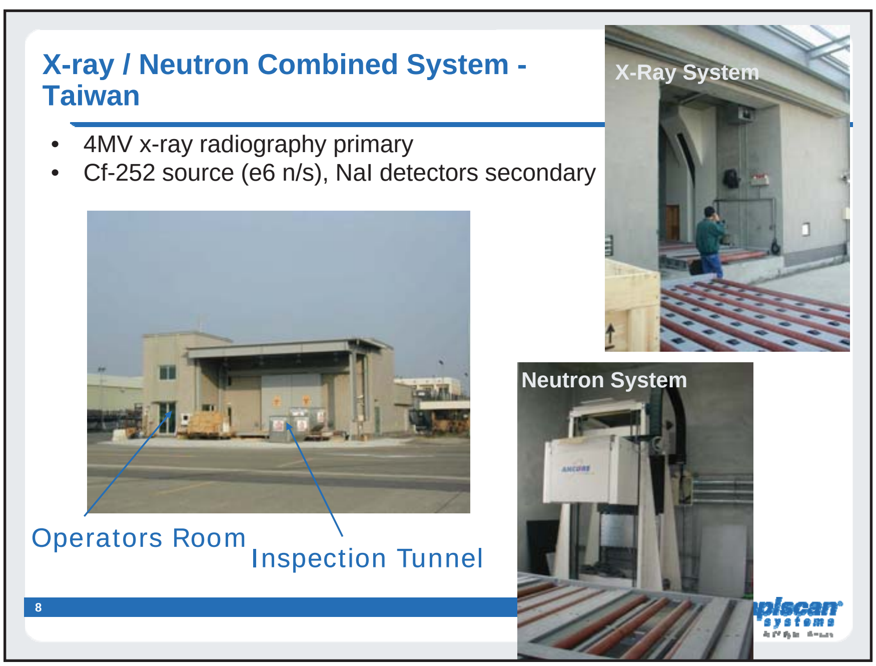
[4] Other gamma-rays escape detection by the system detectors

5

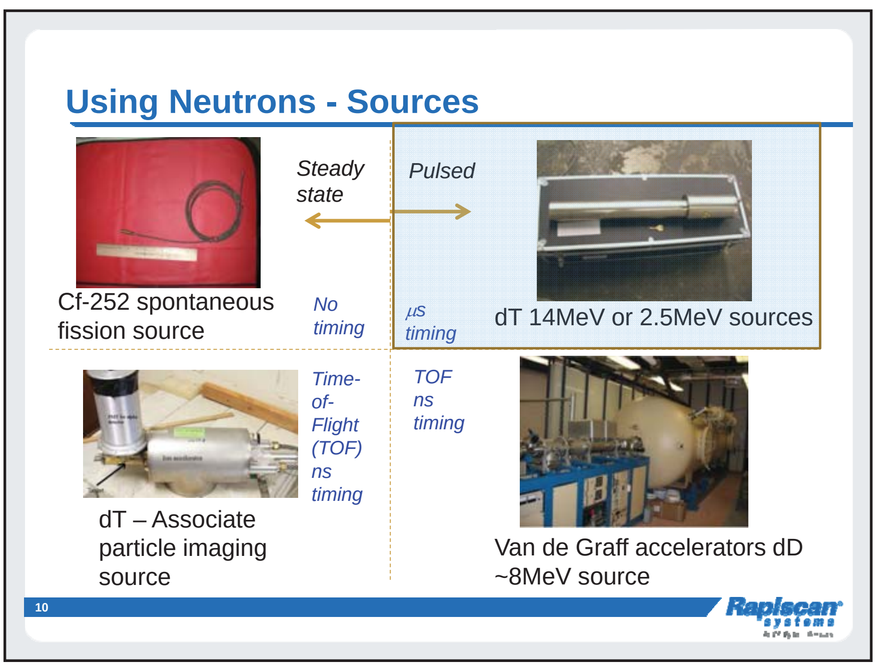
Bulk Measurement Techniques – non-TOF

6

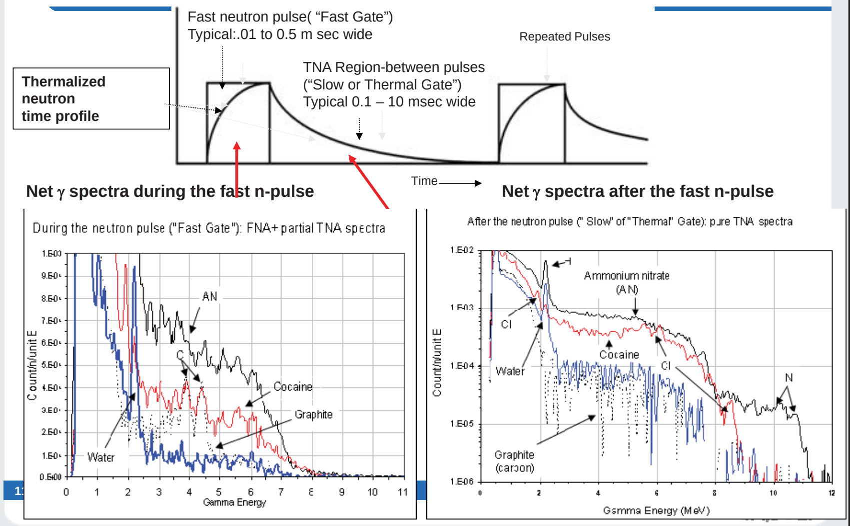

Using Neutrons - Sources
Steady state
Pulsed
Cf-252 spontaneous fission source
No timing
µs timing
dT 14MeV or 2.5MeV sources
Time-of-Flight (TOF) ns timing
TOF ns timing
dT – Associate particle imaging source
Van de Graff accelerators dD ~8MeV source
7
Rapiscan systems


X-ray / Neutron Combined System - Taiwan
X-Ray System
• 4MV x-ray radiography primary
• Cf-252 source (e6 n/s), NaI detectors secondary
Neutron System
Operators Room
Inspection Tunnel
8


Report on Newspaper (Liberty Times) dated June 30th 2004.
The drugs were hidden inside of laptop computer
The weight for these five pieces is 1028 g only.
(Total weight of drugs found was 4409g)
AKE 63070 CI
DRUGS
DRUGS
DRUGS
Taiwan AP Finds Drug in Cargo Container using Rapiscan 4MeV x-ray and Cf-252 based neutron combined system
手提電腦藏毒 闖關失敗
9
Rapiscan systems


Using Neutrons - Sources
Steady state
Pulsed
Cf-252 spontaneous fission source
No timing
µs timing
dT 14MeV or 2.5MeV sources
Time-of-Flight (TOF) ns timing
TOF ns timing
dT – Associate particle imaging source
Van de Graff accelerators dD ~8MeV source
10
Rapiscan systems

Conventional (microsecond) Pulsed Neutron Inspection



TOF Techniques

Using Neutrons - Sources

Steady state ← | → *Pulsed*

Cf-252 spontaneous fission source

No timing

µs timing

dT 14MeV or 2.5MeV sources

Time-of-Flight (TOF) ns timing

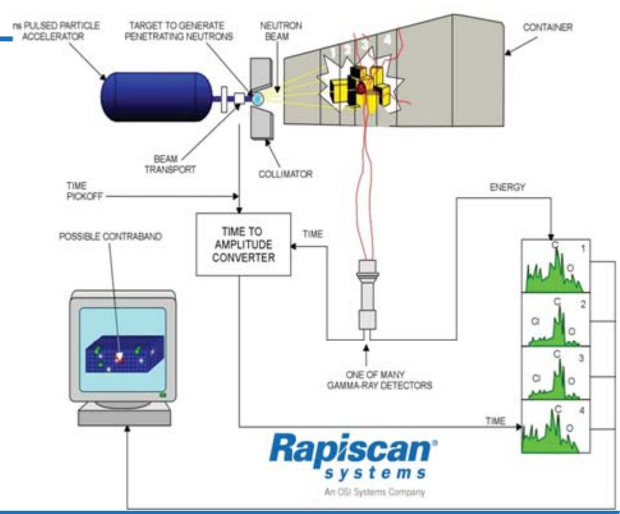
dT – Associate particle imaging source

TOF ns timing

Van de Graff accelerators dD ~8MeV source

13

PFNA Overview



14

PFNA Air Cargo Inspection Project

Support provided by TSA Contract (HSTS04-07-P-CTO099)

Collaborators at Continental Airlines

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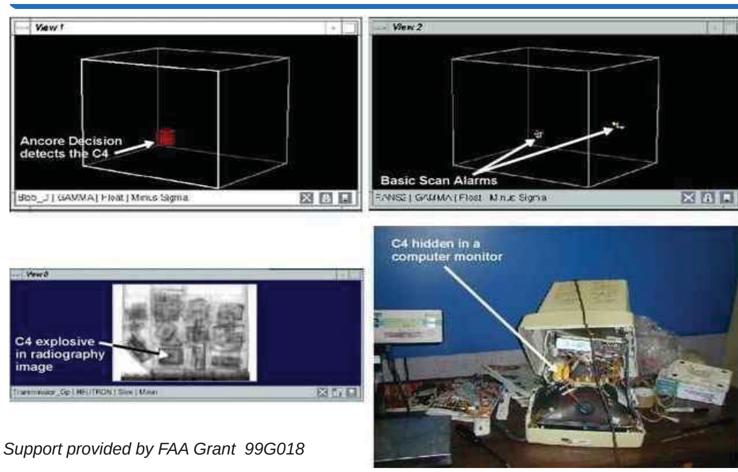
Rapiscan systems

Detection of C4 Explosive



Support provided by FAA Grant 99G018

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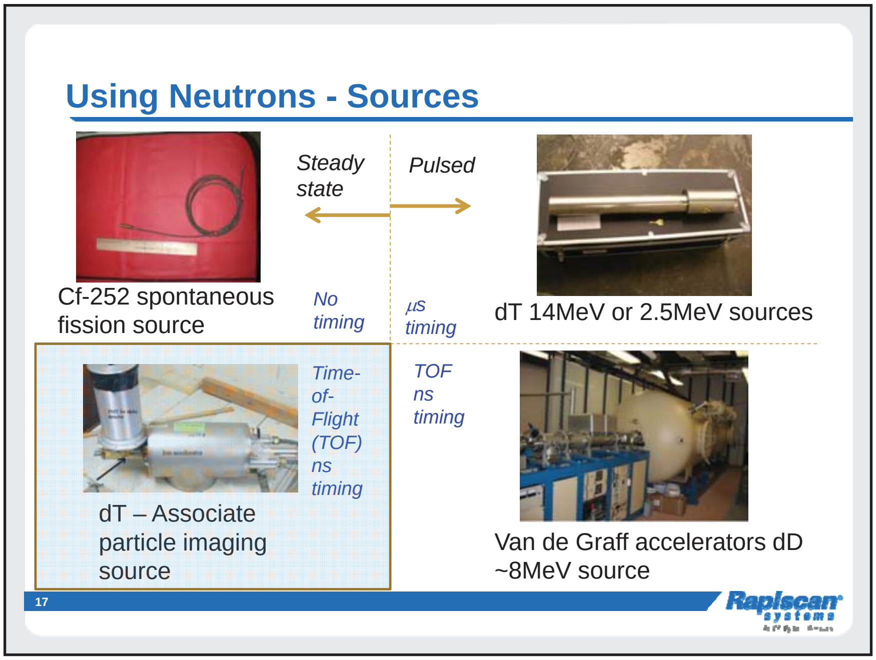
Rapiscan systems


Using Neutrons - Sources
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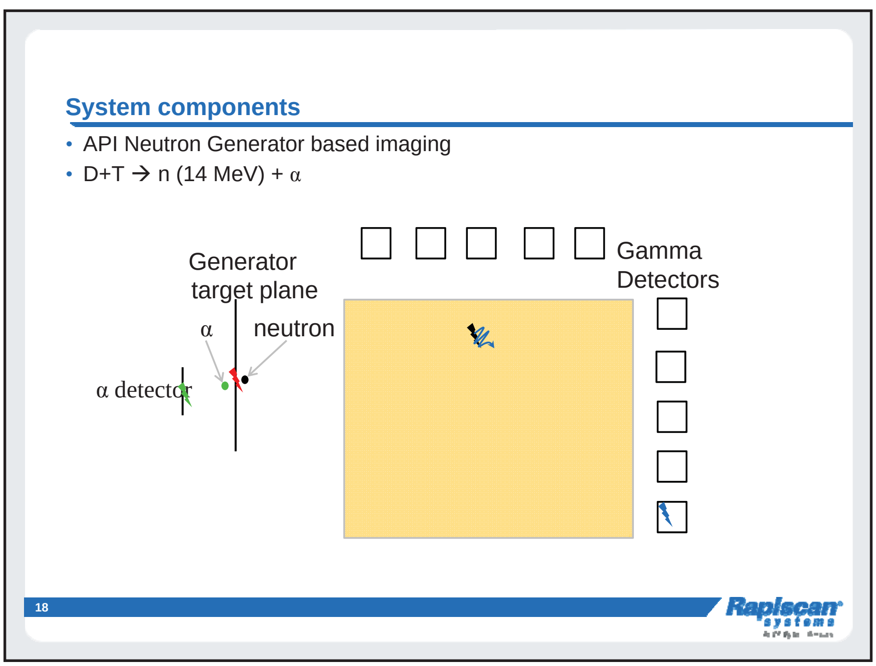
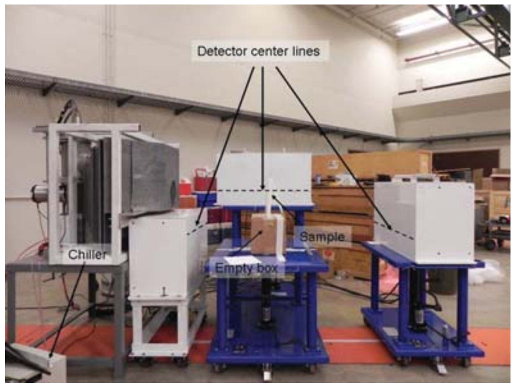
Pulsed
Cf-252 spontaneous fission source
No timing
µs timing
dT 14MeV or 2.5MeV sources
Time-of-Flight (TOF) ns timing
TOF ns timing
dT – Associate particle imaging source
Van de Graff accelerators dD ~8MeV source
17
Rapiscan systems


System components
• API Neutron Generator based imaging
• D+T → n (14 MeV) + α
Generator target plane
α
neutron
α detector
Gamma Detectors
18
Rapiscan systems

Experimental setup



Narcotics detection

Steel and paper cargoes

Support provided by DHS S&T Borders and Maritime Directorate CanScan Project

Collaborators at Purdue University – Applied Physics

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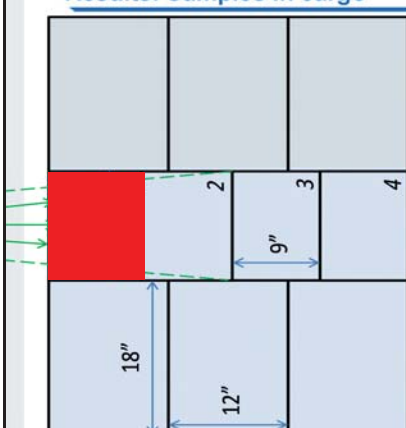
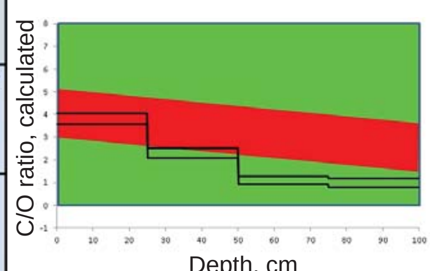
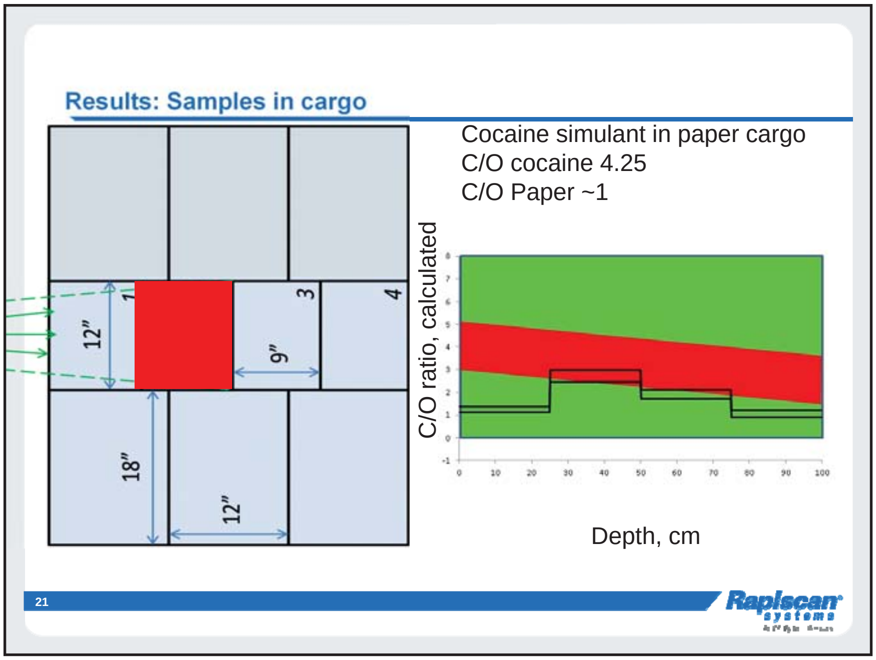
Results: Samples in cargo

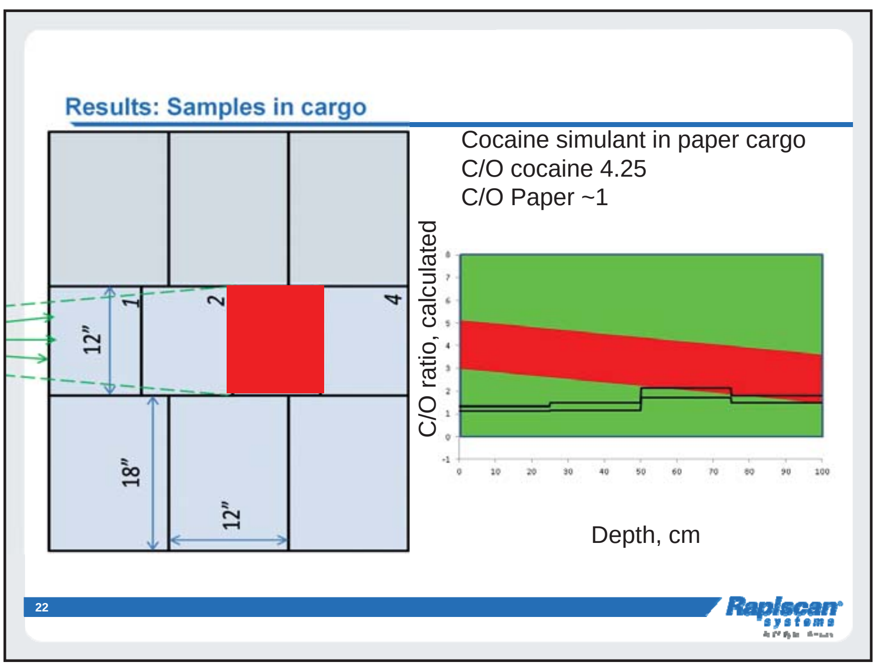


Cocaine simulant in paper cargo
C/O cocaine 4.25
C/O Paper ~1

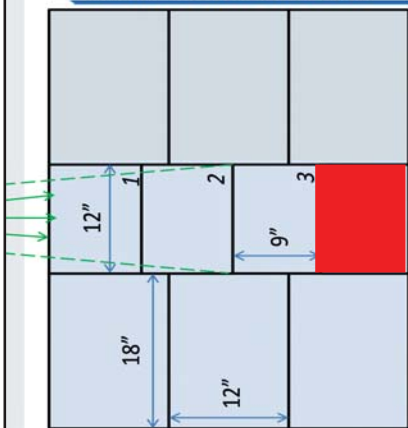


20

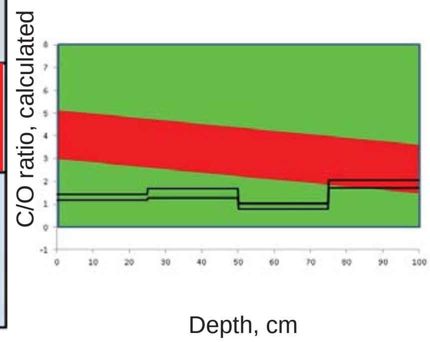

Results: Samples in cargo
Cocaine simulant in paper cargo
C/O cocaine 4.25
C/O Paper ~1
C/O ratio, calculated
Depth, cm
12”
9”
18”
12”
1
3
4
21
Rapiscan systems


Results: Samples in cargo
Cocaine simulant in paper cargo
C/O cocaine 4.25
C/O Paper ~1
C/O ratio, calculated
Depth, cm
12”
18”
12”
1
2
4
22
Rapiscan systems

Results: Samples in cargo



Cocaine simulant in paper cargo
C/O cocaine 4.25
C/O Paper ~1



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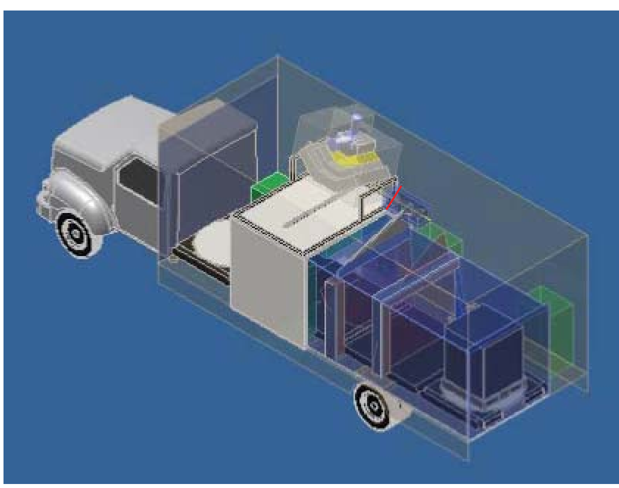
Rapiscan systems

DHS CanScan Prelim Design



- Multi-view x-ray with n cargo rotations for primary screening
- Pencil beam API for alarm clearing
- Mobile platform under 26k lbs

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Rapiscan systems

Summary on Neutron Techniques

- Rapiscan (and predecessors) have been studying neutron-based techniques for security applications for over 3 decades
- Neutron-based technologies are sensitive to elemental composition of the inspected objects, which allow in many cases to identify the materials of interest.
- Time-of-Flight (TOF) technologies allow obtaining elemental information as a function of depth to reduce the elemental superposition, and ultimately improve detection performance
- These techniques have been previously employed with some success.
- Hurdles still exist. Wide spread deployment could only come with:
  1) changes to regulations (like AT for checkpoint),
  2) public acceptance (like AIT), and
  3) possibly technology improvements (smaller and higher output sources)

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Backup

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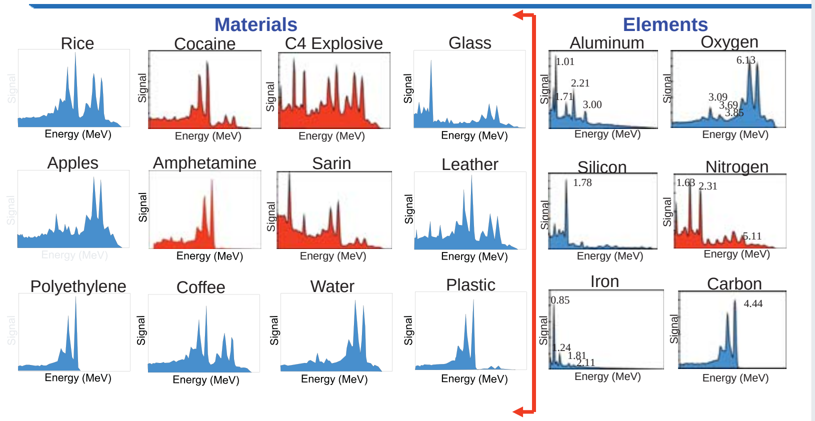
PFNA Material Signatures



The elemental signals combine to give unique material signatures.

The target data base can be continually updated.

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API components: shielding

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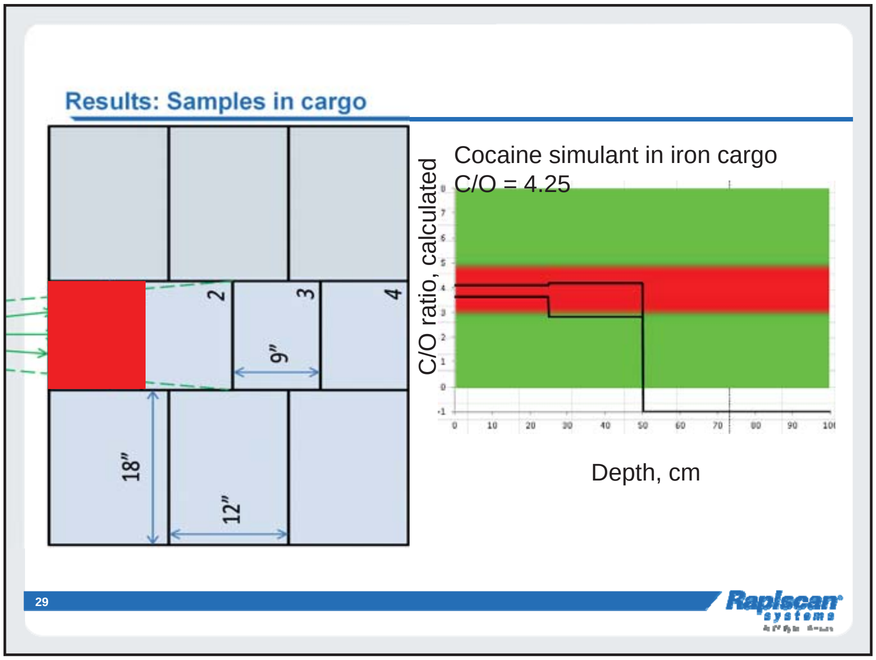
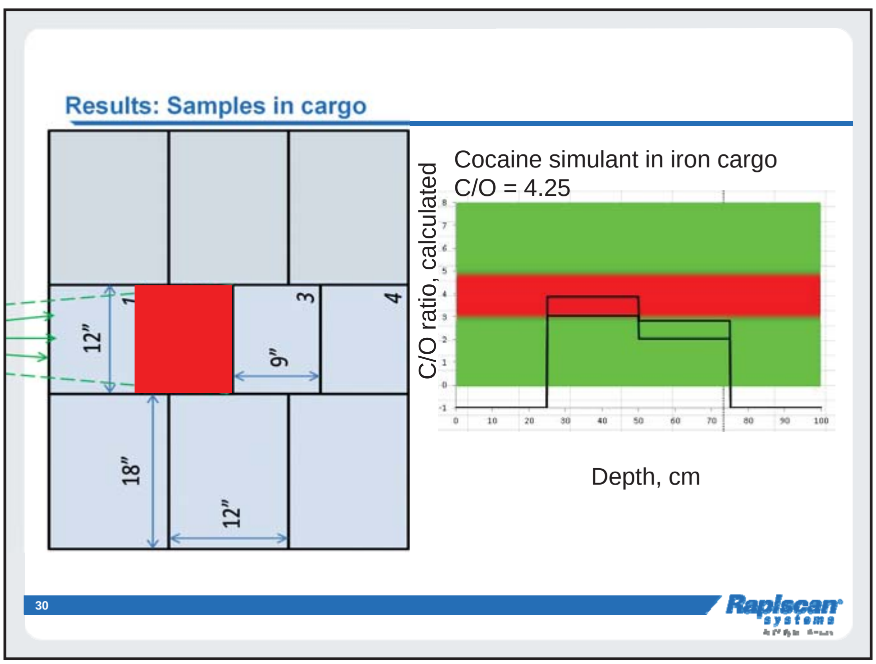
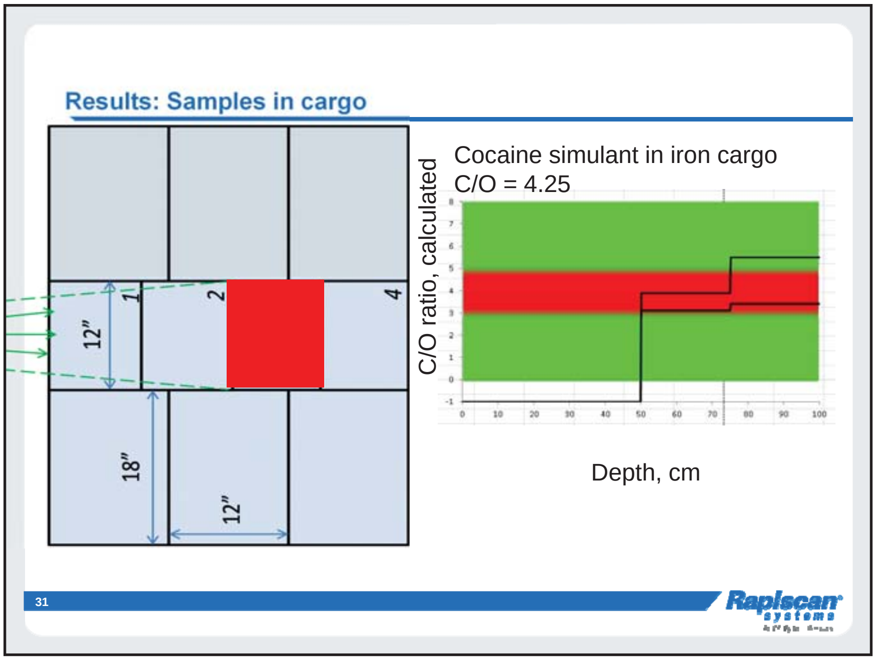
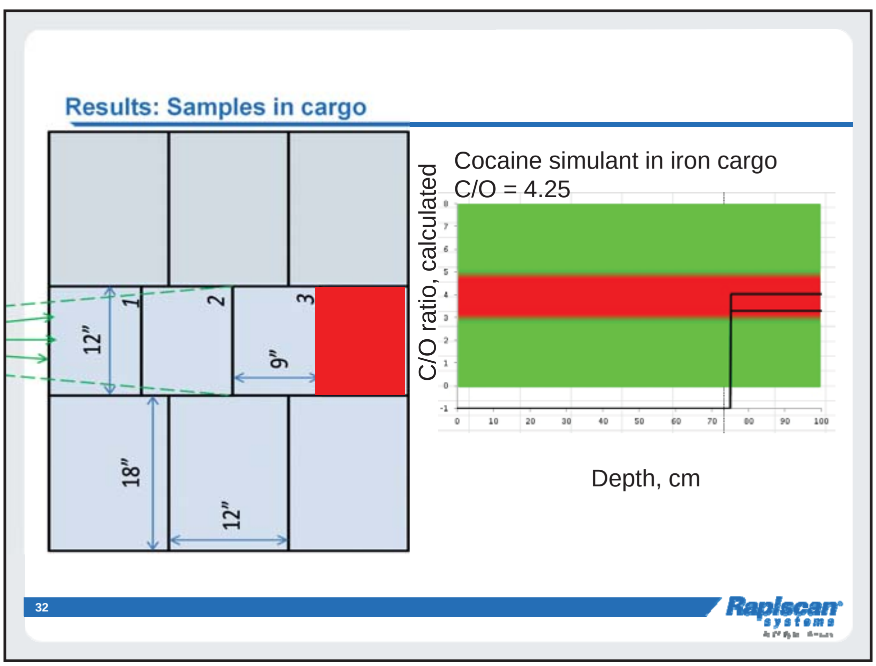

Results: Samples in cargo
Cocaine simulant in iron cargo
C/O = 4.25
C/O ratio, calculated
Depth, cm
2
3
4
9"
18"
12"
29
Rapiscan systems


Results: Samples in cargo
Cocaine simulant in iron cargo
C/O = 4.25
C/O ratio, calculated
Depth, cm
1
3
4
12"
9"
18"
12"
30
Rapiscan systems


Results: Samples in cargo
12"
18"
12"
1
2
4
Cocaine simulant in iron cargo
C/O = 4.25
C/O ratio, calculated
Depth, cm
31
Rapiscan systems


Results: Samples in cargo
12"
18"
12"
9"
1
2
3
Cocaine simulant in iron cargo
C/O = 4.25
C/O ratio, calculated
Depth, cm
32
Rapiscan systems

Lessons learned with API

Significant system performance improvement is expected with:

- Neutron generator with high precision anchor points for easy alignment. Better alignment will reduce background by ~25%
- Better (and heavier) generator and gamma detectors shielding. With better shielding we can increase neutron output by a factor of ~ 2 – 5.
- Optimizing geometry of gamma detector placement. 16 detector configuration will increase signal by a factor of ~2.
- Better spatial resolution can be obtained with faster detector PMTs.

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Summary Conclusions

- With mentioned improvement system performance will improve compared to the system used at Purdue.
- Spatial resolution of ~10 cm is achievable.
- Detected cocaine in paper and steel cargo. System did not alarm on sugar.
- Similar performance demonstrated in other cargos.
- API-based neutron interrogation technique with a compact DT generator is a viable drug detection method in small to medium aircraft-size cargo containers. It provides excellent depth imaging information on the elemental composition of the cargo content.
- Further details on results: CARRI 2014, San Antonio, TX May 26-29, 2014

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16.24 Synho Do: Sparse View CT

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Sparse View Computed Tomography (CT)

Massachusetts General Hospital
And Harvard Medical School
Synho Do, PhD

Conclusions

Sparse view CT will be able to contribute to air cargo imaging.

➔ By increasing scan throughput
:Super fast scan, no need to fill Radon data space fully, less artifacts compared to FBP etc

➔ Freedom in CT geometry
:Multiple sources, Heterogeneous detector, Non-circular scan trajectory (no gantry scanner), Stationary Scanner etc

➔ Reducing iterative image reconstruction time
:Smaller data size, smaller memory etc

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Massachusetts General Hospital and Harvard Medical School

Synho Do, PhD
Department of Imaging, MGH and Harvard Medical School
25 New Chardon Street, Suite 450
Boston, MA 02114 (email)

BIO NEWS PUBLICATIONS RESEARCH

Synho Do, PhD, is an Assistant in Physics at Massachusetts General Hospital, where he is a technical committee member of Webster Center for Advanced Research and Education in Radiation, and Instructor at Harvard Medical School. Dr. Do received the Ph.D. degree in Biomedical Engineering from University of Southern California. He is currently a member of IEEE Signal Processing Society, Bio-Imaging and Signal Processing (BISP). He is a MGH site PI for nVidia CUDA Research Center (CRC). Dr. Do's current research interests include statistical signal and image processing, estimation, detection, and medical signal and image processing, such as computed tomography. He has been a Co-Investigator for multiple medical imaging projects, and Co-PI/PI on medical (i.e., GE, Siemens, and Philips etc) and security (i.e., DHS, DARPA etc) image reconstruction projects.

Latest News
RSNA
DHS meeting

http://scholar.harvard.edu/synho

Nationality: U.S.A. (2013~present)

6/10/2014 3

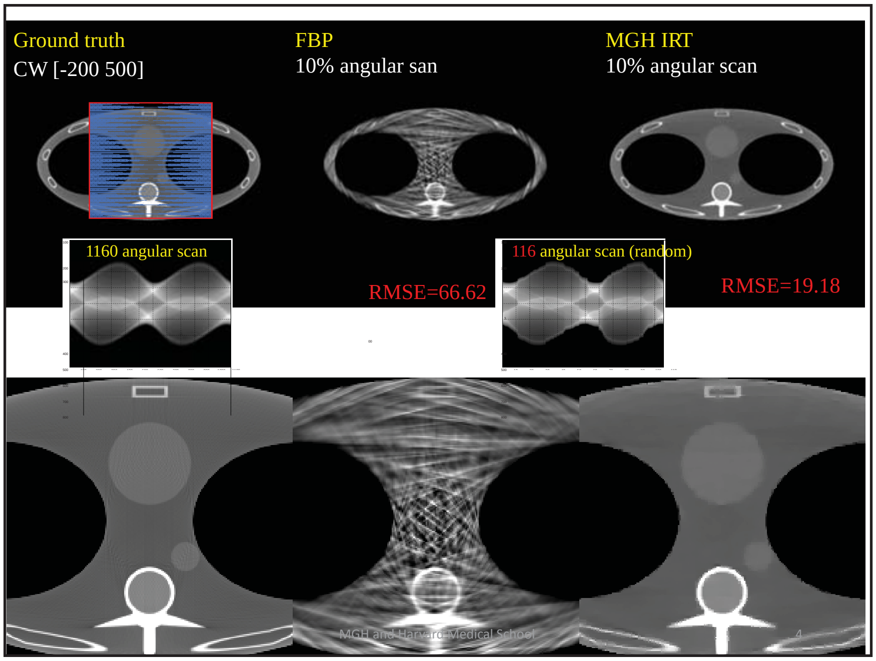
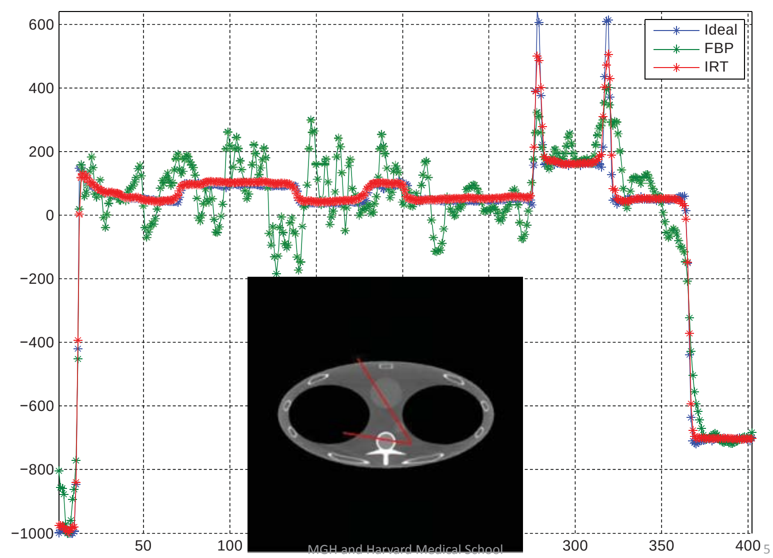
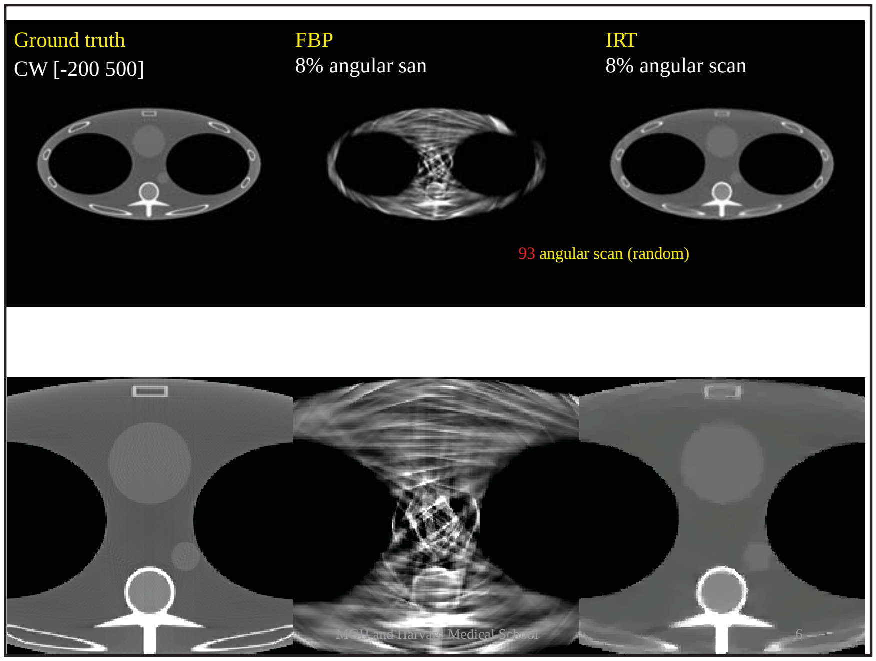
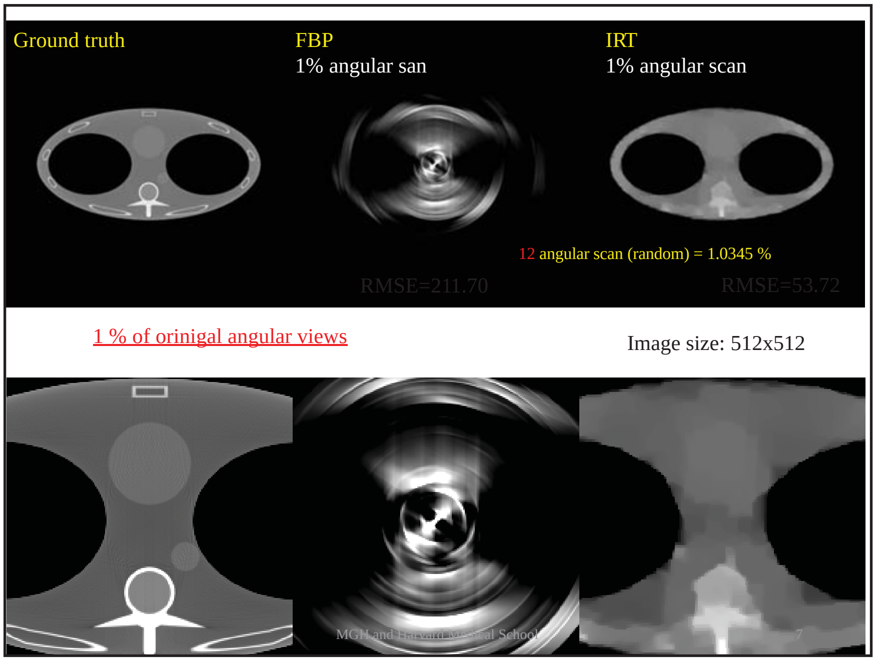


Image profile comparison







Imatron C300 scanner

Emulation using real raw data
- by throwing away angular samples

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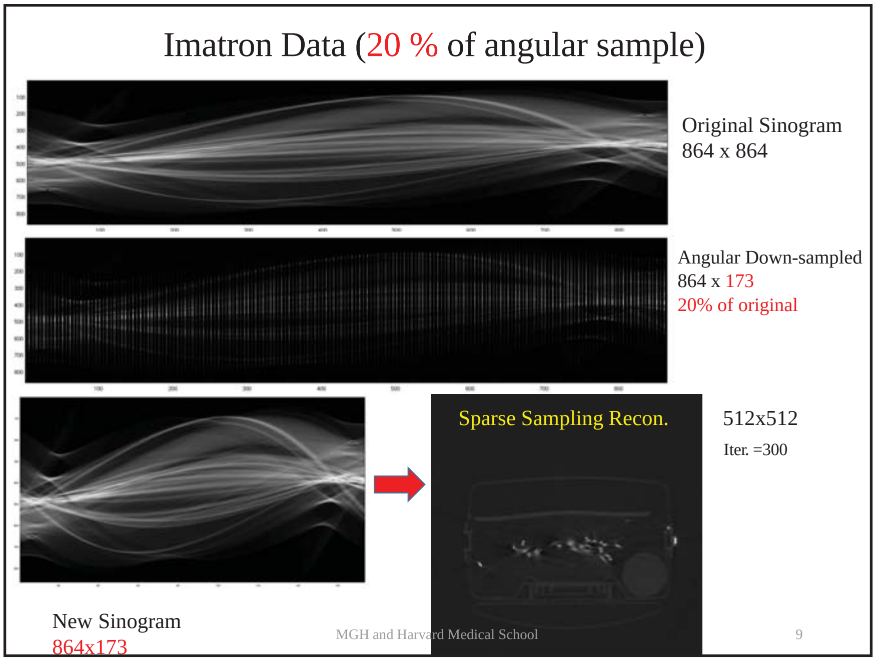
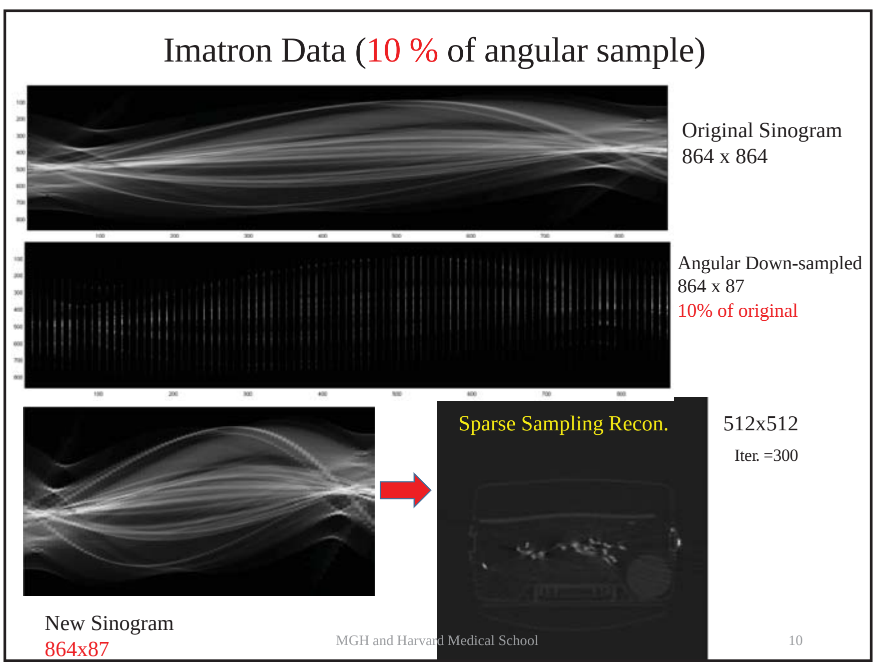

Imatron Data (20 % of angular sample)
Original Sinogram
864 x 864
Angular Down-sampled
864 x 173
20% of original
Sparse Sampling Recon.
512x512
Iter. =300
New Sinogram
864x173
MGH and Harvard Medical School
9


Imatron Data (10 % of angular sample)
Original Sinogram
864 x 864
Angular Down-sampled
864 x 87
10% of original
Sparse Sampling Recon.
512x512
Iter. =300
New Sinogram
864x87
MGH and Harvard Medical School
10

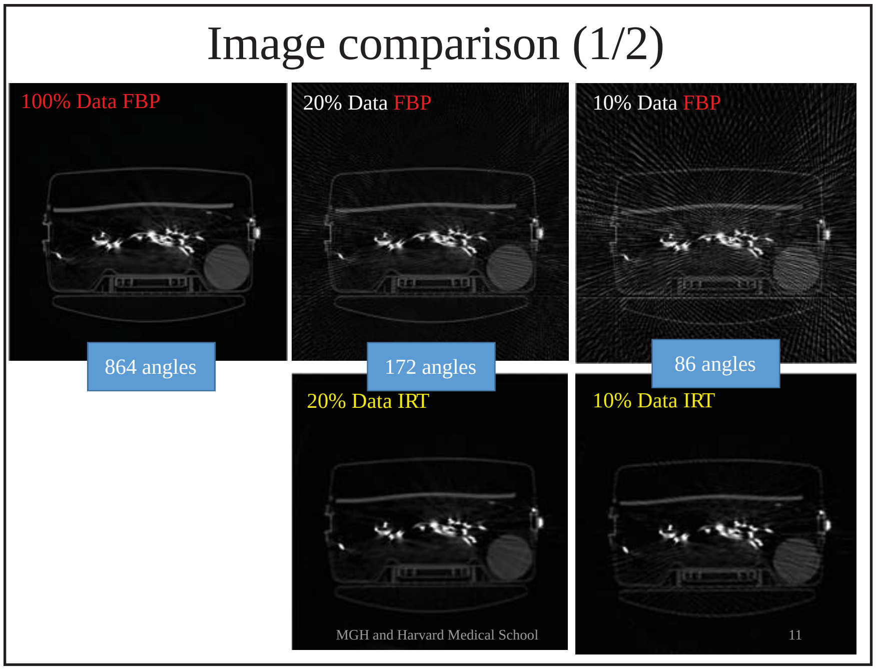


Image comparison (1/2)
100% Data FBP
20% Data FBP
10% Data FBP
864 angles
172 angles
86 angles
20% Data IRT
10% Data IRT
MGH and Harvard Medical School
11

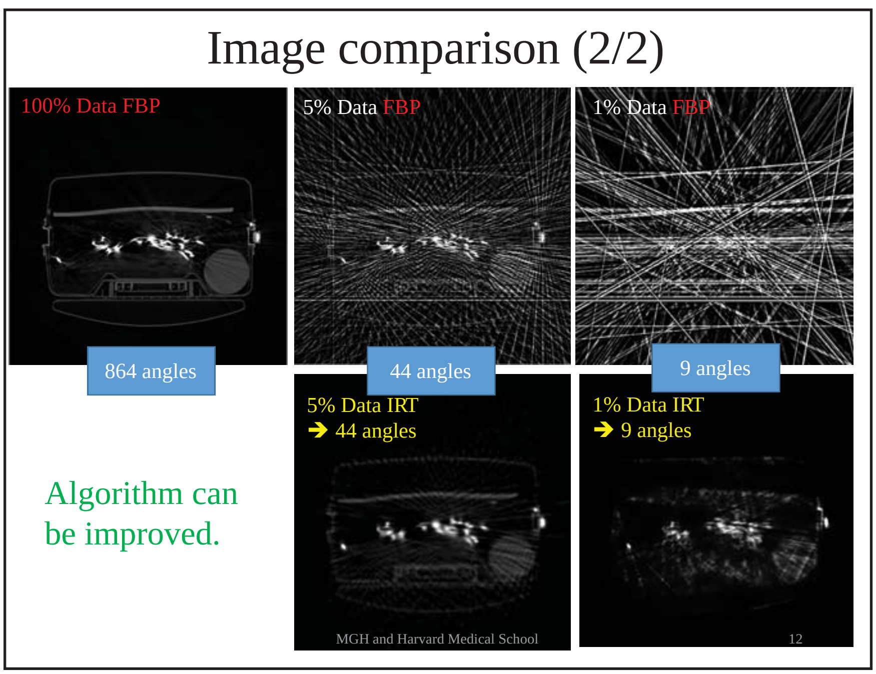
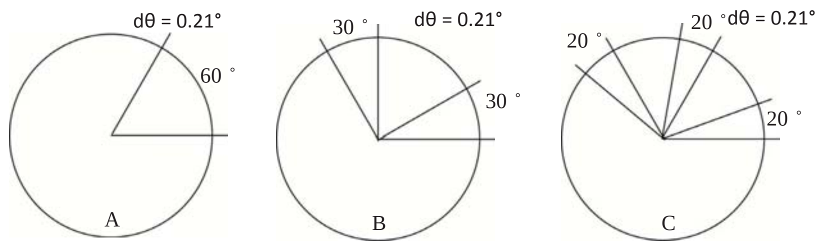
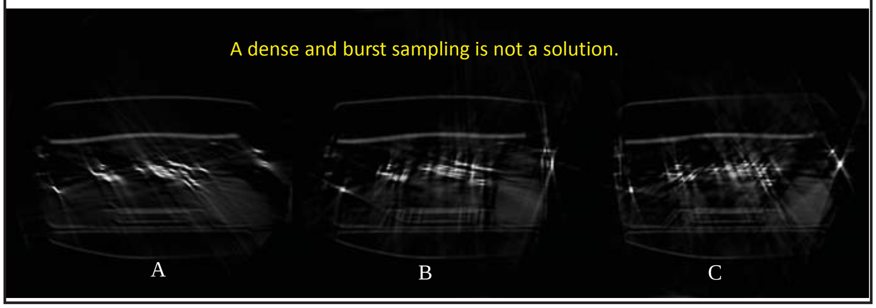


Image comparison (2/2)
100% Data FBP
5% Data FBP
1% Data FBP
864 angles
44 angles
9 angles
5% Data IRT
➔ 44 angles
1% Data IRT
➔ 9 angles
Algorithm can
be improved.
MGH and Harvard Medical School
12

Only 60 degree angular sampling

of angles:288





SSMART
(Sinogram Sparcified Metal Artifact Reduction Technology)

Practical implementation
Supported by ALERT TO3

"This material is based upon work supported by the U.S. Department of Homeland Security, Science and Technology Directorate, Office of University Programs, under Grant Award 2013-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. [12/2013]"

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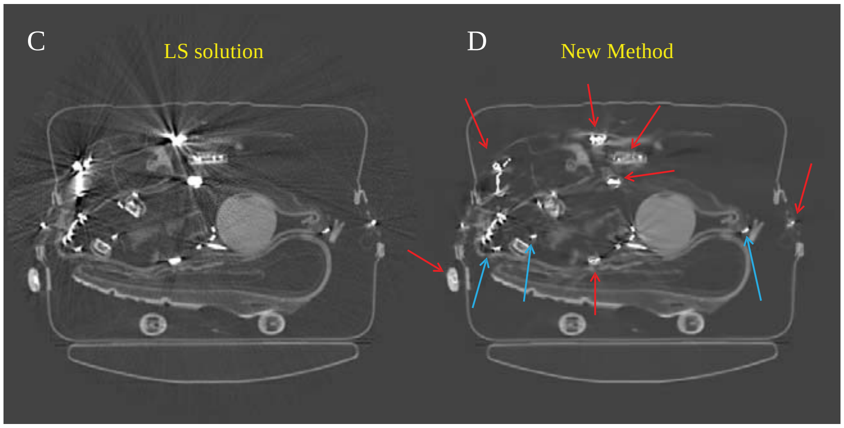
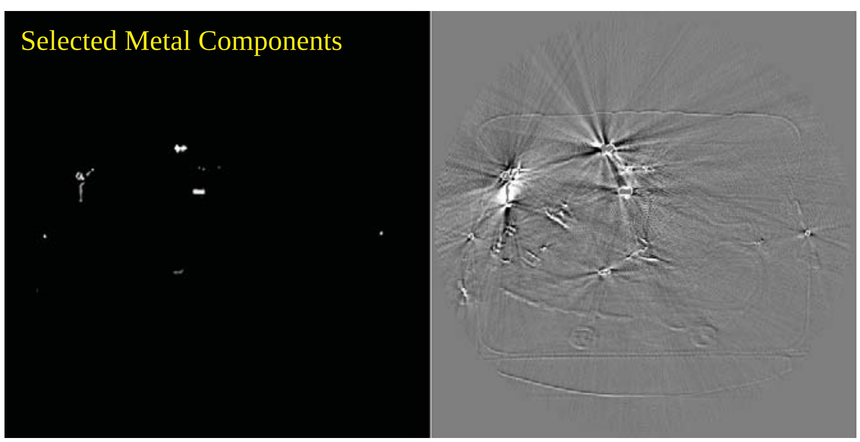
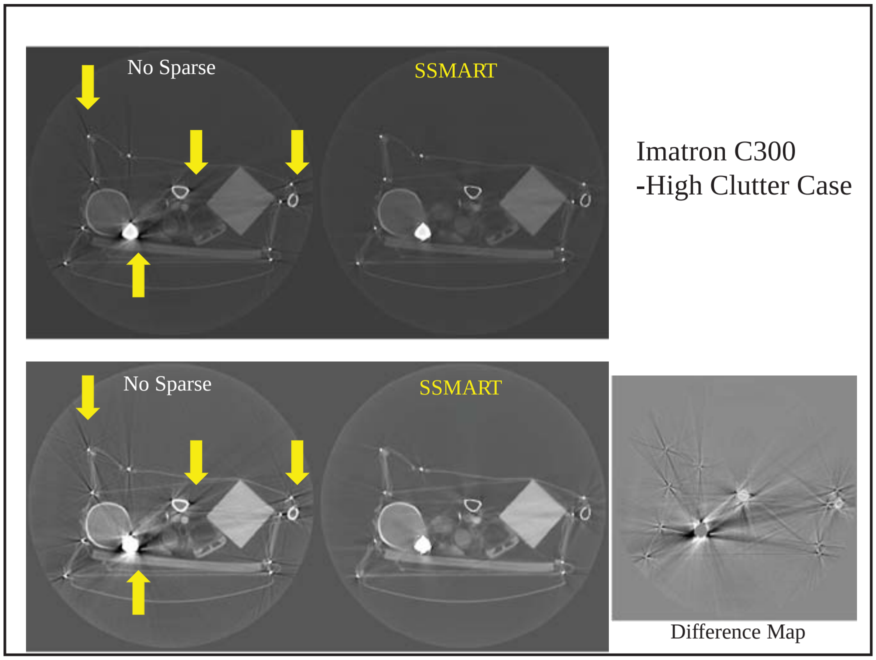
SSMART



1. Metal Artifacts have gone in image D (new method).
2. Metal boundaries are not smooth so parameter tweaking will be needed.
   - Red arrows : Identified as metal components
   - Blue arrows : Not included as metal components

Difference Map




No Sparse
SSMART
Imatron C300
-High Clutter Case
No Sparse
SSMART
Difference Map


Xrec
SSMART
Xrec
6/10/2014

Archimedean Spiral Sparse Sensing CT

- Novel method of sensing

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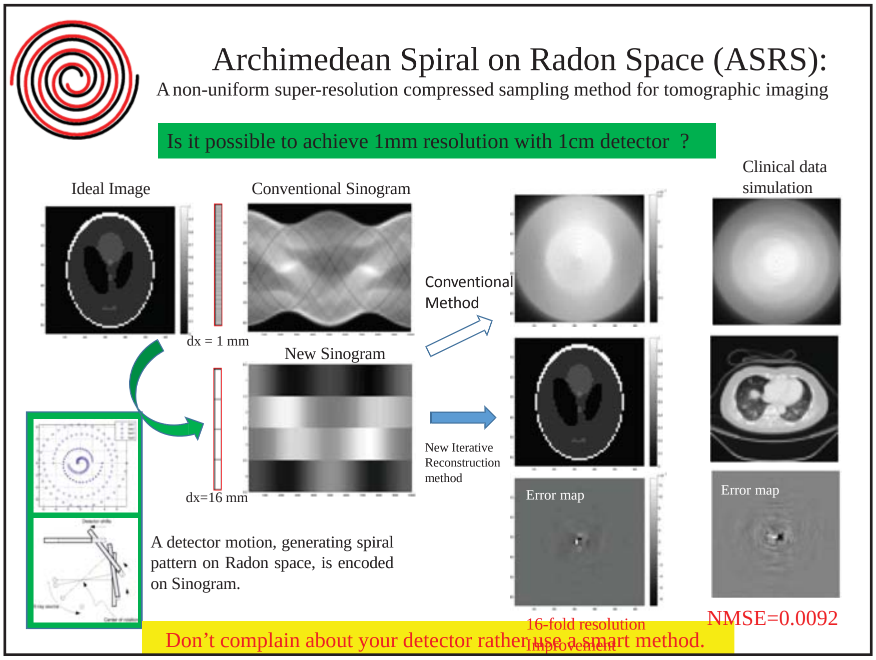
Archimedean Spiral on Radon Space (ASRS):

A non-uniform super-resolution compressed sampling method for tomographic imaging



HARVARD
MEDICAL SCHOOL

- Our team at MGH has the knowledge, expertise, and skills to detect cancer tissues.
- The explosives look like terminal cancer (or cancer in the terminal) of air cargo security.

Thank you for your attention !

MGH and Harvard Medical School 21

16.25 Stuart Harmer: Radar Threat Detection

Millimeter & Microwave Screening of People, Bags and Footwear

Radio Physics Solutions Inc.

RPS
RADIO PHYSICS SOLUTIONS

Manchester Metropolitan University

CENTRE for SENSING & IMAGING

Centre for Sensing & Imaging
Manchester Metropolitan University
http://www.soe.mmu.ac.uk/csi/

Why Bother, Who Cares ?

Non-contact 'pat-down' with handheld millimeter-wave radar

'Conventional' body scanning with cost effective passive millimeter-wave imaging systems

Rapid screening of footwear for concealments without necessitating removal of shoes

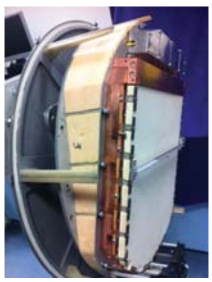
Illustration by Mark Nerys, obtained from http://www.wired.com/2013/06/fa_planehijackings/

Stand-off (25 meter) concealed threat detection with millimeter-wave radar

Radio Physics Solutions Inc.

Radio Physics Solutions is an SME which is based in Salem NH and London UK.

The company develops innovative millimeter-wave technologies for security screening, communications and navigation applications.



CSI Research Group Members

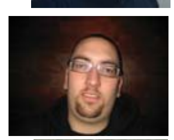
Professor Nicholas Bowring

Dr Christopher Johnson, Research Associate

Dr Nacer Rezgui, Senior Research Fellow

Dr Dave Leonard, Research Associate

Dr Stuart Harmer, Reader



Mr Simon Hutchinson, PhD Student

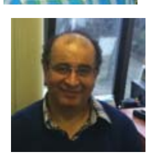
Dr Neil Salmon, Reader

Dr David Andrews, Senior Research Fellow

Dr Mike Fernando, Lecturer

Mr Dean O'Reilly PhD Student

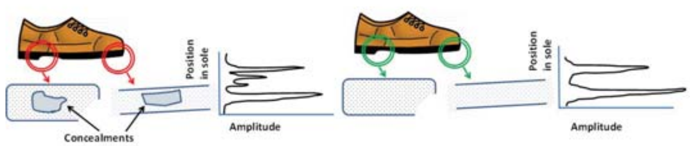
Dr Matthew Southgate, Research Associate



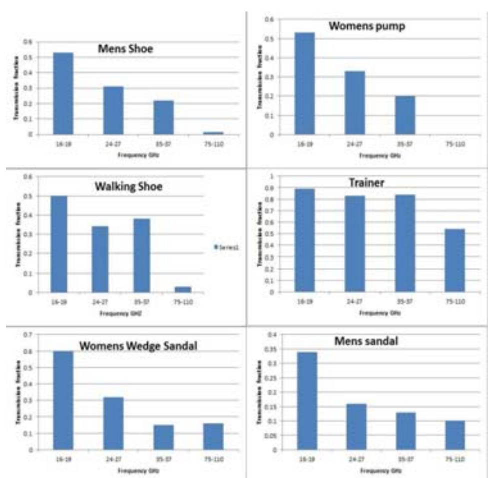
Dr Nader Anani, Senior Lecturer

Microwave Radar for Screening Footwear

- UWB Stepped Frequency Radar is implemented to determine the presence or absence of concealments within the sole of the shoe.
- The scan be carried out without necessitating the removal of the shoe
- Small (< 1cm^3)metallic and non-metallic concealments are detectable with this approach
- Detection relies on reflection of transmitted microwaves at interfaces where the complex permittivity of the propagating medium changes



Why Microwaves ?

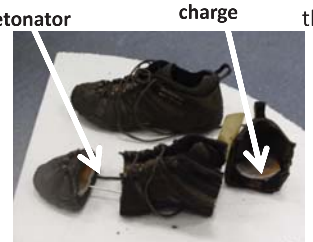


Some data from rough and ready trials designed to estimate the transmittance of typical shoes at different frequency bands.

- The principal loss is by absorption, reflection losses are typically smaller
- Microwave gives suitable penetration into the sole and spatial resolution to enable system to operate reliably over most shoe types
- Higher frequency bands often suffer too great attenuation to be useful

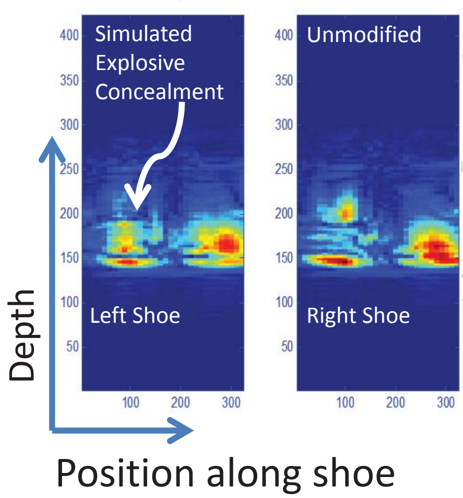
Example Concealments



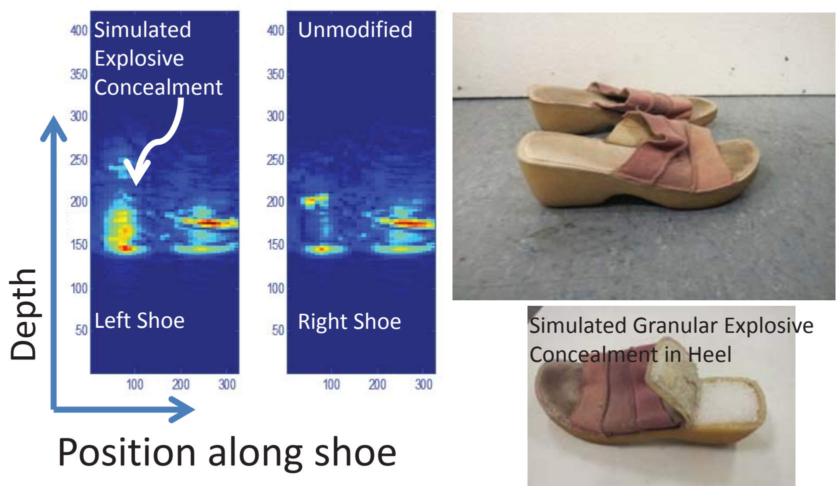



Shoes were modified with concealments made in the sole Explosive simulant was used to mimic 'shoe bombs'. Metallic and non-metallic concealments can be detected easily with the system.

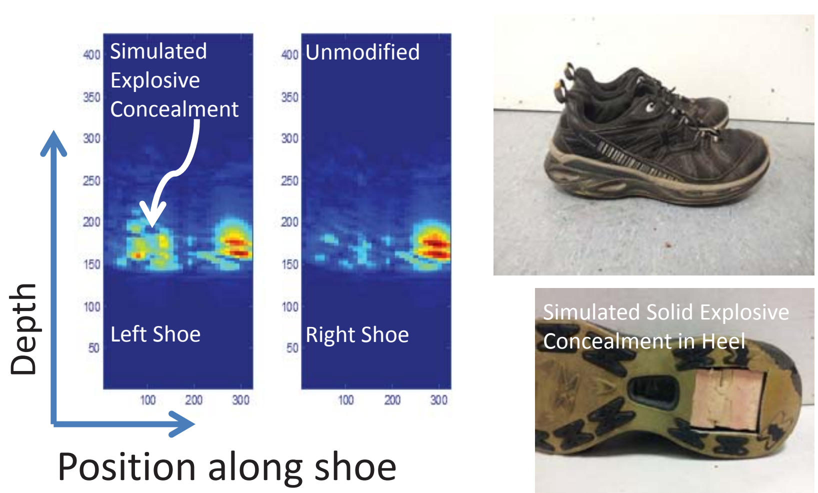
Example Scans: Men's Shoes



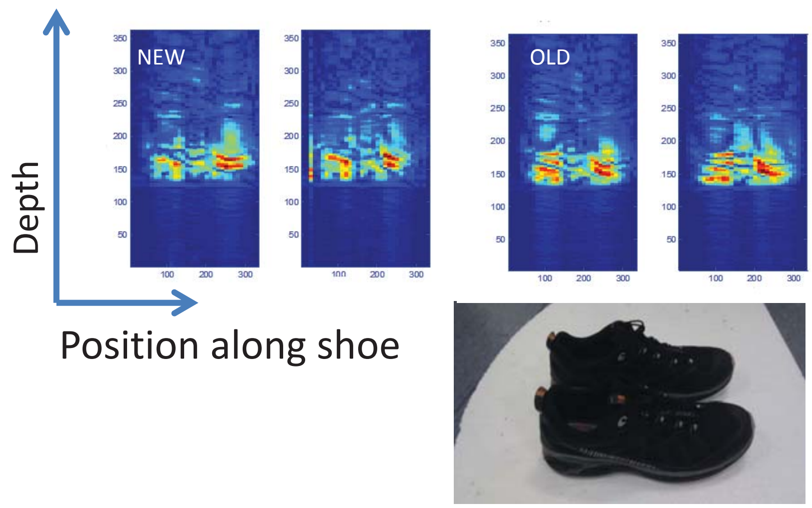

Example Scans: Women's Shoes



Example Scans: Sneakers



Sensitivity

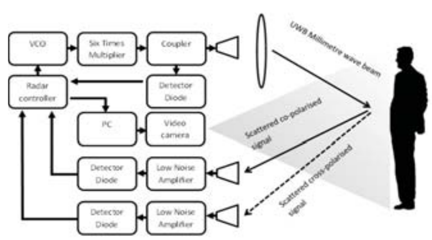


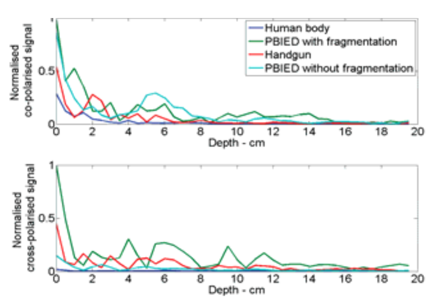
MiRTLE & MiRLIN Radar for Concealed Threat Detection

- Implements simple 'direct detection' radar for UWB sweep
- Beam width < 1 degree
- Targets classified by polarimetric 'depth spectrum'
- Data is classified using Neural Network to render autonomous Threat/No threat indication
- Two systems: handheld for screening up to 10 meters; tripod mounted for screening at up to 25 meters

Trials/Assessments

System Outline





The system has three MMW channels:

- One narrow frequency sweep to range to target
- Two orthogonal UWB channels to produce depth spectrum data
- Depth spectrum data contains information on separation of partially reflecting surfaces, information on range order of surfaces is lost due to direct detection operation

$$S(t) \propto \sum_{m=1}^{M} \Im^{-1}\left\{\sqrt{\sigma_m(\nu)}\right\} \otimes \delta\left(t - \frac{2z_m}{c}\right)$$

$$S(t) \propto \sum_{m=1}^{M}\sum_{n=1}^{M} \Im^{-1}\left\{\sqrt{\sigma_m(\nu)\sigma_n^*(\nu)}\right\} \otimes \delta\left(t - \frac{2|z_m - z_n|}{c}\right)$$

Data Processing Steps

1. Data Acquisition
- Ultra Wide Band sweep 75-108 GHz, 256 points in 1ms
- Orthogonal receivers Co- and Cross-polarised

2. Data Processing
- DIFT → 'Depth Spectrum'
- Select lowest 40 data points (corresponding to optical depths of 6-240 mm)
- Scale signal for range (mix of inverse square and R^{-4})

3. Neural Network

Input data – Hidden layer – output
10 elements 10 nodes

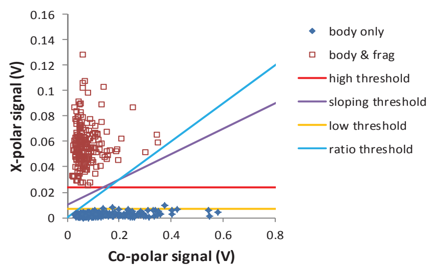
Gives a "threat value" between 0 - 1
- Trained on measurements of person with and without threat items

4. Threshold Filtering
- NN output > "pre-defined confidence level" → Threat Indication "1"

5. Persistence Filtering
- Successive indications …01101111001…..
- Within moving time window, if number of indications > threshold
- → Threat Alarm

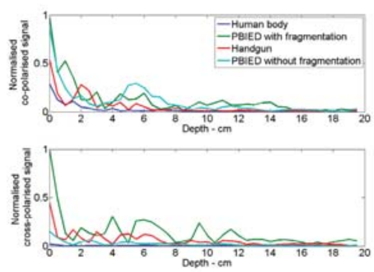
Operation

Video of prototype MiRTLE operation taken with a 100% plastic, 3D printed handgun as the threat object.



Data showing polarising effect of simulated PBIED with fragmentation placed on body.

- This data is the averaged return over the entire depth spectrum and shows clustering.
- Different thresholds can be used to determine whether PBIED is likely to be present based on this crude return



A better method is to measure the relative amount reflected back from the target in different frequency bands and then perform an DIFT on these data to obtain a 'depth spectrum'

- Depth spectrum data reveals information on the axial extent of the target

Millimeter-wave Imaging

- Using active millimetre-wave imaging it is possible to see what is being concealed in carried bags.
- This example is taken from an active imager, in which incoherent illumination is used to avoid specular reflection.
- The system collects images in real time at 8 frames per second.
- Here, there is a concealed 'pressure cooker bomb' concealed in a rucksack.
- Migration toward aperture synthesis with a real time correlator.

18

16.26 Theodore Goodson: Femtosecond Laser Based Truck Mounted Trace Detection

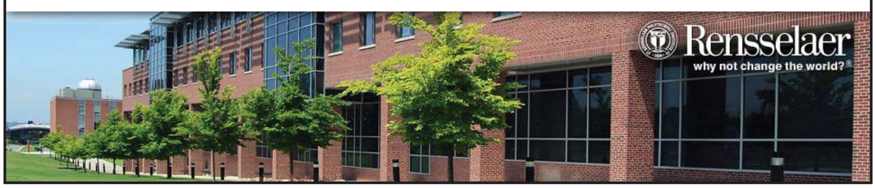
Presentation Omitted

16.27 Ge Wang: Interior Tomography and Spectral CT

Interior Tomography

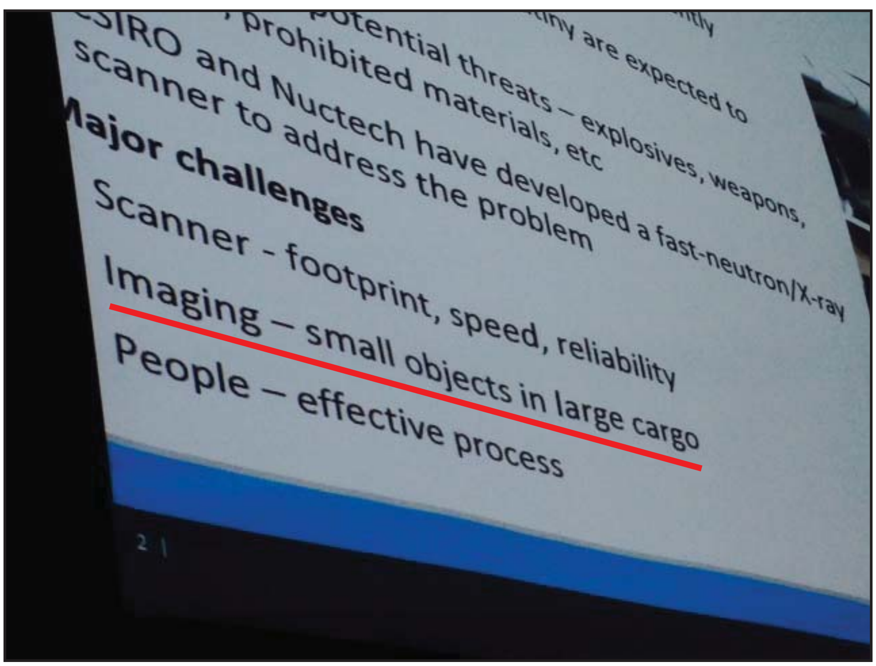
Ge Wang, PhD
Biomedical Imaging Center/Cluster, CBIS/BME
Rensselaer Polytechnic Institute
ge-wang@ieee.org
http://www.rpi-bic.org

May 7, 2014



Detailed Look?

Automatic Workflow!



Interior Tomography

IOP PUBLISHING

PHYSICS IN MEDICINE AND BIOLOGY

Phys. Med. Biol. **58** (2013) R161–R186

doi:10.1088/0031-9155/58/16/R161

TOPICAL REVIEW

The meaning of interior tomography

Ge Wang[1] **and Hengyong Yu**[2,3]

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[2] Department of Radiology, Wake Forest University Health Sciences, Winston-Salem, NC 27157, USA
[3] Biomedical Imaging Division, VT-WFU School of Biomedical Engineering and Sciences, Wake Forest University Health Sciences, Winston-Salem, NC 27157, USA

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Published 2 August 2013

Spiral/Helical Fan-beam CT

Computed tomography scanning with simultaneous patient translation

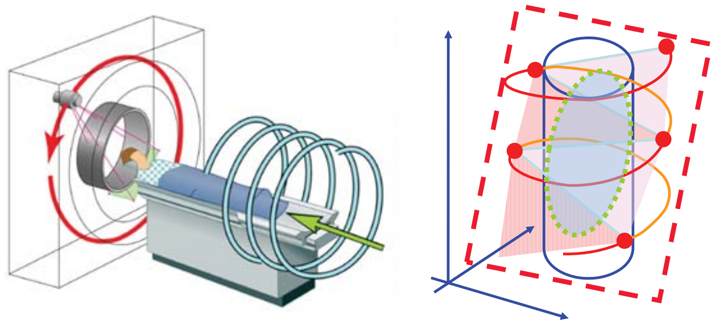
Carl R. Crawford and Kevin F. King
GE Medical Systems, Milwaukee, Wisconsin 53201

(Received 27 November 1989; accepted for publication 14 March 1990)

This paper deals with methods of reducing the total time required to acquire the projection data for a set of contiguous computed tomography (CT) images. Normally during the acquisition of a set of slices, the patient is held stationary during data collection and translated to the next axial location during an interscan delay. We demonstrate using computer simulations and scans of volunteers on a modified scanner how acceptable image quality is achieved if the patient translation time is overlapped with data acquisition. If the concurrent patient translation is ignored, structured artifacts significantly degrade resulting reconstructions. We present a number of weighting schemes for use with the conventional convolution/backprojection algorithm to reduce the structured artifacts through the use of projection modulation using the data from individual and multiple slices. We compare the methods with respect to structured artifacts, noise, resolution and to patient motion. Review of preliminary results by a panel of radiologists indicates that the residual image degradation is tolerable for selected applications when it is critical to acquire more slices in a patient breathing cycle than is possible with conventional scanning.

967 Med. Phys. 17 (6), Nov/Dec 1990 0094-2405/90/060967-16$01.20 © 1990 Am. Assoc. Phys. Med. 967

Spiral/Helical Multi-slice/Cone-beam CT



Wang, G, Lin, TH, Cheng PC, Shinozaki DM, Kim HG: Scanning cone-beam reconstruction algorithms for x-ray microtomography. Proc. SPIE 1556:99-112, July 1991

Wang G, Lin TH, Cheng PC, Shinozaki DM: A general cone-beam reconstruction algorithm. IEEE Trans. on Med. Imaging 12:486-496, 1993

Citation Counts

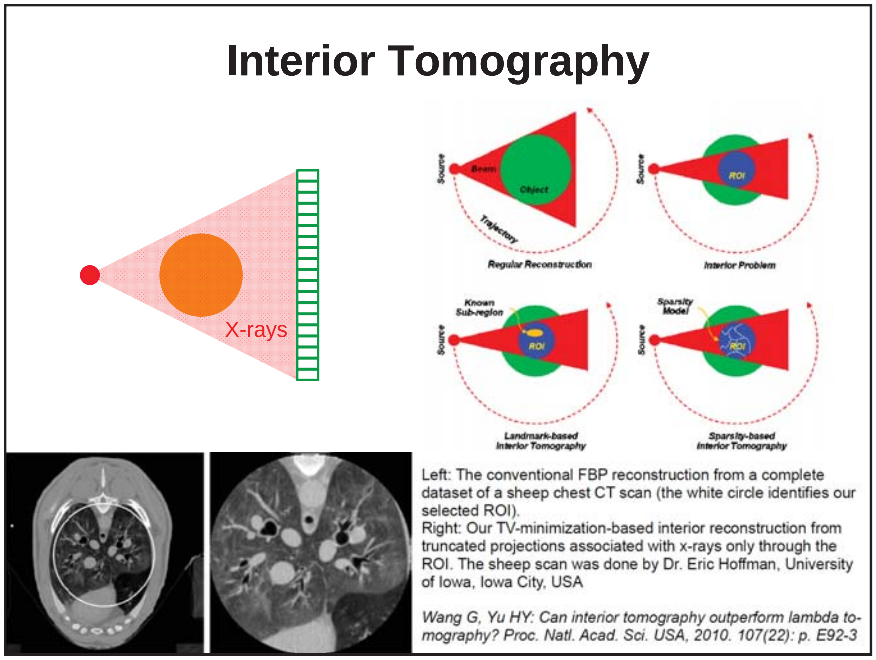
To solve the long-object problem, a first level of improvement with respect to the 2D FBP algorithms was obtained by backprojecting the data in 3D, along the actual measurement rays. The prototype of this approach is the algorithm of Wang et al.

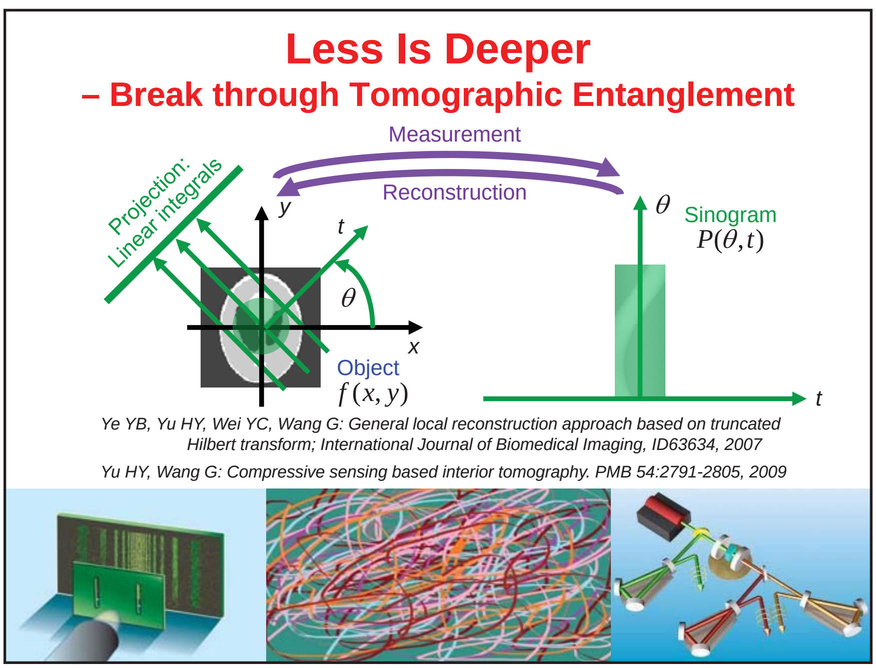
Defrise, Noo, Kudo: A solution to the long-object problem in helical cone-beam tomography. Phys. Med. Biol. 45:623-643, 2000

Many advances in CB reconstruction have been made recently thanks to the quest for an attractive reconstruction method in helical CB tomography.

Pack, Noo, Clackdoyle: Cone-beam reconstruction using the backprojection of locally filtered projections. IEEE Trans. Medical Imaging 24:1-16, 2005

100M Multi-slice/Cone-beam CT Scans Annually


Interior Tomography
X-rays
Source
Beam
Object
Trajectory
Regular Reconstruction
ROI
Interior Problem
Known Sub-region
Landmark-based Interior Tomography
Sparsity Model
Sparsity-based Interior Tomography
Left: The conventional FBP reconstruction from a complete dataset of a sheep chest CT scan (the white circle identifies our selected ROI).
Right: Our TV-minimization-based interior reconstruction from truncated projections associated with x-rays only through the ROI. The sheep scan was done by Dr. Eric Hoffman, University of Iowa, Iowa City, USA
Wang G, Yu HY: Can interior tomography outperform lambda tomography? Proc. Natl. Acad. Sci. USA, 2010. 107(22): p. E92-3


Less Is Deeper
– Break through Tomographic Entanglement
Measurement
Reconstruction
Projection:
Linear integrals
y
t
θ
x
Object
f(x, y)
θ
Sinogram
P(θ,t)
t
Ye YB, Yu HY, Wei YC, Wang G: General local reconstruction approach based on truncated Hilbert transform; International Journal of Biomedical Imaging, ID63634, 2007
Yu HY, Wang G: Compressive sensing based interior tomography. PMB 54:2791-2805, 2009

IOP Publishing — Inverse Problems
Inverse Problems **28** (2012) 000000 (28pp) — UNCORRECTED PROOF

Stability of the interior problem for polynomial region of interest

E Katsevich[1], A Katsevich[2] and G Wang[3]

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[2] Department of Mathematics, University of Central Florida, Orlando, FL 32816-1364, USA
[3] Biomedical Imaging Division, VT-WFU School of Biomedical Engineering and Sciences, Virginia Tech, Blacksburg, VA 24061, USA

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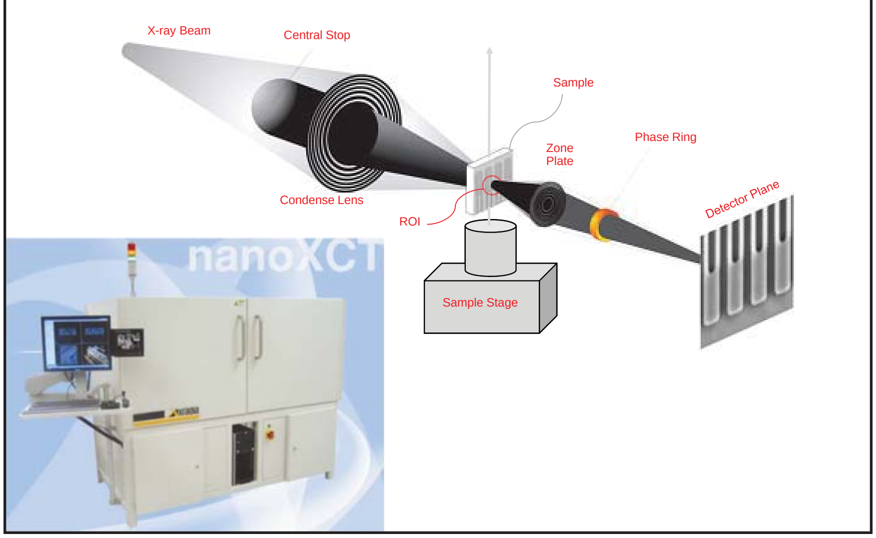
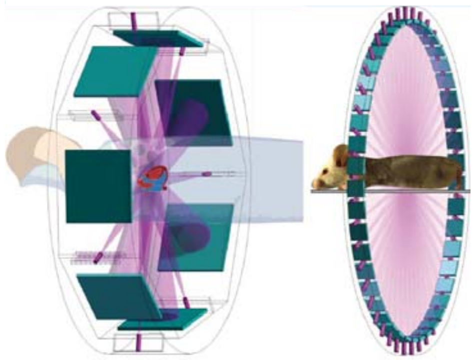
Received 14 September 2011, in final form 20 April 2012
Published DD MMM 2012
Online at stacks.iop.org/IP/28/000000

Abstract
In many practical applications, it is desirable to solve the interior problem of tomography without requiring knowledge of the attenuation function f_a on an open set within the region of interest (ROI). It was proved recently that the interior problem has a unique solution if f_a is assumed to be piecewise polynomial on the ROI. In this paper, we tackle the related question of stability. It is well known that lambda tomography allows one to stably recover the locations and values of the jumps of f_a inside the ROI from only the local data. Hence, we consider here only the case of a polynomial, rather than piecewise polynomial, f_a on the ROI. Assuming that the degree of the polynomial is known, along with some other fairly mild assumptions on f_a, we prove a stability estimate for the interior problem. Additionally, we prove the following general uniqueness result. If there is an open set U on which f_a is the restriction of a real-analytic function, then f_a is uniquely determined by only the line integrals through U. It turns out that two known uniqueness theorems are corollaries of this result.

Less = Larger
– Interior Nano-CT



Less = Faster
– Multi-source Interior (Stationary) CT



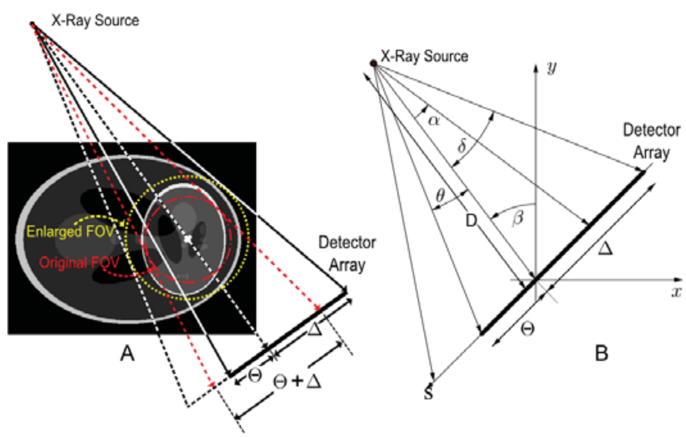
Less =
Deeper understanding
Larger object
Less radiation dose
Finer image resolution
Wider dynamic range
… …
***Faster* imaging speed**

Wang G, Yu HY, Ye YB: A scheme for multi-source interior tomography. Med. Phys. 36:3575-3581, 2009

Wang G: The meaning of interior tomography. Proc. of ICASSP, 5764-5767, 2011

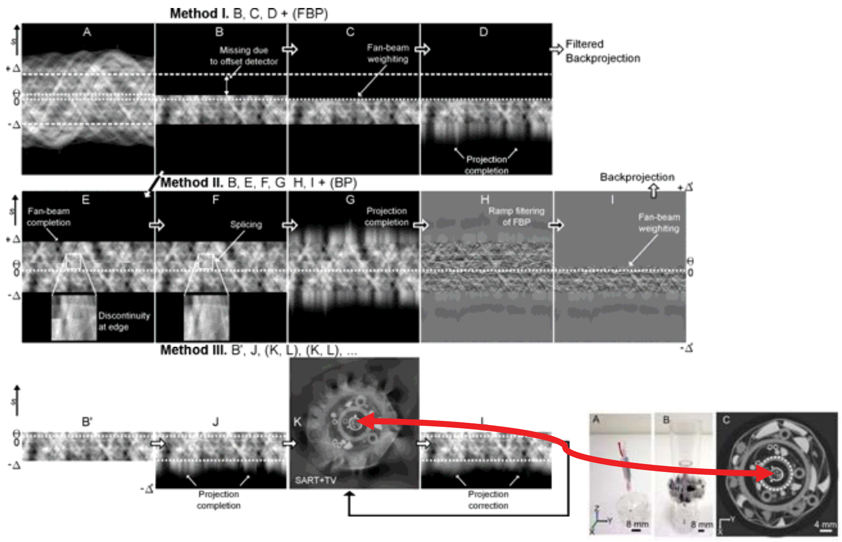
Ritman EL, Kinsey JH, Robb RA, Gilbert BK, Harris LD, Wood EH: Three-dimensional image of the heart, lungs, and circulatory. Science 210:273-280, 1980

Interior Tomography with Offset Detector



Shamar KS, Gong H, Ghasemalizadeh O, Yu HY, Wang G, Cao GH: Interior micro-CT with an offset detector. To appear in Med. Phys., 2014

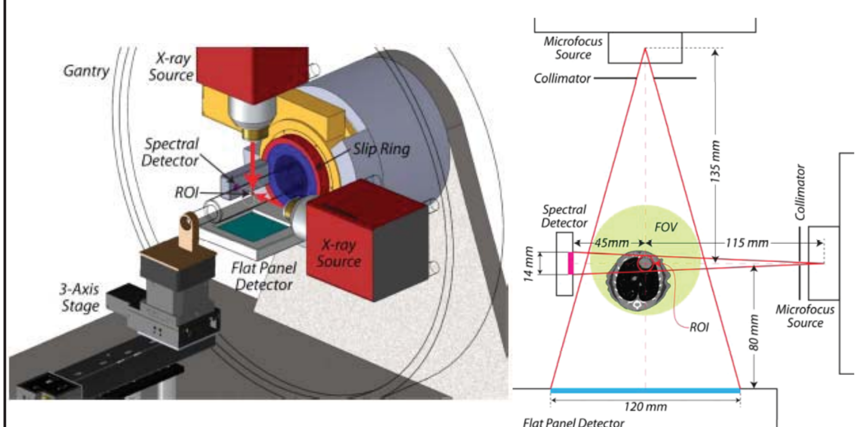
Phantom Examples



IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 59, NO. 6, JUNE 2012 1711

Image Reconstruction for Hybrid True-Color Micro-CT

Qiong Xu, Hengyong Yu*, *Senior Member, IEEE*, James Bennett, Peng He, Rafidah Zainon, Robert Doesburg, Alex Opie, Mike Walsh, Haiou Shen, Anthony Butler, Phillip Butler, Xuanqin Mou, and Ge Wang*, *Fellow, IEEE*



IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 59, NO. 6, JUNE 2012 1711

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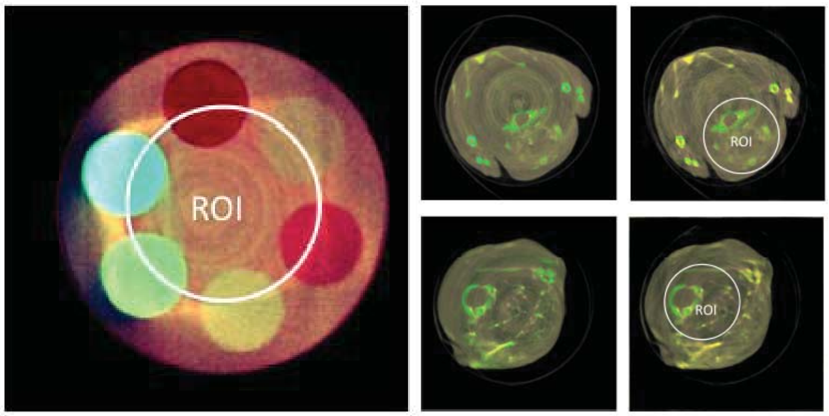
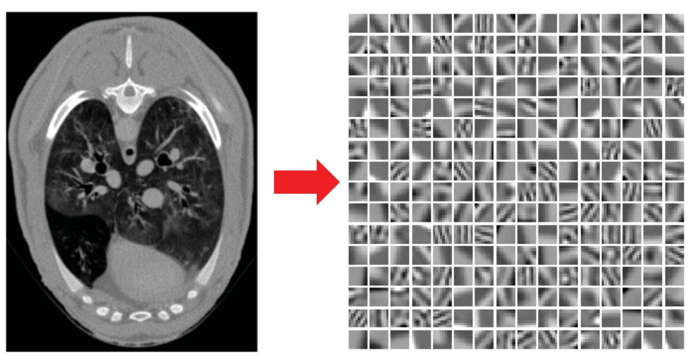


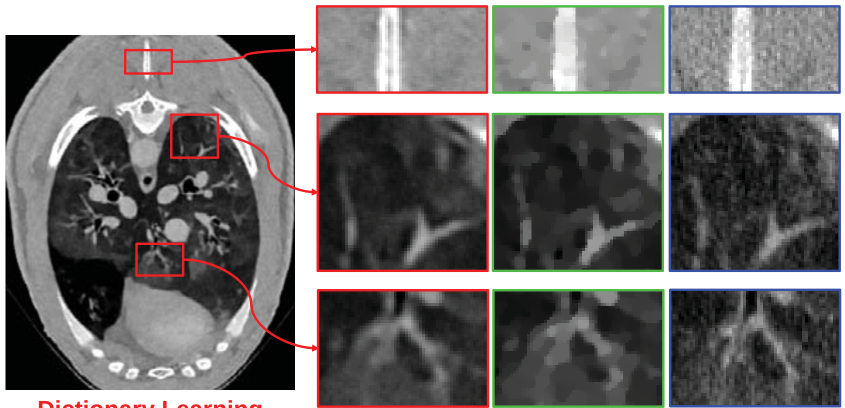
Features Extracted as Patches



A CT image for training **Dictionary of 256 patches**

Xu Q, Yu HY, Mou XQ, Zhang L, Wang G, Low-dose x-ray CT reconstruction via dictionary learning. IEEE Transactions on Medical Imaging 31:1682-1697, 2012

Dictionary-based Imaging



Dictionary Learning Reconstruction From 290 Views

Total Variation Minimization From 290 Views

Filtered Backprojection From 1160 Views

Xu Q, Yu HY, Mou XQ, Zhang L, Wang G, Low-dose x-ray CT reconstruction via dictionary learning. IEEE Transactions on Medical Imaging 31:1682-1697, 2012

PRISM: Prior Rank, Intensity & Sparsity Model

We model X as the sum of two matrices X_L and X_S

$$X = X_L + X_S$$

and enforce the following regularization

$$R(X_L, X_S) = \lambda_* \| T_L(X_L) \|_* + \lambda_1 \| T_S(X_S) \|_1 + \lambda_t \| X \|$$

By our **PRISM**, we have

$$(X_L, X_S) = \underset{(X_L, X_S)}{\arg\min} \| A(X_L + X_S) - Y \|^2 + R(X_L, X_S)$$

Remark: $\|\cdot\|_*$ is the nuclear norm for the rank regularization on X_L; $\|\cdot\|_1$ is the L_1 norm for the sparsity regularization on X_S; $\|\cdot\|$ is a regularizing norm on the total image X

Gao H, Cai JF, Shen Z, Zhao H: Robust principle component analysis based four-dimensional computed tomography. Phys. Med. Biol. 56:3181–98, 2011

Gao H, Yu HY, Osher S, Wang G: Multi-energy CT based on a Prior Rank, Intensity and Sparsity Model (PRISM). Inverse Problems 27:115012 (22pp), 2011

Generalized Interior Imaging Principle

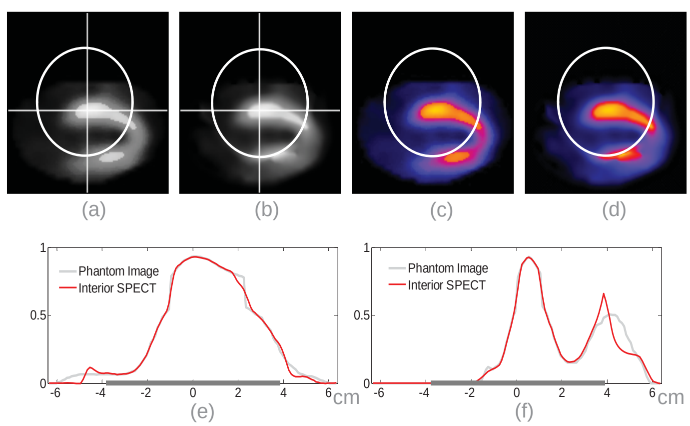
Version 1: Localized tomographic reconstruction needs and only needs local data.

Version 2: Tomographic characterization can be performed with the least amount of information.

Version 3: Tomographic imaging of an interior region of interest (ROI) can be in principle exactly and stably performed from a subset *I* of a dataset *G* where *G* contains indirectly measured data sufficient for theoretically exact and stable reconstruction over the whole support of an object, and *I* contains and only contains those indirectly measured data that directly involve the ROI.

Wang G, HY Yu: The meaning of interior tomography. Phys. Med. Biol. 58:R161–R186, 2013; also the PMB Editor's Choice on http://medicalphysicsweb.org, 08/05/13

Interior SPECT



Yu HY, Yang JS, Jiang M, Wang G: Interior SPECT- Exact and stable ROI reconstruction from uniformly attenuated local projections. Communications in Numerical Methods in Engineering DOI:10/1002/cnm.1206, 18 pages, 2008

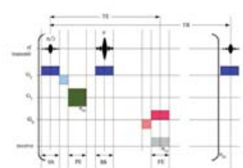
Yang JS, Yu HY, Jiang M, Wang G: High order total variation minimization for interior tomography. Inverse Problems 26:1-29, 2010

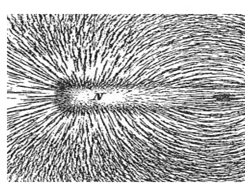
Yang JS, Yu HY, Jiang M, Wang G: High order total variation minimization for interior SPECT. Inverse Problems. Accepted pending minor revisions

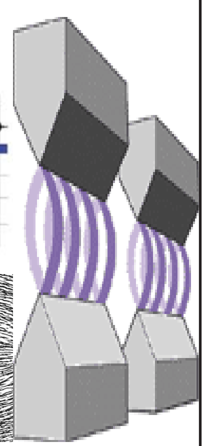
Interior φCT

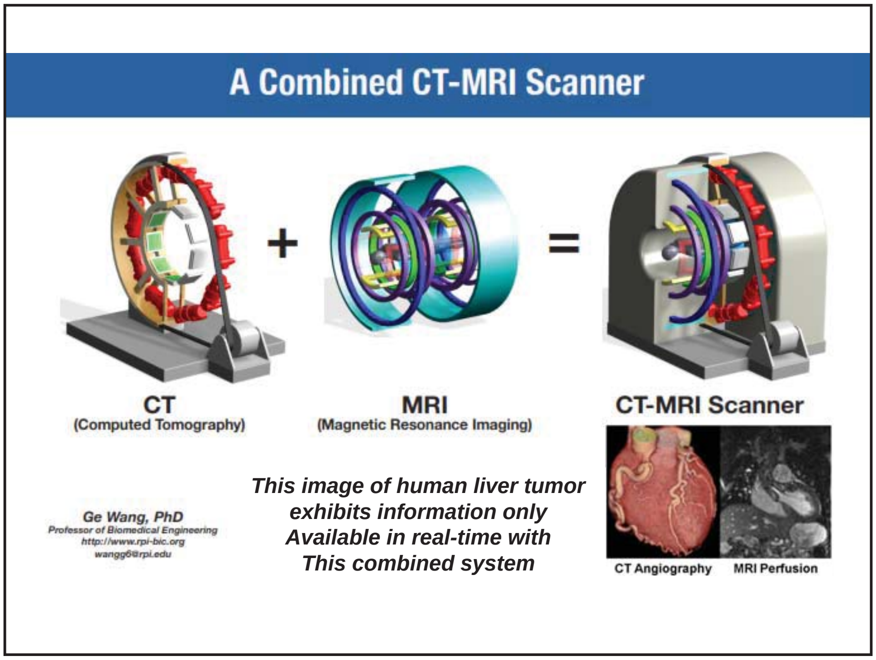
Interior MRI

- Localized Magnetic Field
- Focused RF Excitation
- Truly Interior Algorithms








A Combined CT-MRI Scanner
+
=
CT
(Computed Tomography)
MRI
(Magnetic Resonance Imaging)
CT-MRI Scanner
Ge Wang, PhD
Professor of Biomedical Engineering
http://www.rpi-bic.org
wangg6@rpi.edu
This image of human liver tumor
exhibits information only
Available in real-time with
This combined system
CT Angiography
MRI Perfusion

16.28 Simon Bedford: MVCTC

ASTROPHYSICS™

Multi-View CT Capable System (MVCTC)

Explosives Detection in Air Cargo ADSA10

Simon Bedford

Director of Government Programs

May 2014

ASTROPHYSICS™

About Astrophysics

- **Founded in 2002**
- **Headquarters and Production in City of Industry, California**
- **Present in over 100 countries with over 100 agents**
  - Offices in Washington DC, UK, India, Lebanon, Mexico, Philippines
- **Over 1,200 customers and 10,000 units installed**
  - United Nations, US Air Force, US Navy, Federal Bureau of Prisons, CA Court Houses…
- **13 different tunnel sizes / 34 different models**
  - Energy Levels / Beam Orientations / Single View / Dual View / Mobility
    - Checkpoint (TSA Capacity A)
    - Hold Baggage (TSA Capacity B)
    - Cargo (TSA Capacity C)
    - Mobile Systems, High Energy Container Scanners
- **TSA Air Cargo Screening Technology List (ACSTL)**
  - 19 qualified systems, most recent a 1.8m x 1.8m Dual View 320kV pallet scanner

ASTROPHYSICS™

Acknowledgments

- **Funding & Support from DHS, S&T Directorate**
  - **Screening of Palletized Air Cargo Program**
    - Stephen Surko, Explosives Division
    - Curtis Bell, Transportation Security Laboratory

ASTROPHYSICS™

What benefit would TSA obtain from our technology?

- **Multi-view X-ray transmission imaging of pallets**
  - Through up to 360 degrees
- **Volumetric ("3D" / CT) X-ray imaging when needed**
  - Automated detection
- **Screening operations similar to current pallet X-ray systems**
  - 20cm/s conveyor speed in multi-view mode
  - Expect operational throughput > TSA's requirement of 20 pallets/hour
- **Operating costs similar to current pallet X-ray systems**
- **Moderate system cost**
- **Significant upgrade to detection**

ASTROPHYSICS™

MVCTC Pallet Scanner

- **Dual function Multi-View & CT system**
  - Adapted Astro's multi-view technology to pallet scale
    - High-resolution detector arrays
    - Operates as a "1st level" transmission screening system with high throughput
  - Computer tomography (CT)
    - Enhanced screening tool when multi-view cannot clear (use OCAST?)
    - Improved & automated threat detection
    - Reduced rejects / false alarms

MVCTC Air Cargo
Pallet Screening System

ASTROPHYSICS™

Summary

- **Astrophysics roadmap:**
  - Continuing to develop and evaluate the technology
  - Trials planned with DHS S&T under the Screening of Palletized Air Cargo Program

- **Major benefits:**
  - Transmission & CT screening tools
  - Automated CT detection
  - Good operational throughput (comparable to existing 320kV systems)
  - Good penetration (source may be a monoblock, tube, betatron or linac)
  - <u>Moderate cost</u>
  - <u>Minimal disruption to current screening CONOPS</u>
  - <u>Significant upgrade from technology currently available</u>

16.29 Dan Strellis: Misc. Topics

ONE COMPANY - TOTAL SECURITY

Rapiscan systems
An OSI Systems Company

Materials Discrimination for Air Cargo
Ed Morton and Dan Strellis

www.rapiscansystems.com

What Benefit Can TSA Gain?

TSA already uses materials discrimination technology – the focus of this talk

The issue is how best to optimize systems for Air Cargo inspection which suffer from

- Large Tunnel Size
- Complex Cargo Contents

Here we discuss the effect of changing X-ray beam quality on the ability to categorize explosive materials

2 ONE COMPANY - TOTAL SECURITY Rapiscan systems An OSI Systems Company

Explosives Detection in Air Cargo with X-ray Systems: The Challenge

Tunnel Size

Large tunnel sizes mean that we need higher energies to penetrate cargo.

This means that Z-effective resolution tends to drop which impacts ability to discriminate explosive materials

Image Complexity

Contents of air cargo is much more diverse than cabin baggage

This makes inspection of images much more difficult than standard cabin baggage style image inspection

3 ONE COMPANY - TOTAL SECURITY Rapiscan systems An OSI Systems Company

Explosives Detection in Air Cargo with X-ray Systems: The Challenge

Penetration

High density air cargo requires high energy system to achieve penetration performance:

- 160kV – 40mm
- 300kV – 60mm
- 1MV – 120mm
- 6MV – 400mm

The higher the energy, the less the ability to categorize explosives reliably

Spatial Resolution

High complexity cargo requires images of excellent resolution to achieve good diagnostic quality

Higher energy systems tend to have lower spatial resolution due to physics reasons including:

- power density on X-ray target
- longer range of Compton recoil electrons in the detector

4 ONE COMPANY - TOTAL SECURITY Rapiscan systems An OSI Systems Company

Explosives Detection in Air Cargo with X-ray Systems: The Challenge

Overlapping Structures	Anomaly Detection

Overlapping Structures

In principle, we can get rid of overlapping structures (which affect Z-effective) by going to CT style imaging

This gets very expensive since you still need to use high energy sources to meet penetration requirements and reduce streak artefact

In principle with voxel based density and Z-effective, explosives categorization can be good

Anomaly Detection

By use of anomaly detection, it may be possible to see threat materials

- Multiple objects in one consolidated cargo are identical except that one is slightly different
- Comparison of image to manifest (e.g. expect three boxes but see four)

Summary

This is a difficult problem whose complexity should not be underestimated

Large tunnels really need high energy inspection beams to achieve penetration requirements but this severely compromises ability to categorize materials into specific types

Once an image is formed, it is then difficult to analyze due to clutter and overlapping structures

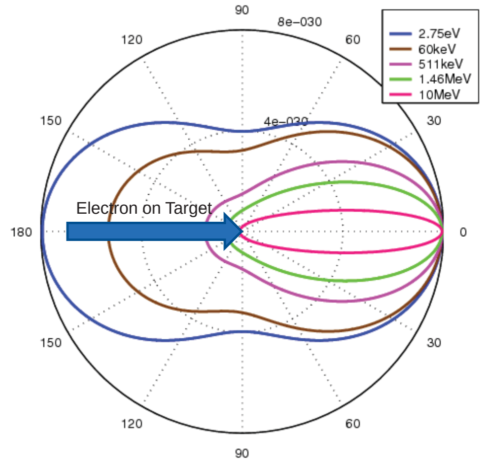
Rapiscan systems
An OSI Systems Company

Backup

Rapiscan systems
An OSI Systems Company

Basic Physics

X-Ray Generation

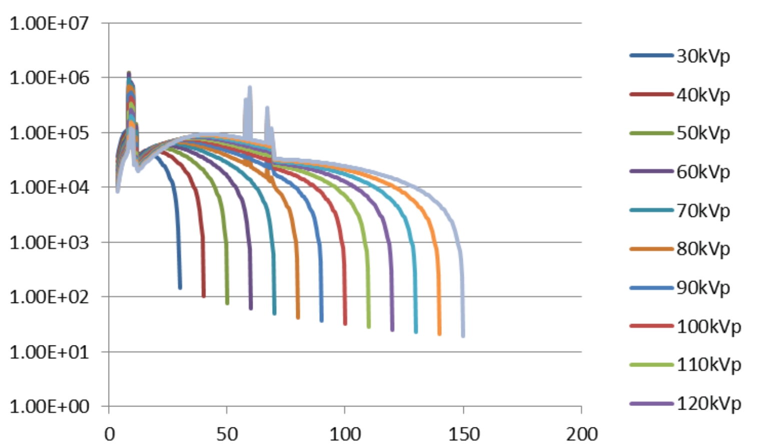


At low energies, X-ray production is almost isotropic

At high energies, X-ray production is much more forward directed

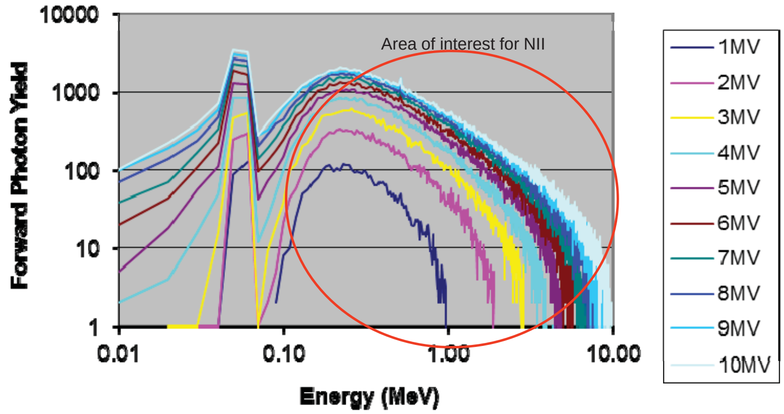
9 ONE COMPANY - TOTAL SECURITY Rapiscan systems

X-Ray Spectra – Low Energy



10 ONE COMPANY - TOTAL SECURITY Rapiscan systems

X-Ray Spectra – High Energy



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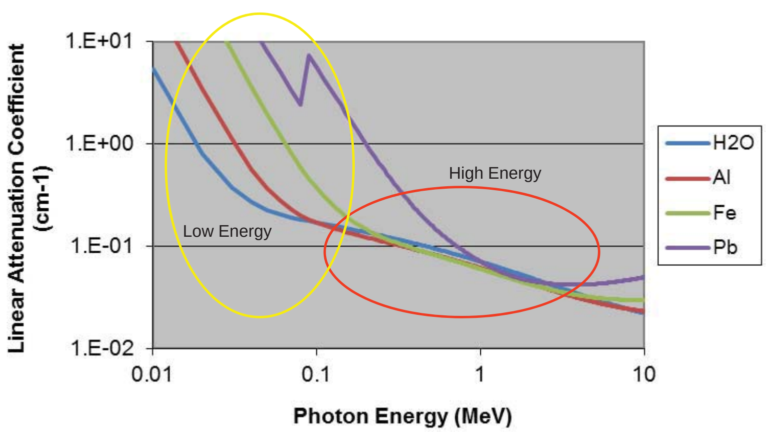
Material Attenuation



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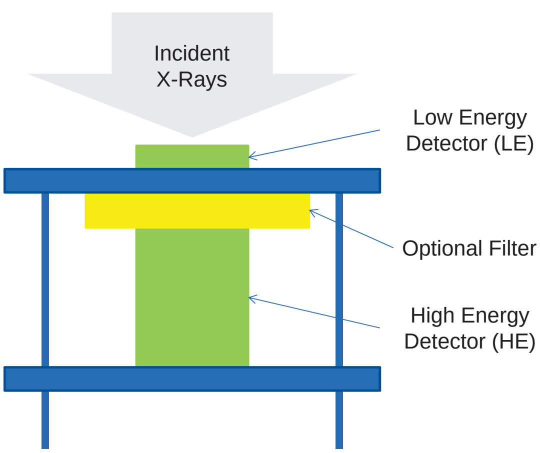
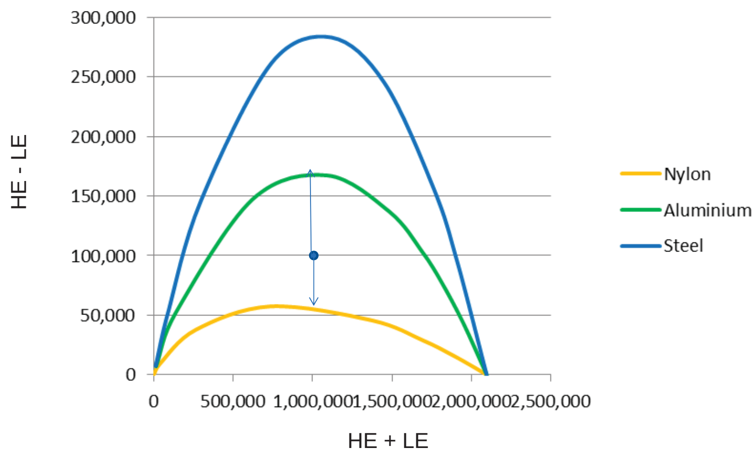
Materials Discrimination
Low Energy (Small Tunnel)

Dual Energy Detection



14 ONE COMPANY - TOTAL SECURITY

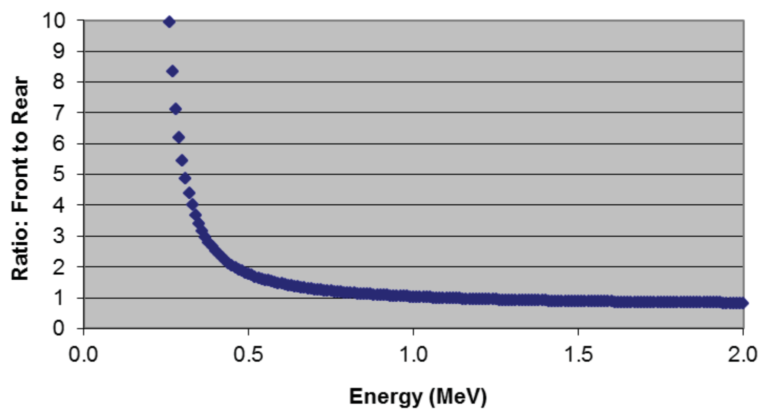
Dual Energy Materials Discrimination



15

Materials Discrimination
High Energy (Large Tunnel)

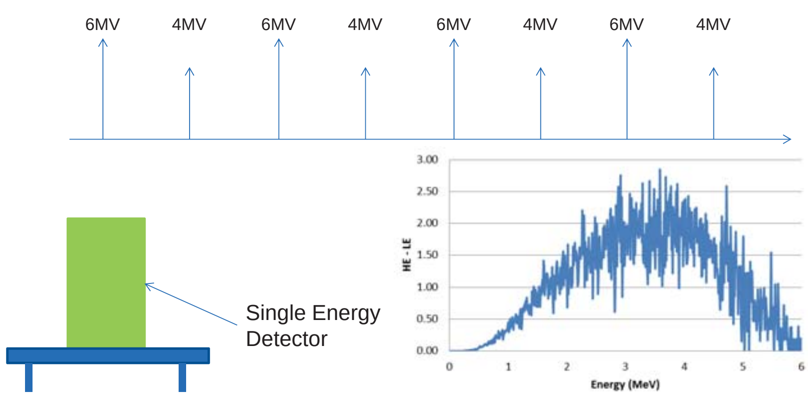
Dual Energy Detection at High Energy



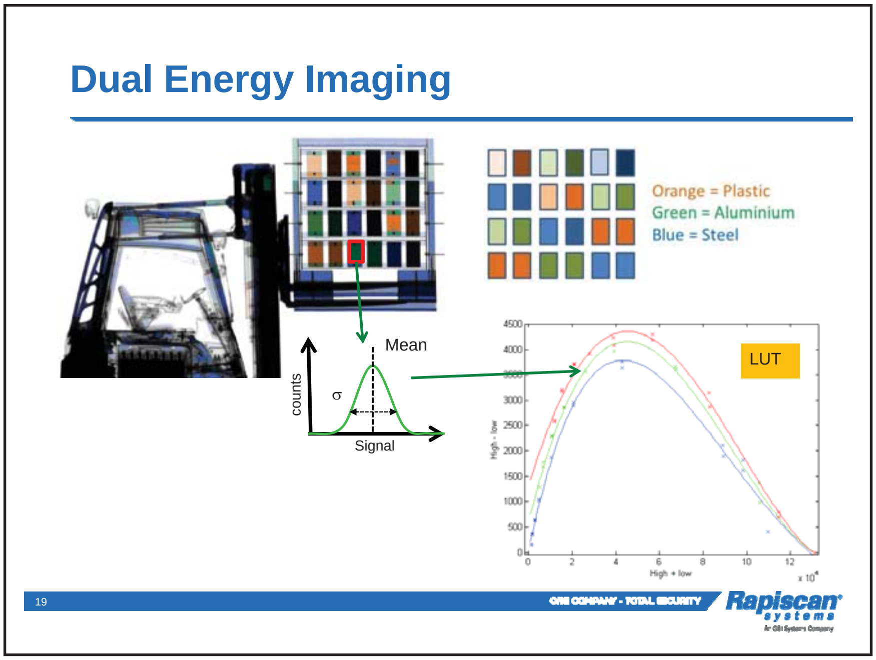
17 ONE COMPANY - TOTAL SECURITY Rapiscan systems

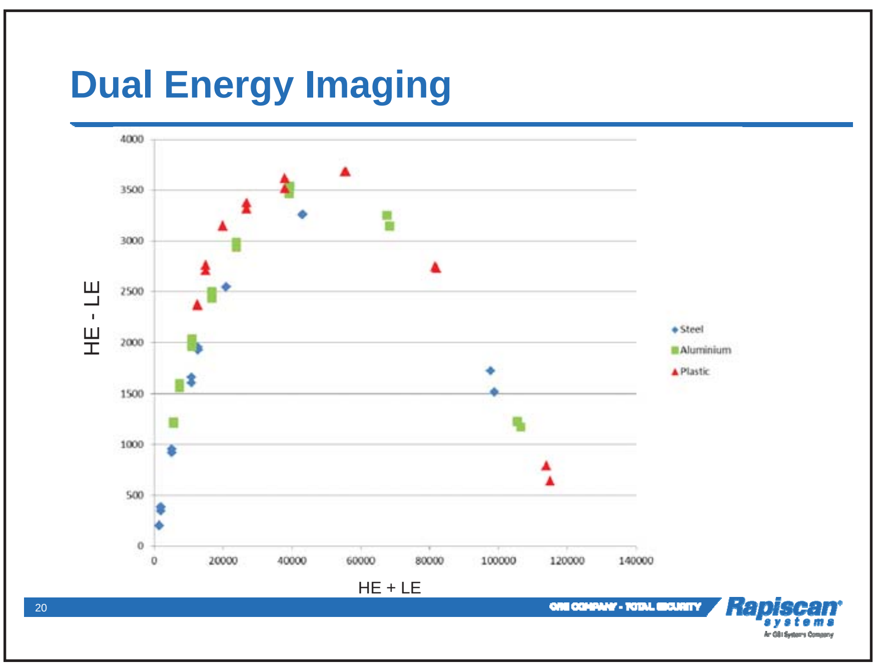
Dual Energy Imaging at High Energy

Interlaced Energy Beams from a Linear Accelerator X-Ray Source



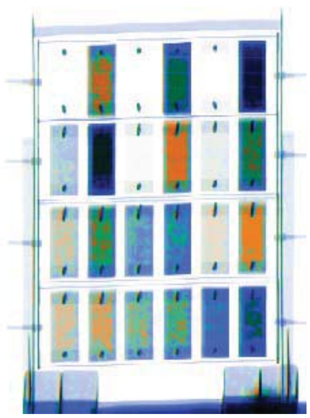
18 ONE COMPANY - TOTAL SECURITY Rapiscan systems


Dual Energy Imaging
Orange = Plastic
Green = Aluminium
Blue = Steel
Mean
counts
σ
Signal
LUT
High - low
High + low
19
ONE COMPANY - TOTAL SECURITY
Rapiscan systems

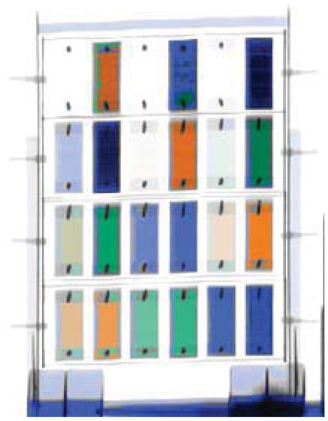

Dual Energy Imaging
HE - LE
HE + LE
Steel
Aluminium
Plastic
20
ONE COMPANY - TOTAL SECURITY
Rapiscan systems

Dual Energy Imaging

Raw Data



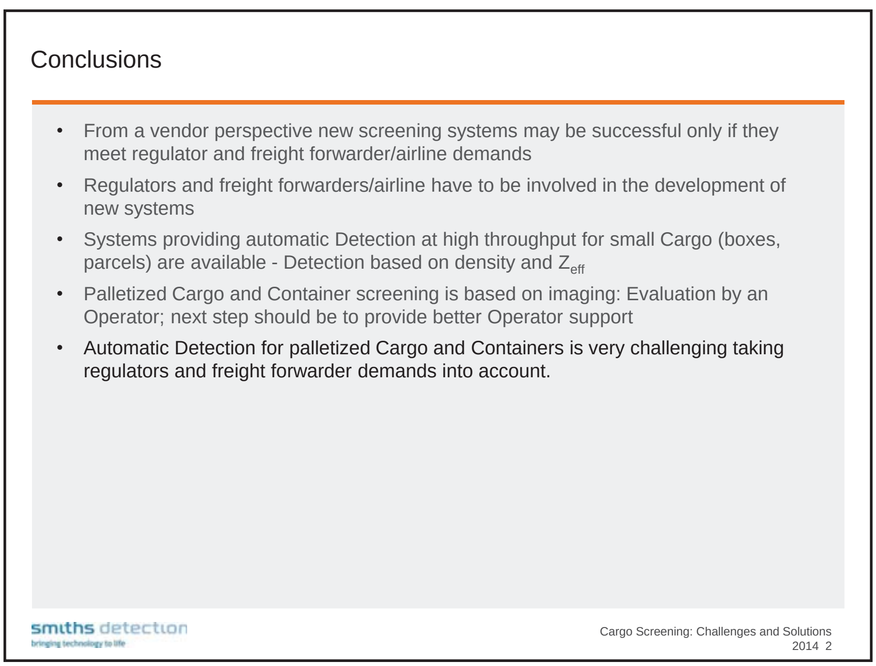
Smoothed Data



21

Materials Discrimination for Air Cargo

16.30 Martin Hartick: Challenges and Solutions of Air Cargo Screening



US Air Cargo Screening Regulator Requirements

US Cargo Screening Background

- “Cargo” means boxes, pallets, and ULD (unit load device) containers
- 100% screening of cargo is the mandate
- Air Cargo must be screened in a manner consistent with checked luggage
- “EDS Certified” systems can be used with ATR
- “Accepted” systems from other programs can be used in imaging mode

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Cargo Screening: Challenges and Solutions
2014 3

Cargo Carrier Requirements

Customer (freight forwarders, shipping companies, airlines) requirements

- SPEED (high throughput)
- Cost (unit and personnel)
- CONOPS (Don’t disrupt operational flow)
- Automation (Detection and Reporting)
- Footprint in their warehouse or business
- Non-intrusive (don’t touch or open my box!)
- Detection Capability

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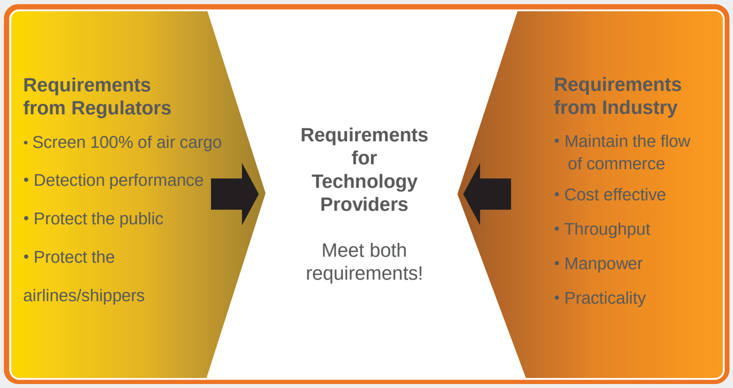
Cargo Screening: Challenges and Solutions
2014 4

The GOALS



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Cargo Screening: Challenges and Solutions
2014 5

Technical Challenges

Challenges:

- Multiple commodity types
  - Food
  - Clothing
  - Electronics
  - Machnery
- Variation in object size (from small to large)
  - Small
  - Large

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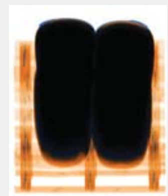
Cargo Screening: Challenges and Solutions
2014 6

Technical Challenges

Challenges:

- Variation in object absorption is very high

Filter Pads



Barrels

- Exposure to harsh operating conditions
  - Extreme temperature swings
  - Aircraft and vehicular exhaust fumes and soot
  - Vibration

Smiths Detection Technologies

Solutions:

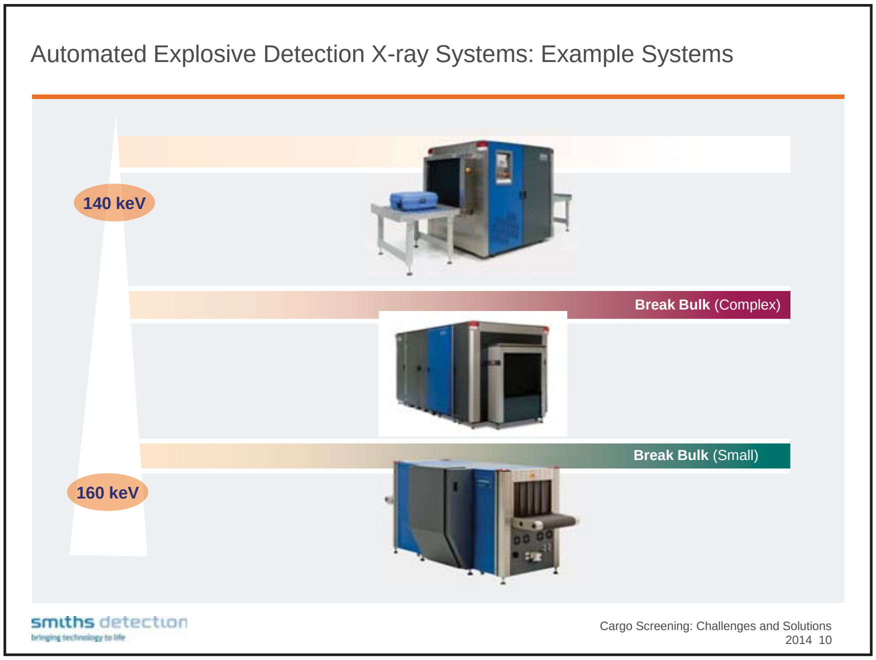
Parcel Capable Systems

Pallet Capable Systems

Explosive Detection Systems

Trace

Bar code reader &
data base Capabilities


Automated Explosive Detection X-ray Systems: Example Systems
140 keV
Break Bulk (Complex)
Break Bulk (Small)
160 keV
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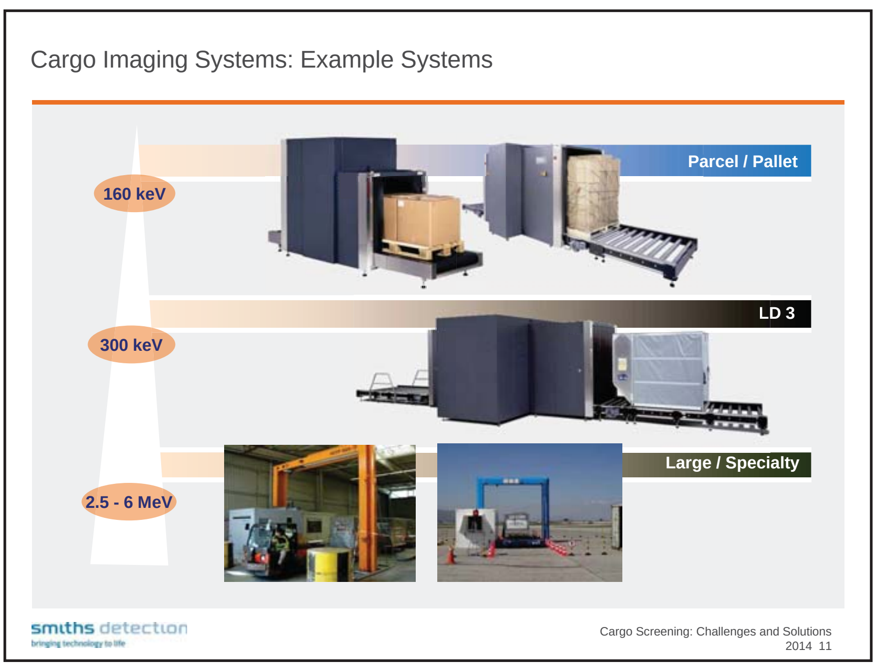
Cargo Screening: Challenges and Solutions
2014 10


Cargo Imaging Systems: Example Systems
160 keV
Parcel / Pallet
LD 3
300 keV
Large / Specialty
2.5 - 6 MeV
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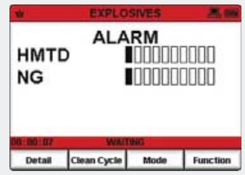
Cargo Screening: Challenges and Solutions
2014 11

Explosive Trace Detection Capability

Handheld

- Primary or Secondary Screening Use
- Vapor or Particle
- Carry to cargo / vehicle
- Contact or air sample
- Cost Efficient
- Proven (in use)



Desktop/Cart

- Primary or Secondary Screening Use
- Batch Sampling (10)
- Mobile through facility
- Cost Efficient
- Proven (in use)

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Technology Needs

Material ID Technology:

- Automatic Threat Recognition for imaging system for E>200 keV
- Highlight suspicious areas in the image
- Determine material properties of scanned objects:
  - Z_{eff}
  - Density
- Adaptive Methodologies
  - Address large object density variability
  - Adapt screening parameters to object under investigation
- High throughput
  - Number of scans per hour > 1000
  - Minimize need to perform secondary check

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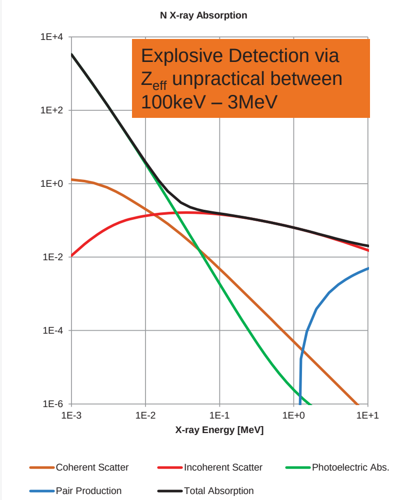
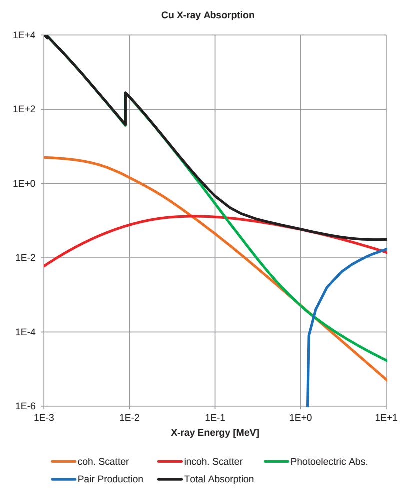
Material ID Challenges





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Cargo Screening: Challenges and Solutions
2014 14

New Technologies/Ideas

New Technology

- 3D Imaging

Rotating Gantry CT

Laminography

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Cargo Screening: Challenges and Solutions
2014 15

New Technologies/Ideas

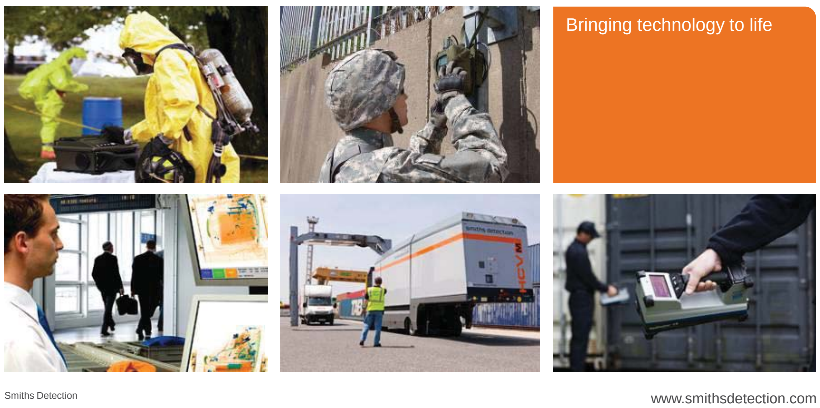
Other Technologies

Nuclear techniques:

- Neutron transmission
- Pulsed fast Neutron Analysis
- Thermal Neutron Analysis
- Nuclear Resonance Absorption

Conclusions

- From a vendor perspective new screening systems may be successful only if they meet regulator and freight forwarder/airline demands
- Regulators and freight forwarders/airline have to be involved in the development of new systems
- Systems providing automatic Detection at high throughput for small Cargo (boxes, parcels) are available - Detection based on density and Z_{eff}
- Palletized Cargo and Container screening is based on imaging: Evaluation by an Operator; next step should be to provide better Operator support
- Automatic Detection for palletized Cargo and Containers is very challenging taking regulators and freight forwarder demands into account.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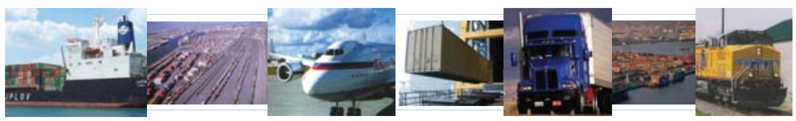
Smiths Detection
www.smithsdetection.com

16.31 Steve Korbly: Passport's Explosive Detection Technology

Contraband Detection in Air Cargo Containers

Algorithm Development for Security Applications 2014

Steve Korbly, Ph.D.
Passport Systems, Inc.



Work Supported in part by U.S. Department of Homeland Security Domestic Nuclear Detection under competitively awarded Contract No. HSHQDC-12-C-00059. This support does not constitute an express or implied endorsement on the part of the government. All claims and representations contained herein are those of Passport Systems, Inc. alone

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What Could TSA Obtain?

- Integrated solution to detect explosives, nuclear material and other contraband
- Automated detection – Think CT machine for air cargo
- 3D volumetric data of density and effective Z for region of interests
  - Available for operator review
  - Locates any potential threat
- Ability to resolve regions of interest to the elemental level
- Increased throughput due to larger scan volume (LD size)
- Low False Alarms due to orthogonal information
  - Alarms match in density, effective Z, and elemental ratios
- Ability to clear containers with confidence

2

Passport Systems Inc.

EZ-3D Volumetric Data of Density and Effective Z

Color Scale = Zeff Range

Transparency = Density

- Organic
- Inorganic
- Metals
- Dense Metals

Targets

- Tobacco
- C4 Explosive
- Cocaine
- High - Z

- Cargo is scanned slice-by-slice and reconstructed in 3D
- The voxels are aggregated into regions-of-interest
- These ROI's are analyzed for targeted materials at elemental level

3

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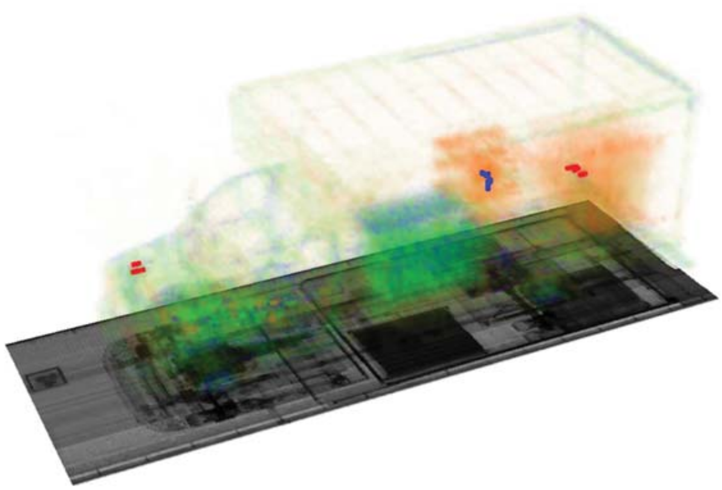
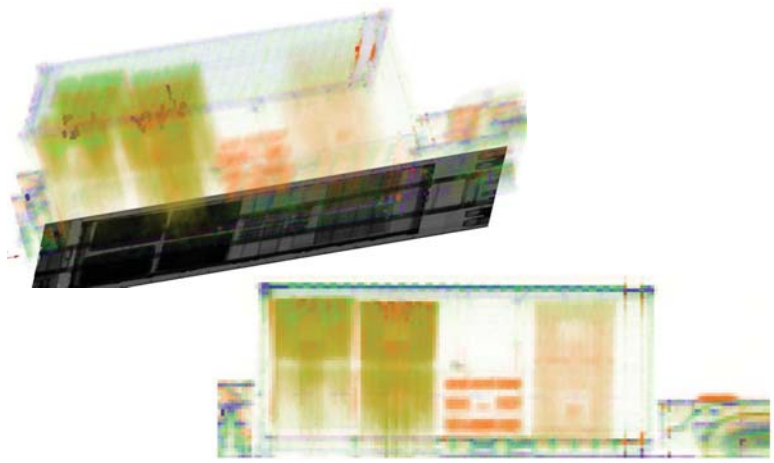
EZ-3D Volumetric Data of Density and Effective Z with Targeted Materials



4

Cargo measurements



5

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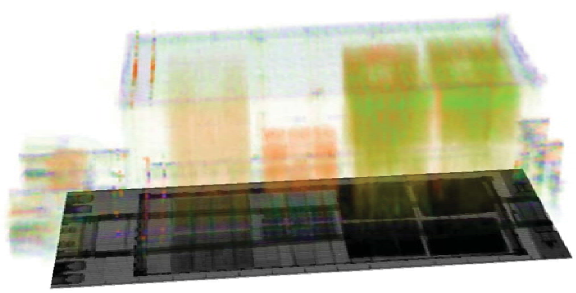
Cargo measurements



6

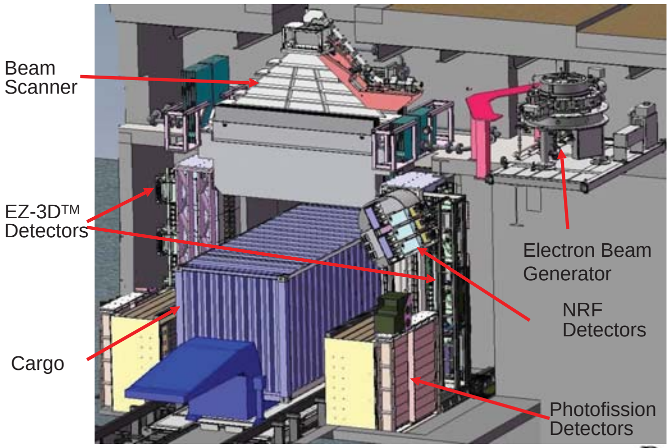
Standalone Cargo Scanning Facility

Design for facility to be installed at Port of Boston

7

Passport

Passport's Cargo Scanner



8

Passport

Passport Scanner Technologies

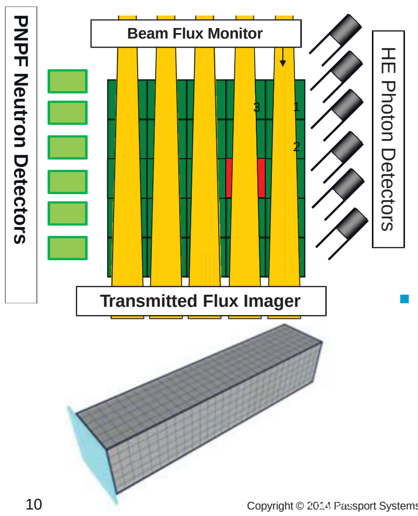
Beam
9 MeV Bremstrahlung Photons

Measured Particle
Photons: Effective-Z (EZ-3D™)
Nuclear Resonance Fluorescence (NRF)
Neutrons: Photofission (prompt)

Scan	Algorithm	Functionality / Output
Primary	EZ-3D™ Reconstruction	3-D density and Effective-Z map Anomaly identification/3D location
Primary	Transmission X-ray	Anomaly 2D location & density Shape/edge recognition
Primary	Portal Networked Detection System	Identification and localization of radioactive sources
Primary & Secondary	Photofission	Identifies presence of fissionable material
Secondary	NRF 3D	Complete isotopic composition in the region-of-interest
	Anomaly Classification	Performs data fusion, classifies anomaly as threat or innocuous, predicts detect/clear time

9

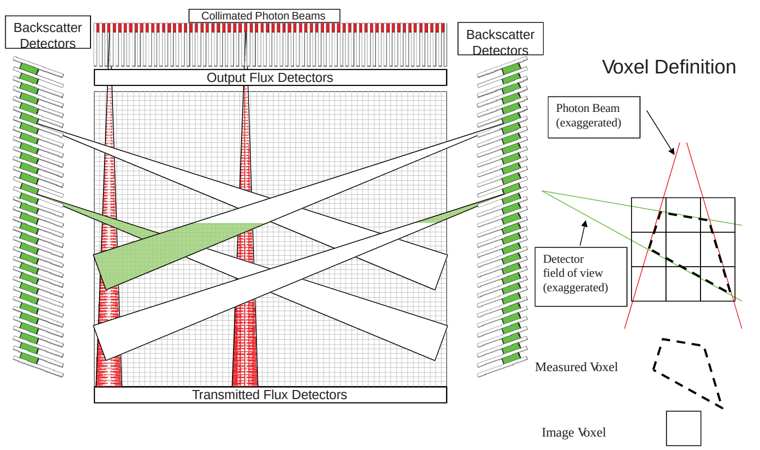
Scan Geometry and Process



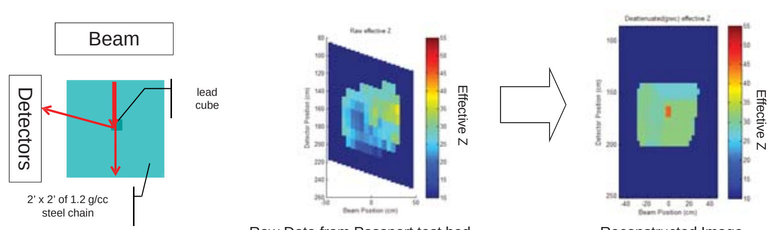
- **Primary Scan:**
  - Beam scans in the beam plane
  - Container traverses the beam
  - → 3D backscatter image (EZ-3D™)
    - ~15 s/20' container
    - 3D map of effective Z & density
  - → 2D transmission image
  - → 2D neutron image
    - Fissionable Material Alarm
  - → ROIs for secondary scan
- **Secondary Scan – ROI inspection:**
  - PNPF, beam dwell on ROIs (~seconds)
    - Fissionable Material Alarm
  - NRF, beam dwell on ROIs (~minutes)
    - Elemental Composition

10

EZ-3D™ Geometry



EZ-3D™ Reconstruction



Raw Data from Passport test bed

Reconstructed Image

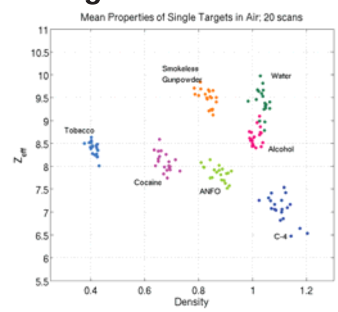
- Constraints
  - Transmission
  - Attenuation In
  - Attenuation Out
  - Regularizer – Biases toward “likely” solutions

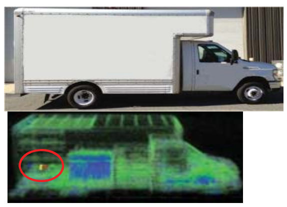
Output for Data Fusion

- Position
- Surface area
- Attenuation In
- Photon Attenuation Out
- Neutron Attenuation Out
- Density
- Effective Z

EZ-3D™ Detection Algorithm

- Utilize Z_{eff} and density image produced by Reconstruction
- Detection: use simple axis aligned upper and lower thresholds on Z_{eff} and density
- Thresholds determined by using reconstructed image voxels from training scans

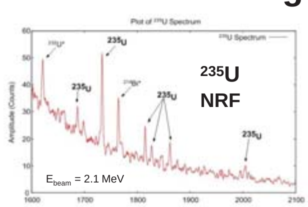




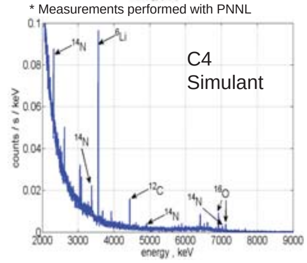
Threat Object	Type	Color
Calcium Hypochlorite	Oxidizer	Blue
Butane	Flammable Gas	Yellow
Gasoline	Flammable Liquid	Red
Hydrogen Cyanide	Toxic	Green

13

NRF Algorithms Overview



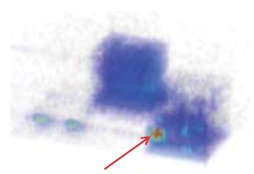
* Measurements performed with PNNL



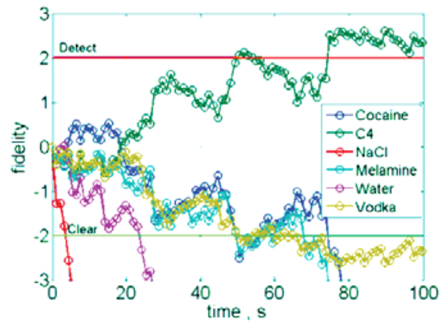
- NRF Data
  - Integrated counts for each line / detector
  - Background rate for each line / detector
- Anomaly identification
  - Calculate expected signal count rate for threat hypothesis
  - Calculate likelihood of measured NRF counts for hypothesis
  - Determine if anomalies from user-defined list are present / absent at defined level of PD / FP
- Supporting functions
  - Background estimation
  - Spectrum smoothing

14

Explosive Detection Example



'Explosive' Anomaly detected by density & EZ



- Potential explosive anomaly detected by density, EZ
- Identified as C4 in minutes

15

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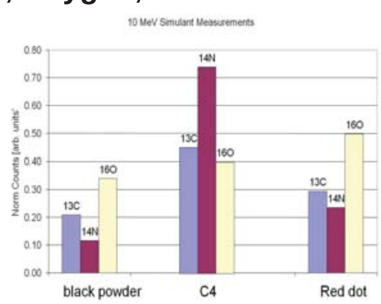
Nitrogen, Oxygen, and Carbon as Signatures



El.	C4 (%) Mass Spec	C4 (%) NRF	Red Dot (%) Mass Spec	Red Dot (%) NRF	Black Powder (%) Mass Spec	Black Powder (%) NRF
C	23.0	21.6±2.7	25.2	27.4±3.4	14.8	15.2±2.2
N	32.9	41.0±6.7	13.9	11.2±1.8	11.2	11.5±1.9
O	38.8	37.4±3.6	58	61.4±5.9	33.7	41.4±4.3

- Isotopic identification offers clear discrimination between other materials
- NRF technique agrees well with other techniques

16

Passport Systems Inc.

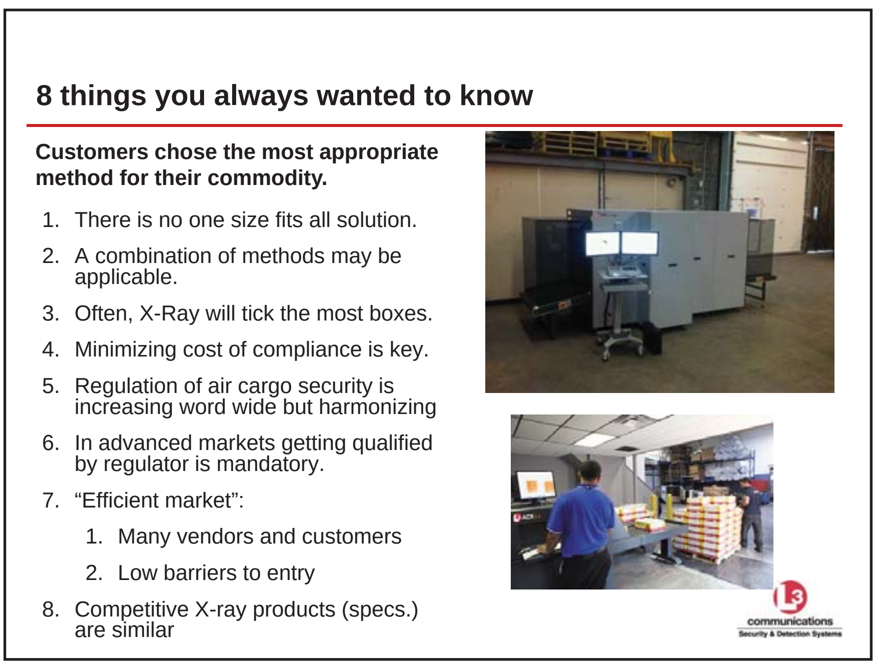
Summary

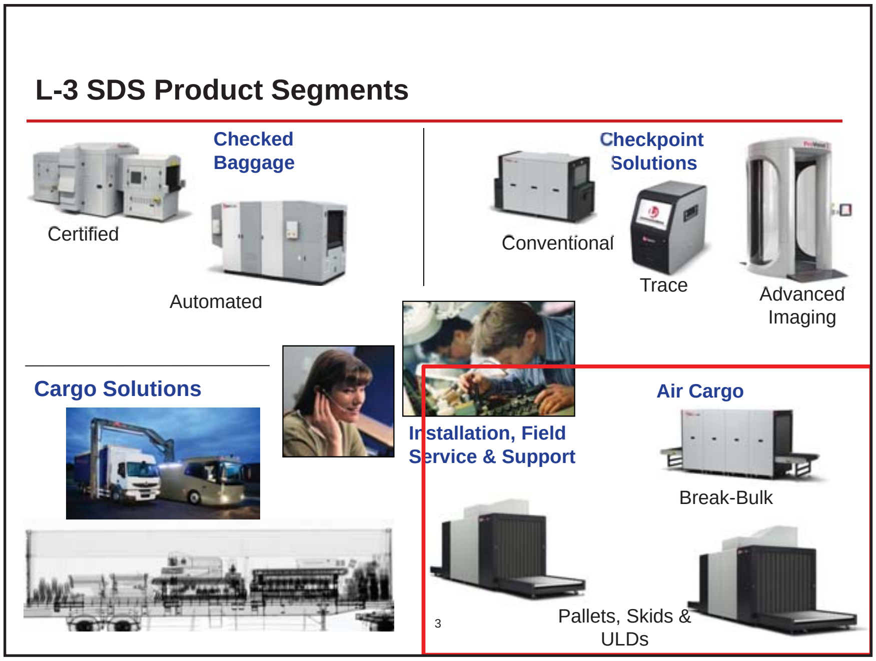
- EZ-3D™ reconstruction - novel imaging technique for automated contraband detection
- NRF provides isotopic/elemental identification
- Passport's scanner provides unique solution for
  - Explosives
  - Nuclear Material
  - Contraband
  - Material Identification
- Passport building land/sea cargo container scanner at port of Boston

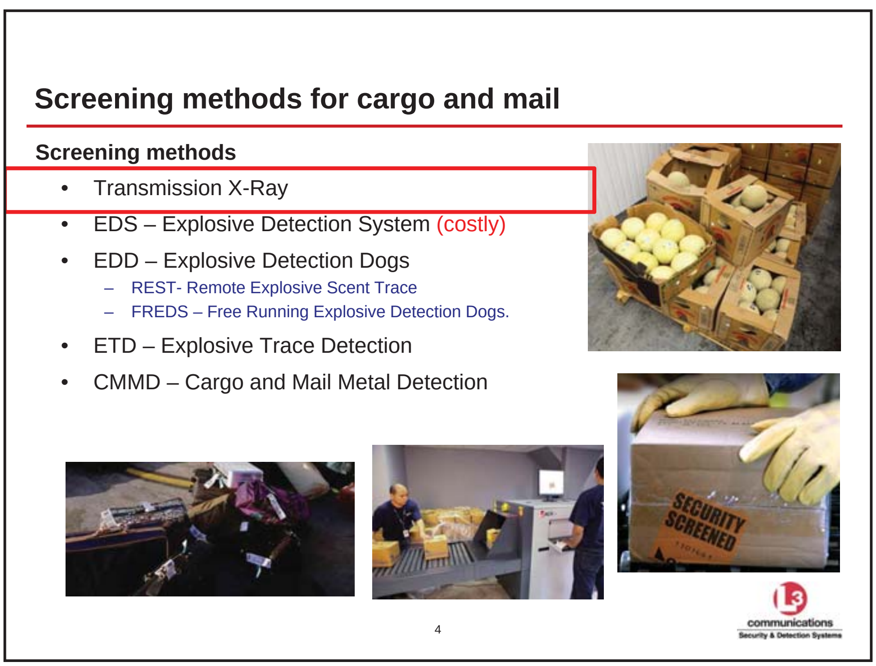
17

Passport
Systems Inc.

16.32 Stewart Hampton: L-3 Commercial Offerings




L-3 SDS Product Segments
Checked Baggage
Certified
Automated
Checkpoint Solutions
Conventional
Trace
Advanced Imaging
Cargo Solutions
Installation, Field Service & Support
Air Cargo
Break-Bulk
Pallets, Skids & ULDs
3


Screening methods for cargo and mail
Screening methods
• Transmission X-Ray
• EDS – Explosive Detection System (costly)
• EDD – Explosive Detection Dogs
– REST- Remote Explosive Scent Trace
– FREDS – Free Running Explosive Detection Dogs.
• ETD – Explosive Trace Detection
• CMMD – Cargo and Mail Metal Detection
SECURITY SCREENED
L3 communications
Security & Detection Systems
4

L-3 Air Cargo Solutions to Keep Commerce Moving

Leading TSA-Qualified X-ray Screening Systems

Automated: ACX 6.4, ACX 6.4-MV, VDS 108, VIS-HR, MVT-HR

Conventional: PX 107, PX 10.10-MV, PX 15.17-MV, PX 18.18-MV

High-Energy Pallet

L-3 Air Cargo Experience

- Providing airports and shippers with systems for break-bulk, skids, pallets* and ULDs* for more than a decade
- World's most advanced multi-sensor pallet scanner used by Dutch customs at Schiphol Airport in Amsterdam
- Over 150 company-employed field service techs in US
- Full service solutions

*subject to applicable regulatory requirements

Air Freight Forwarder issues

- **Regulator qualified**
- **Form factor / Size / Weight**
- **Cost to buy and operate**
- **Performance (imaging)**
- **Throughput**
- **Uptime**
- **Service / time to repair**
- **Networking – centralized screening (emerging)**

6

L3 communications
Security & Detection Systems

L-3 Air Cargo Solutions to Keep Commerce Moving

Leading TSA-Qualified X-ray Screening Systems

Automated

ACX 6.4 | ACX 6.4-MV | VDS 108 | VIS-HR | MVT-HR

Conventional

PX 107 | PX 10.10-MV | PX 15.17-MV | PX 18.18-MV

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- Over 150 company-employed field service techs in US
- Full service solutions

*subject to applicable regulatory requirements

Screening methods – X-ray

Break bulk, parcel and mail

- Dual View
- Image Quality Compliant
- Minimize density alarms

L3 communications
Security & Detection Systems

PX™10.10-MV
Non-Palletized Freight X-ray System

TSA ,Transport Canada, and DfT Qualified

APPLICATIONS
- **Large Parcel / Light Freight Screening**
- **Break-Bulk Cargo Screening**
- **Out –of-Gauge Luggage Screening**

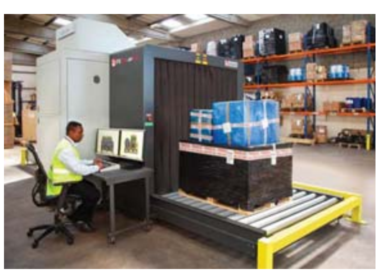
Features
- Dual-energy material discrimination
- Patented heads-up operator interface
- Optimal combination of belt height (19"/480mm) and geometry (up-shooter)
- High-power X-ray tank standard:
  - Improved penetration (42-44 mm steel)
- Upgradeability – 1 or 2 views
- Modularity – fits through doorways and in most elevators
- Options – motorized inclined conveyor capacity to **200 kg (440 lb)**
- EU-approved TIP library (1K images)
- Multi-language support

9

Screening methods – X-ray

Bulk or consolidated cargo

- Dual View
- Image Quality Compliant
- High power penetration required to minimize density alarms



PX™ 15.17-MV & PX™ 18.18-MV Palletized Freight X-ray System

TSA, Transport Canada, STAC and DfT Qualified

Tank Power	Steel penetration (mm)*	Wire (AWG)*
200kV Tank	50-52 mm	38-40 AWG
320kV Tank	75-80 mm	38-40 AWG

Features:

- Dual-energy material discrimination
- Low conveyor height with 2,000 kg capacity and powered, close-pitch rollers
- 6-color imaging with atomic Z-number correlation
- Continuous scanning and zoom 2x – 32x
- Reliable and easy to service
- Multi-language feature supported

APPLICATIONS

- Air Cargo Skid / Pallet / Most ULD screening
- Large parcel / Bulk Mail screening
- Manifest Verification

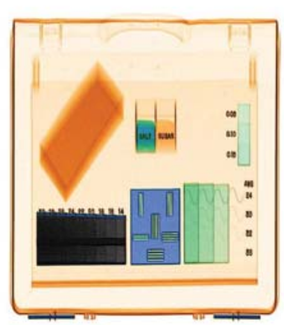
11

communications
Security & Detection Systems

Note: * Using L-3 standard test piece

Standard Test Piece

- •STP Default Image. No Image enhancement tools applied.
- •Determines x-ray systems resolution and penetration and organics.
- •ASME / STP
- •Human Based Evaluation (ensure you tester has 20/20 or better vision!)



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communications
Security & Detection Systems

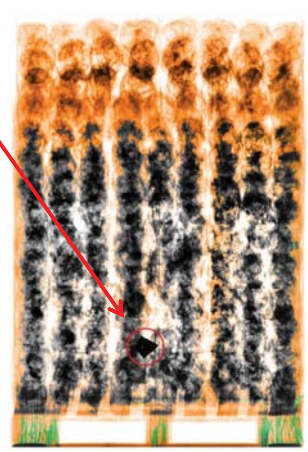
L-3 Air Cargo Qualified X-Ray Scanners

TSA Classification	Product	Tunnel Size (mm/in)	Certified EDS (CT)	Advanced Technology (AT)	Multiview	Transport Canada Approved	TSA Qualified
Large X-ray	PX 160P	1501 x 1650 59.1 x 65					✔
	PX 15.17 200	1501 x 1702 59.1 x 67					
	PX 15.17-MV 200	1501 x 1702 59.1 x 67			✔	✔	✔
	PX 15.17-MV 320	1509 x 1706 59.4 x 67.2			✔		✣
	PX 18.18 200	1803 x 1805 71 x 71.1					
	PX 18.18-MV 200	1803 x 1804 71 x 71			✔		✔
	PX 18.18-MV 320	1810 x 1807 71.3 x 71.1			✔		✔
	CX-Pallet 6000 P DV	3 m x 3.5 m 9.8 ft x 11.5 ft			✔		✔
Medium X-ray	PX 208	825 x 654 32.5 x 25.7					✔
	VDS 108	1000 x 800 39.4 x 31.5				✔	✔
	VIS-HR	1000 x 800 39.4 x 31.5		✔		✔	✔
	MVT-HR	1000 x 800 39.4 x 31.5		✔	✔	✔	✔
	PX 107	1011 x 1011 39.8 x 39.8					✔
	PX 10.10-MV	1013 x 1016 40 x 40			✔	✔	✔
Certified Explosives Detection Systems (EDS)	eXaminer 3DX (inline)	800 x up to 630 (31.5 x 24.8)	✔			✔	✔
	eXaminer HTSA (stand-alone)	800 x up to 630 (31.5 x 24.8)	✔			✔	✔
Small X-ray	PX 6.4	640 x 430 25.2 x 16.9					✔
	ACX 6.4	640 x 430 25.2 x 16.9		✔		✔	✔
	ACX 6.4-MV	640 x 430 25.2 x 16.9		✔	✔	✔	✔

L3 communications
Security & Detection Systems

Lettuce Scan on a PX18.18-MV 320 kV

Scan of a pallet of lettuce with triangular
Steel wedge visible behind the pallet



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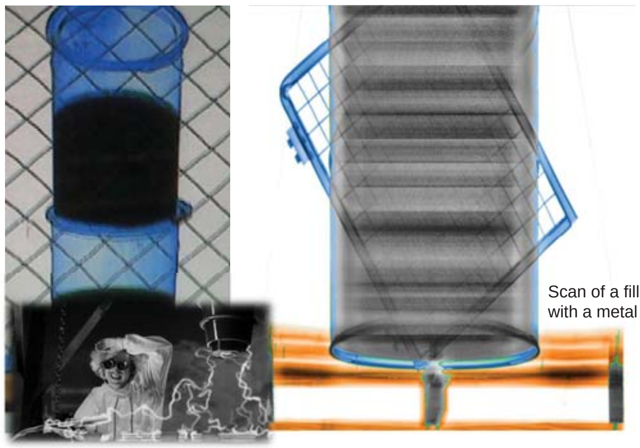
L3 communications
Security & Detection Systems

Oil Drum Example: 300kV and L-3's 320kV



Scan of a filled 55 gallon oil drum with a metal fence behind it

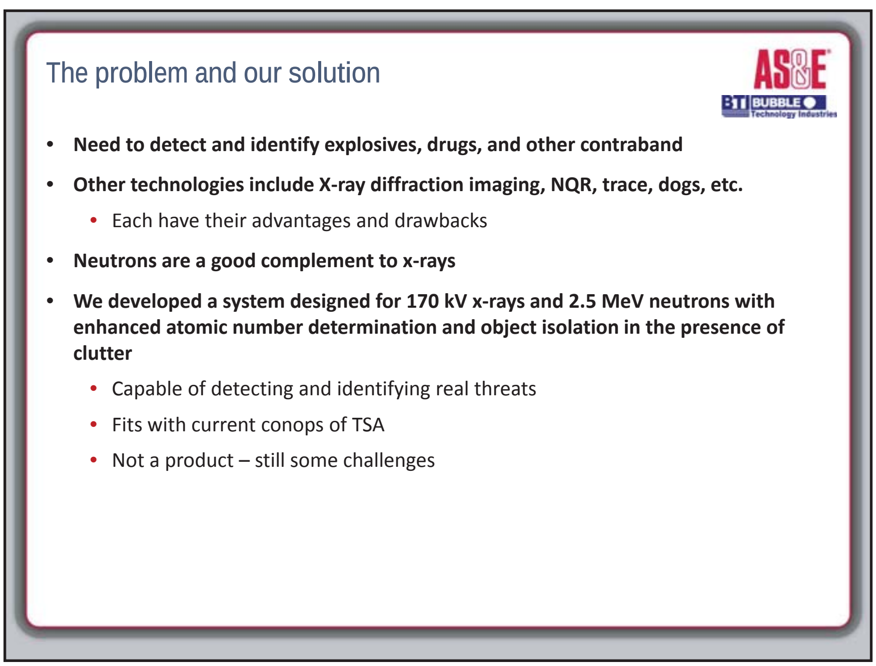
15

8 things you always wanted to know

Customers chose the most appropriate method for their commodity.

1. There is no one size fits all solution.
2. A combination of methods may be applicable.
3. Often, X-Ray will tick the most boxes.
4. Minimizing cost of compliance is key.
5. Regulation of air cargo security is increasing word wide but harmonizing
6. In advanced markets getting qualified by regulator is mandatory.
7. "Efficient market":
    1. Many vendors and customers
    2. Low barriers to entry
8. X-ray products (specs.) are similar

16.33 Seth Van Liew: A Mobile X-Ray/Neutron Cargo System for Aviation Security



X-ray attenuations

AS&E
BTI BUBBLE

Attenuation coefficients with X-ray [cm?¹]

1a	2a	3b	4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	0
H 0.02																	He 0.02
Li 0.06	Be 0.22											B 0.28	C 0.27	N 0.11	O 0.16	F 0.14	Ne 0.17
Na 0.13	Mg 0.24											Al 0.38	Si 0.33	P 0.25	S 0.30	Cl 0.23	Ar 0.20
K 0.14	Ca 0.26	Sc 0.48	Ti 0.73	V 1.04	Cr 1.29	Mn 1.32	Fe 1.57	Co 1.78	Ni 1.96	Cu 1.97	Zn 1.64	Ga 1.42	Ge 1.33	As 1.50	Se 1.23	Br 0.90	Kr 0.73
Rb 0.47	Sr 0.86	Y 1.61	Zr 2.47	Nb 3.43	Mo 4.29	Tc 5.06	Ru 5.71	Rh 6.08	Pd 6.13	Ag 5.67	Cd 4.84	In 4.31	Sn 3.98	Sb 4.28	Te 4.06	I 3.45	Xe 2.53
Cs 1.42	Ba 2.73	La 5.04	Hf 19.70	Ta 25.47	W 30.49	Re 34.47	Os 37.92	Ir 39.01	Pt 38.61	Au 35.94	Hg 25.88	Tl 23.23	Pb 22.81	Bi 20.28	Po 20.22	At	Rn 9.77
Fr	Ra 11.80	Ac 24.47	Rf	Ha													
Lanthanides	Ce 5.79	Pr 6.23	Nd 6.46	Pm 7.33	Sm 7.68	Eu 5.66	Gd 8.69	Tb 9.46	Dy 10.17	Ho 10.91	Er 11.70	Tm 12.49	Yb 9.32	Lu 14.07			
*Actinides	Th 28.95	Pa 39.65	U 49.08	Np	Pu	Am	Cm	Bk	Vf	Es	Fm	Md	No	Lr x-ray			

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Neutron attenuations

AS&E
BTI BUBBLE Technology Industries

Attenuation coefficients with neutrons [cm?¹]

1a	2a	3b	4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	0
H 3.44																	He 0.02
Li 3.30	Be 0.79											B 101.60	C 0.56	N 0.43	O 0.17	F 0.20	Ne 0.10
Na 0.09	Mg 0.15											Al 0.10	Si 0.11	P 0.12	S 0.06	Cl 1.33	Ar 0.03
K 0.06	Ca 0.08	Sc 2.00	Ti 0.60	V 0.72	Cr 0.54	Mn 1.21	Fe 1.19	Co 3.92	Ni 2.05	Cu 1.07	Zn 0.35	Ga 0.49	Ge 0.47	As 0.67	Se 0.73	Br 0.24	Kr 0.61
Rb 0.08	Sr 0.14	Y 0.27	Zr 0.29	Nb 0.40	Mo 0.52	Tc 1.76	Ru 0.58	Rh 10.88	Pd 0.78	Ag 4.04	Cd 115.11	In 7.58	Sn 0.21	Sb 0.30	Te 0.25	I 0.23	Xe 0.43
Cs 0.29	Ba 0.07	La 0.52	Hf 4.99	Ta 1.49	W 1.47	Re 6.85	Os 2.24	Ir 30.46	Pt 1.46	Au 6.23	Hg 16.21	Tl 0.47	Pb 0.38	Bi 0.27	Po	At	Rn
Fr	Ra 0.34	Ac	Rf	Ha													
*Lanthanides	Ce 0.14	Pr 0.41	Nd 1.87	Pm 5.72	Sm 171.47	Eu 94.58	Gd 1479.04	Tb 0.93	Dy 32.42	Ho 2.25	Er 5.48	Tm 3.53	Yb 1.40	Lu 2.75			
**Actinides	Th 0.59	Pa 8.46	U 0.82	Np 9.80	Pu 50.20	Am 2.86	Cm	Bk	Cf	Es	Fm	Md	No	Lr neut.			

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Outline

- Using neutrons in security
- A mobile X-ray / Neutron system
- Laboratory hardware and data
- Algorithms
- X-ray / neutron fusion
- Conclusions

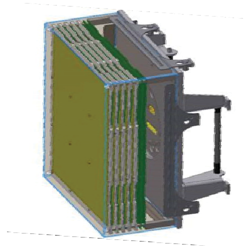
What we sought to accomplish

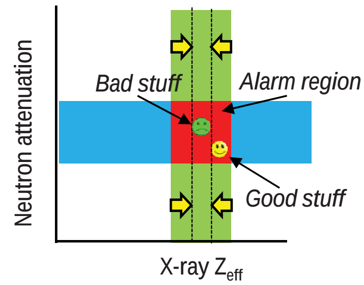
- Positive identification of explosives, oxidizers, and narcotics
- Compact, mobile x-ray / neutron system that could potentially be used in a TSA environment
- Could fit with current conops at TSA
  - 20 cm/s belt speed
  - 1 m x 1 m tunnel size for checked baggage
- A reasonable unit price
  - COTS components wherever possible
  - Smart system integration of components allowing for improved performance
  - Focus on innovative algorithms

Challenges

AS&E
BTI BUBBLE Technology Industries

- **Need to deal with clutter**
  - Multiple views
  - De-cluttering segmentation algorithms
  - Object isolation algorithms
- **Need to improve x-ray Z_{eff} accuracy so benign materials would not be present in alarm region**
- **Need to develop high resolution, scalable neutron detector**
- **Need high efficiency neutron detector without liquid scintillator**





What we want in a neutron system

AS&E

Fast

Good detection

Low shielding weight

Pick two of the three!

...and low cost

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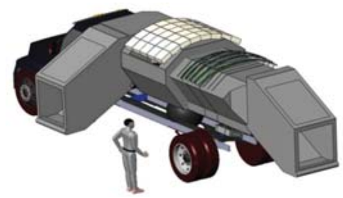
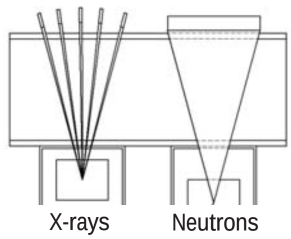
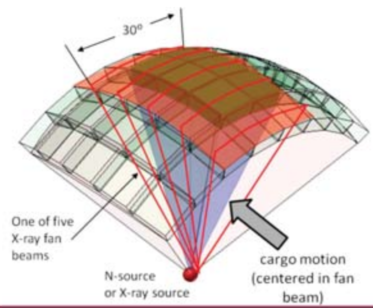
System Concept

AS&E

- Matched field of views for neutrons and x-rays
  - Use sparse linear arrays for x-rays
- Bottom shooter to reduce neutron shielding weight
- D-D neutron generator (2.5 MeV)
- 170 kV x-ray source







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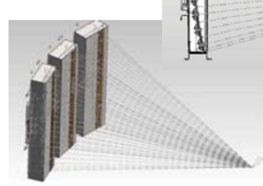
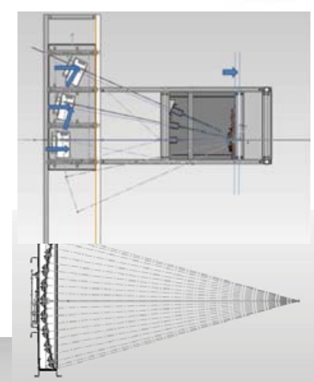
X-ray hardware

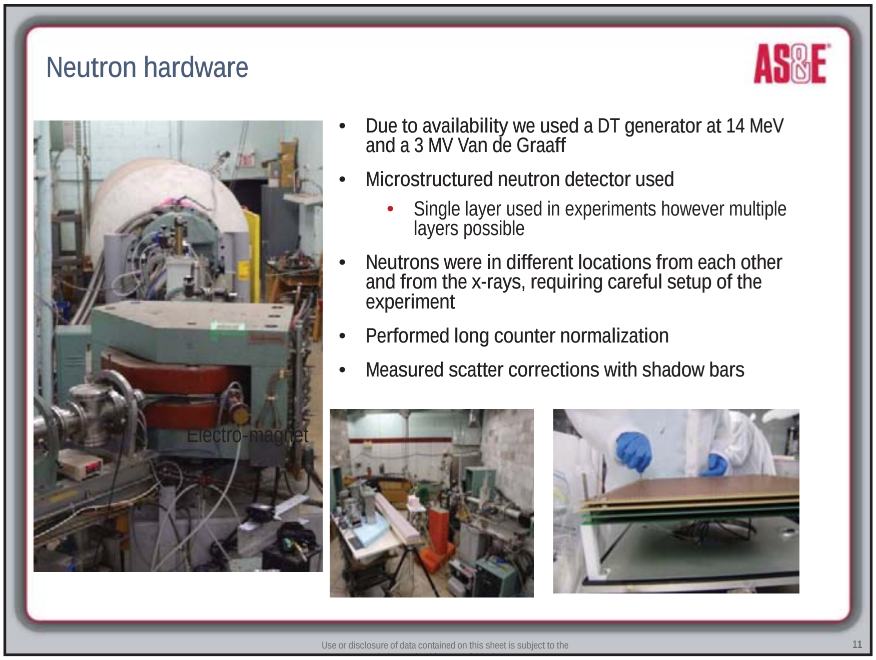
AS&E

- 5 views arranged across 48°
- To save space and cost for testing, only implemented three physical views over half the span
  - Ran cargo through backwards to get other two views
- Used a 140 kV source





 10


Neutron hardware
AS&E
Due to availability we used a DT generator at 14 MeV and a 3 MV Van de Graaff
Microstructured neutron detector used
Single layer used in experiments however multiple layers possible
Neutrons were in different locations from each other and from the x-rays, requiring careful setup of the experiment
Performed long counter normalization
Measured scatter corrections with shadow bars
Electro-magnet
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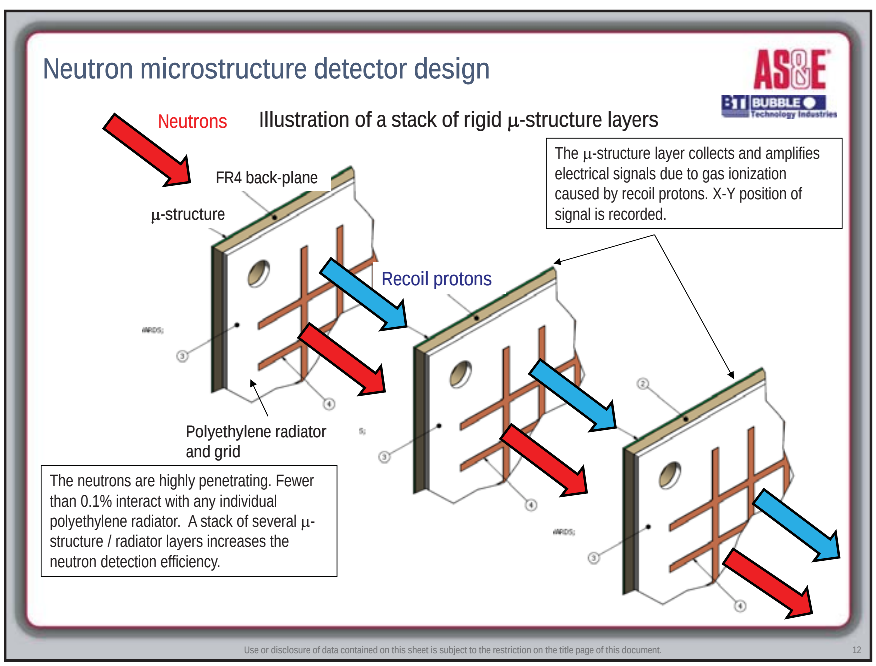
Neutron microstructure detector design
AS&E
BTI BUBBLE Technology Industries
Neutrons
Illustration of a stack of rigid μ-structure layers
FR4 back-plane
μ-structure
The μ-structure layer collects and amplifies electrical signals due to gas ionization caused by recoil protons. X-Y position of signal is recorded.
Recoil protons
Polyethylene radiator and grid
The neutrons are highly penetrating. Fewer than 0.1% interact with any individual polyethylene radiator. A stack of several μ-structure / radiator layers increases the neutron detection efficiency.
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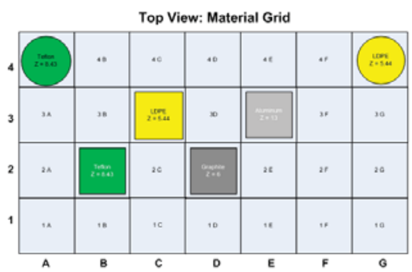
Experiments: Phantom

AS&E

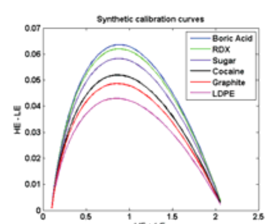
- How to get good data with when systems are not collocated?
- Registered phantom!
- This phantom was supplied with bar and rectangular stock
- Has dimensions of typical bag
- Can simulate clutter, overlap, etc, but in a controlled environment
- Used for both neutron and x-ray data
- Tested a variety of configurations of different benign materials and threats

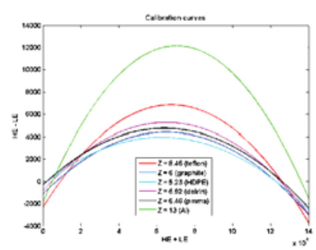


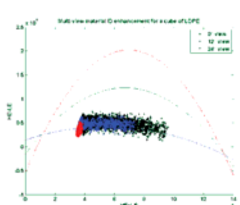
Better Zeff determination

AS&E

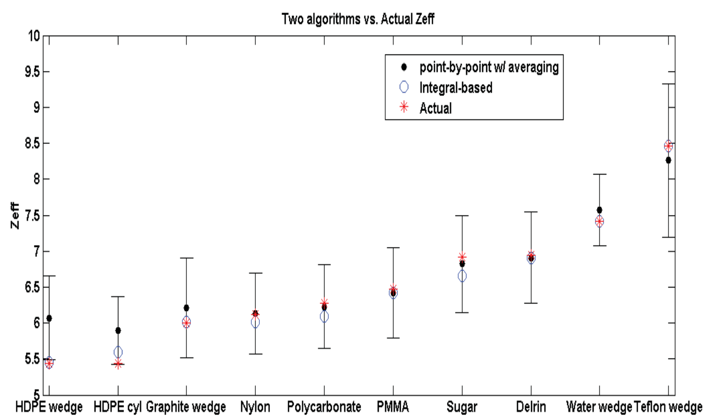
- Used finer calibration curves than the standard three calibration materials
  - Roughly every half-step in Z
- In addition, attempted to statistically match a given threat material to its own calibration curve using synthetic data
- Used multiple views to obtain better Zeff
- Developed new algorithm using a bulk-object averaging approach to enhance Zeff accuracy







X-Ray Analysis: Algorithm Comparison – New and Old



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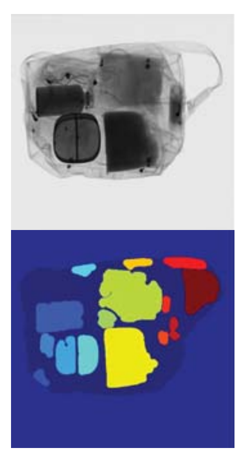
Multi-Stage Segmentation - Identify Objects

- We needed a way to automatically segment both overlapping and non-overlapping objects.
- We developed a segmentation algorithm that could do that
- This is a two-pass algorithm that feeds both sets of data to a material stripping algorithm that can then identify contiguous objects and where they overlap with other objects.



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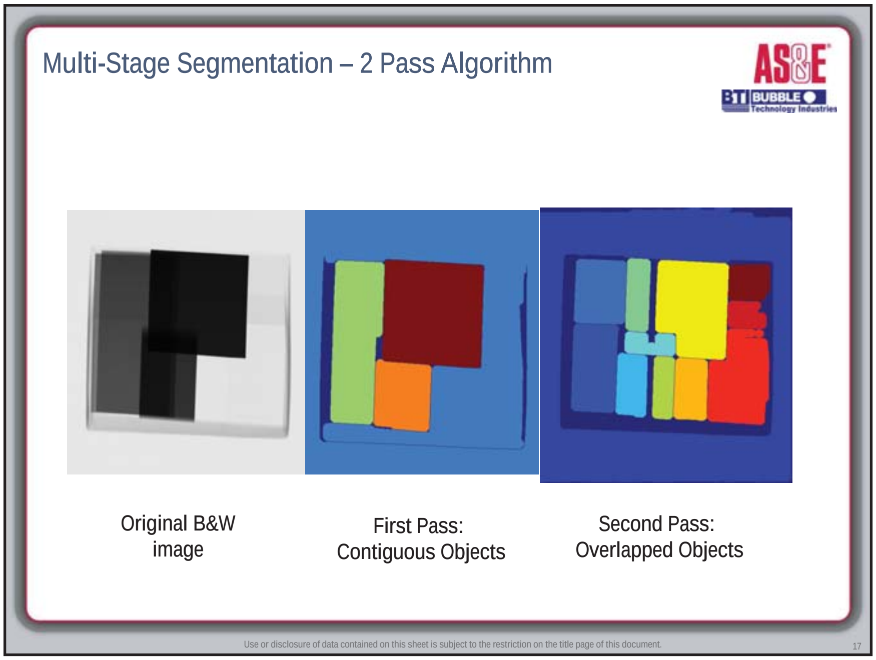
Multi-Stage Segmentation – 2 Pass Algorithm
AS&E
BTI BUBBLE Technology Industries
Original B&W image
First Pass: Contiguous Objects
Second Pass: Overlapped Objects
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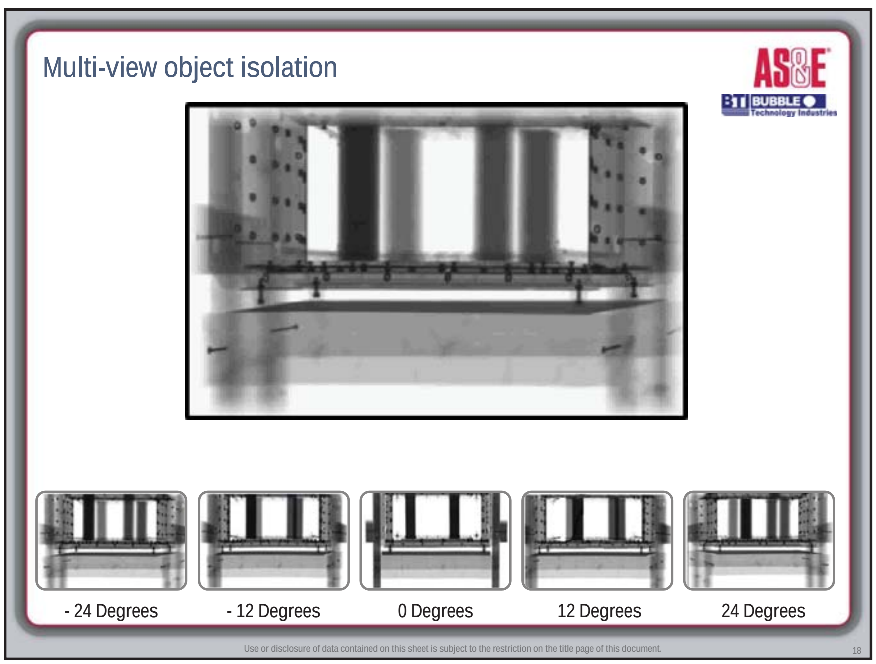
Multi-view object isolation
AS&E
BTI BUBBLE Technology Industries
- 24 Degrees
- 12 Degrees
0 Degrees
12 Degrees
24 Degrees
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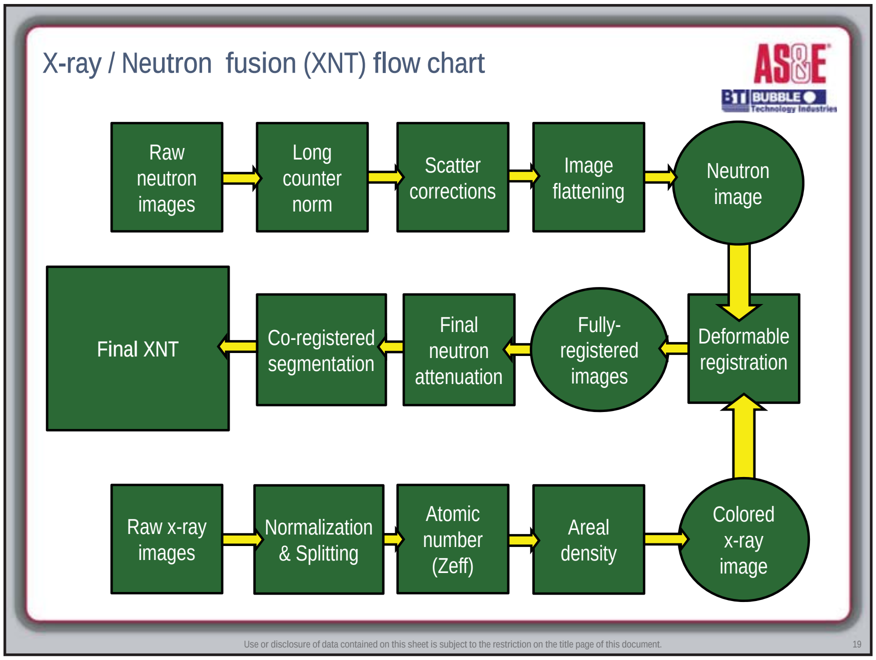
X-ray / Neutron fusion (XNT) flow chart
AS&E
BTI BUBBLE Technology Industries
Raw neutron images
Long counter norm
Scatter corrections
Image flattening
Neutron image
Final XNT
Co-registered segmentation
Final neutron attenuation
Fully-registered images
Deformable registration
Raw x-ray images
Normalization & Splitting
Atomic number (Zeff)
Areal density
Colored x-ray image
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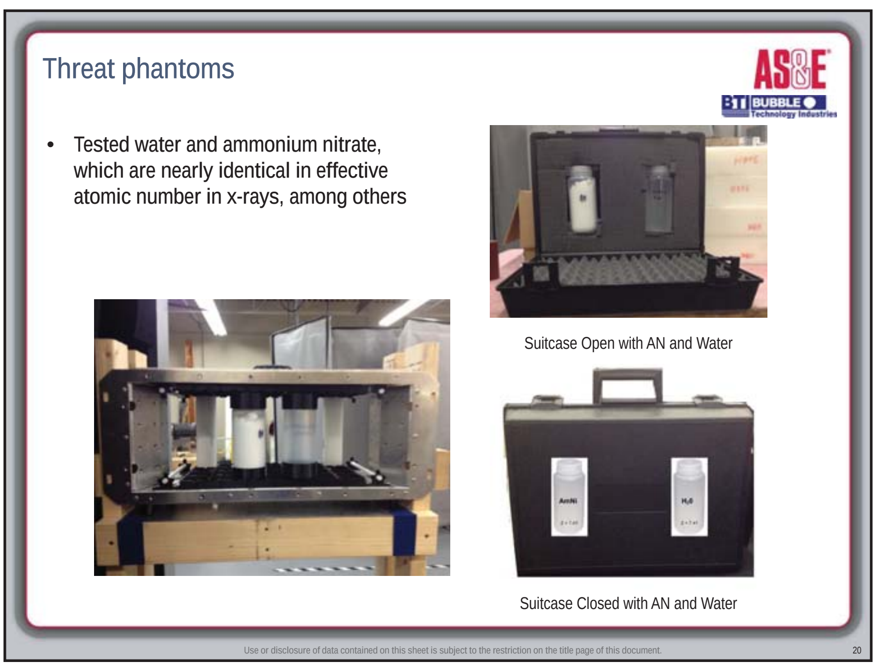
Threat phantoms
AS&E
BTI BUBBLE Technology Industries
• Tested water and ammonium nitrate, which are nearly identical in effective atomic number in x-rays, among others
Suitcase Open with AN and Water
Suitcase Closed with AN and Water
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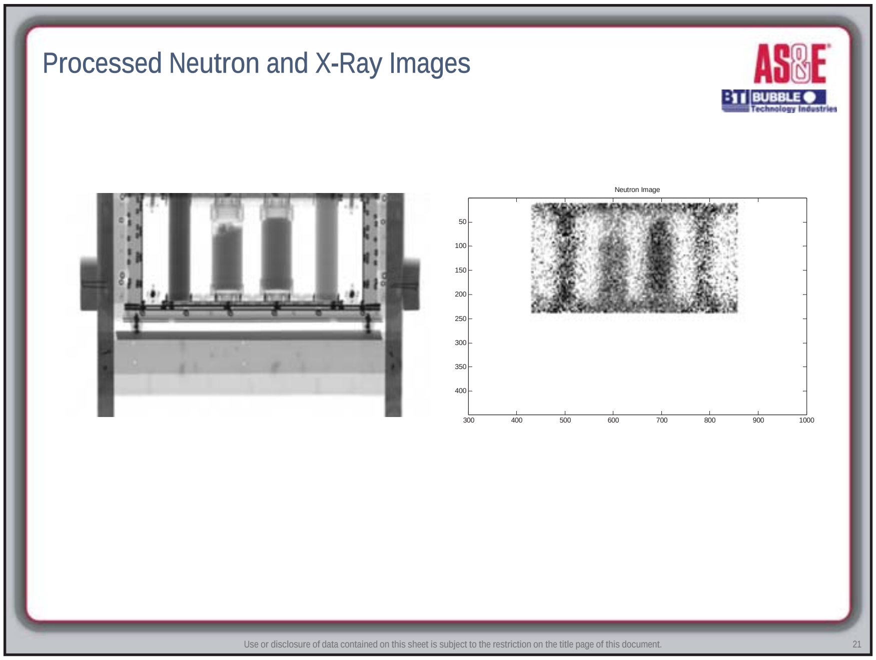
Processed Neutron and X-Ray Images
AS&E
BTI BUBBLE Technology Industries
Neutron Image
50
100
150
200
250
300
350
400
300
400
500
600
700
800
900
1000
Use or disclosure of data contained on this sheet is subject to the restriction on the title page of this document.
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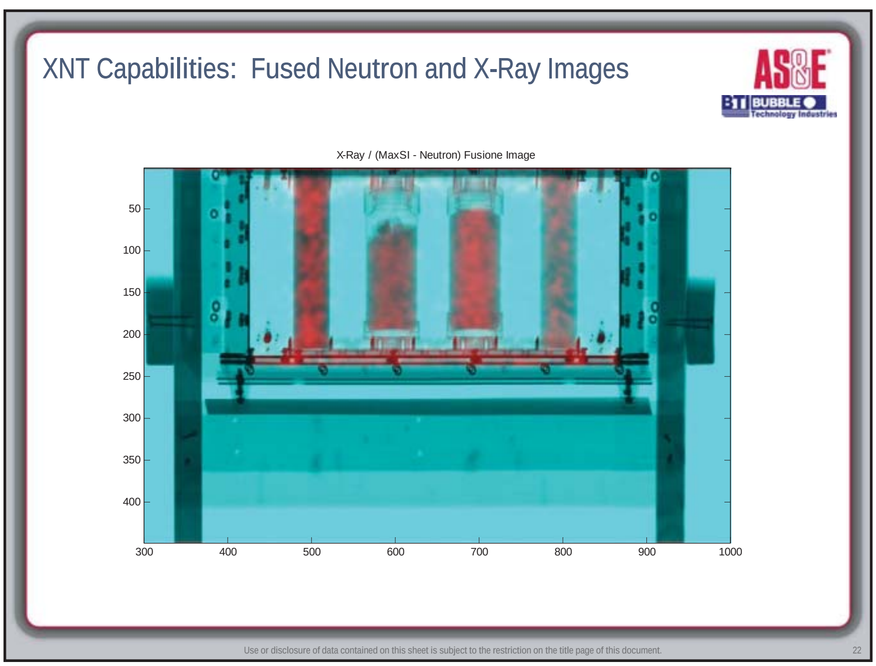
XNT Capabilities: Fused Neutron and X-Ray Images
AS&E
BTI BUBBLE Technology Industries
X-Ray / (MaxSI - Neutron) Fusione Image
50
100
150
200
250
300
350
400
300
400
500
600
700
800
900
1000
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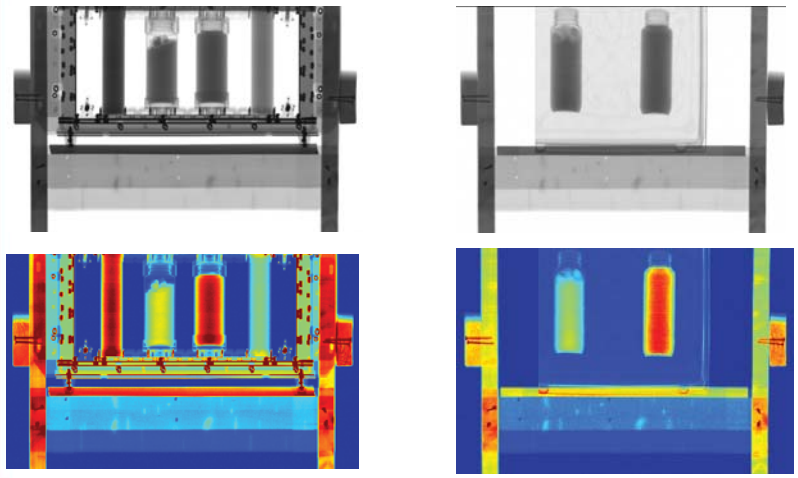
XNT Capabilities: X-ray and areal density images



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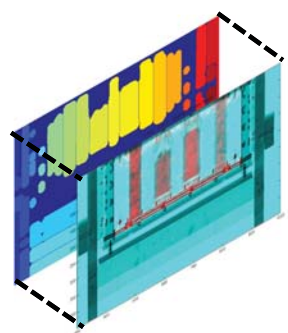
Segmentation and Feature Extraction

- Segmentation is performed on the co-registered images in order to identify all contiguous objects in the XNT overlay.
- This segmentation identifies all regions of the image whether they be air, benign material, or threat.
- Mechanically, segmentation is performed on the high-resolution XNT overlay, and the contours are then transferred to the individual images.
- Each region is then analyzed in both images to ascertain its atomic number and neutron attenuation.
- If a given region alarms based on a lookup table of XNT attenuations, the operator is notified.



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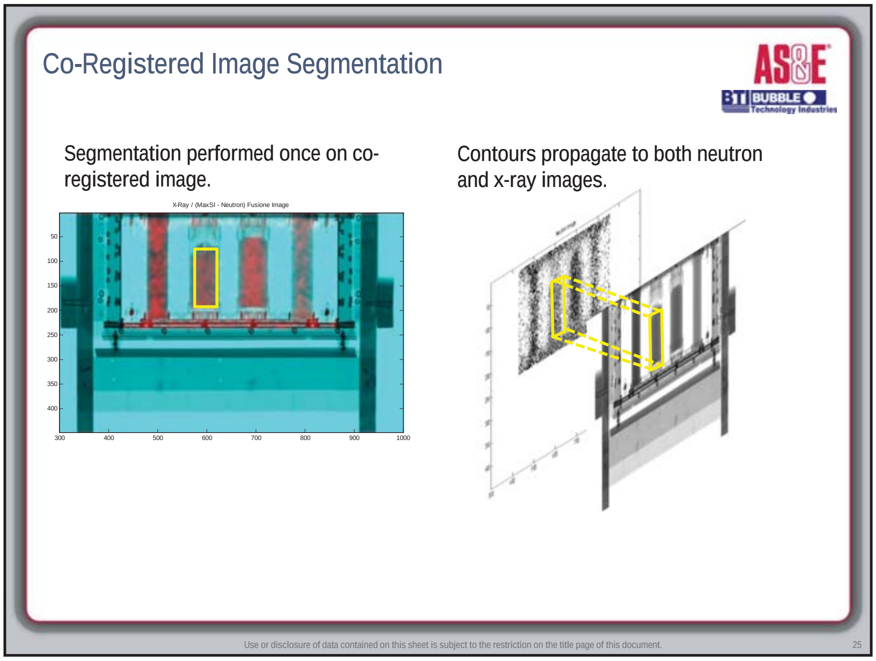
Co-Registered Image Segmentation
AS&E
BTI BUBBLE Technology Industries
Segmentation performed once on co-registered image.
X-Ray / (MaxSI - Neutron) Fusione Image
50
100
150
200
250
300
350
400
300
400
500
600
700
800
900
1000
Contours propagate to both neutron and x-ray images.
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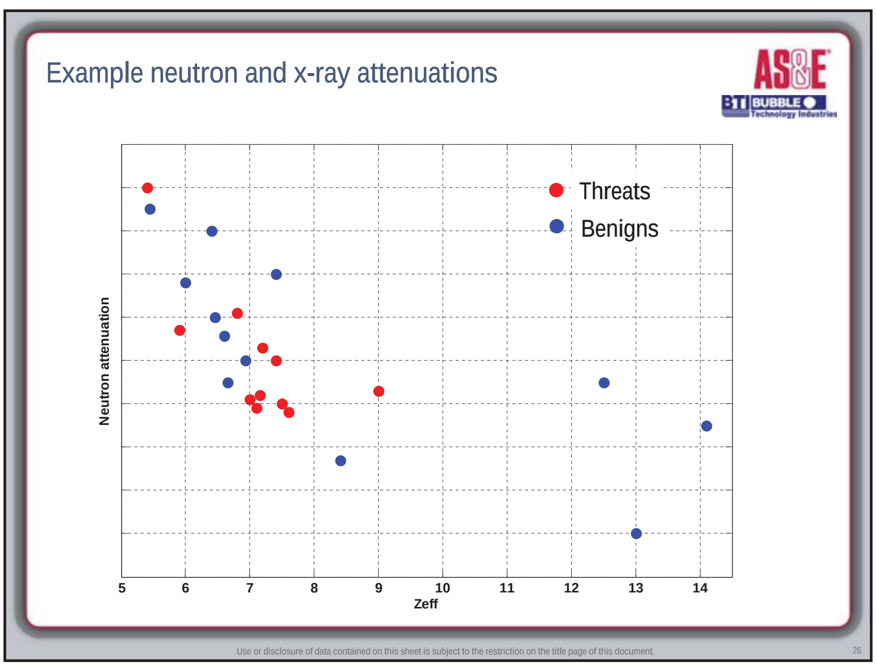
Example neutron and x-ray attenuations
AS&E
BTI BUBBLE Technology Industries
Threats
Benigns
Neutron attenuation
5
6
7
8
9
10
11
12
13
14
Zeff
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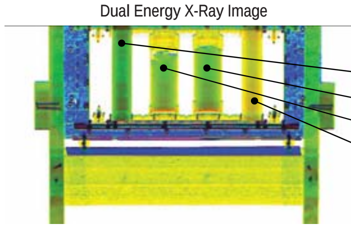
XNT Material identification procedure

Dual Energy X-Ray Image



X-ray Zeff	Neutron attenuation
8.5	0.10
7.4	0.15
7.4	0.09
5.4	0.26

Each contoured region analyzed in both x-ray and neutron space

After comparing each region with the lookup table, threats can be identified

Threat	Zeff	Neutron
Thermite	21.5	0.0493
AN	7.41	0.0854
Cocaine	6.31	0.1708
Ecstasy	6.20	0.1844
Meth	5.72	0.2243
…	…	…

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Conclusions

- XNT demonstrated to exceed material ID threshold for x-rays or neutrons alone.
- Multi-view x-ray technology dramatically improves material ID and decluttering of cargo.
- “Stackable” neutron microstructure detector is versatile and can work in a variety of environments
- **Image and data fusion of neutrons and X-rays demonstrated and can be automated.**
- Although the technology is still in development, it looks promising for certain applications
  - In the end, it’s all about flux, detection, and shielding
  - …and cost

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Collaborators

• **Vernon Koslowsky** – Lead Scientist at BTI	BTI
• **Ming Zhang** – Deformable registration	AS&E
• **Chris Alvino** – Image segmentation	AS&E
• **David Walazek** – Mechanical Design	AS&E
• **Cristian Dinca, Martin Rommel** – Concept and System Design and Simulations	AS&E
• **Dan Wakeford, Marius Facina** – Detector Development	BTI
• **Andrew Shinn, Patrick Forget, Ted Clifford** – Electronics & FW Design	BTI
• **Darren Locklin, Nick Bray, Richard Davis** – Mechanical Design	BTI
• **Gerry Mead, Ken Robins, Matthias Koslowsky** –System Assembly & Integration	BTI
• **Martin Koslowsky, Nicholas Hartmann** – Data Collection & Analysis	BTI
• **Harry Ing, Bob Andrews** – Physics Consultation & Technical Oversight	BTI

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16.34 Harry Martz: Next Steps

Next Steps

Harry Martz and Carl Crawford

ADSA10

May 6, 2013

Version 3

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We heard what the ideal Cargo system is

- Cargo needs to be screened in a manner consistent with checked baggage
- Hardened ULDs
- Detect small masses of explosives
- With high PD
- Very low PFA
- High throughput
- Small footprint
- Reliable
- Low cost $50k
- Low operating costs (labor, maintenance, etc)

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- Low operating costs (labor, maintenance, etc)

There seems to be a Silver Bullet: ETD

If ETD is not a Silver Bullet, there is no evidence there is one

- By themselves neutrons, photons, etc. do not satisfy the requirements for the ideal system
  - i.e., No single system exists

Options for going forward

- Regulations change
- CONOPS change
- Use/fuse manifest information
- Combined photons, neutrons, ETD, etc.
- Determine the best combination of technologies
- Per commodity
- Look for coincidences
- Integrate and fuse them
- Reduce their size & costs, especially personnel costs
  - Eliminate unpacking; scan before consolidation
- Improve deterrence, risk-based security

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Awareness and Localization of Explosives-Related Threats

Northeastern University — 360 Huntington Avenue — Boston MA 02115
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