Sensor Fusion for PBIED Detection

ADSA-06

Boston, Massachusetts

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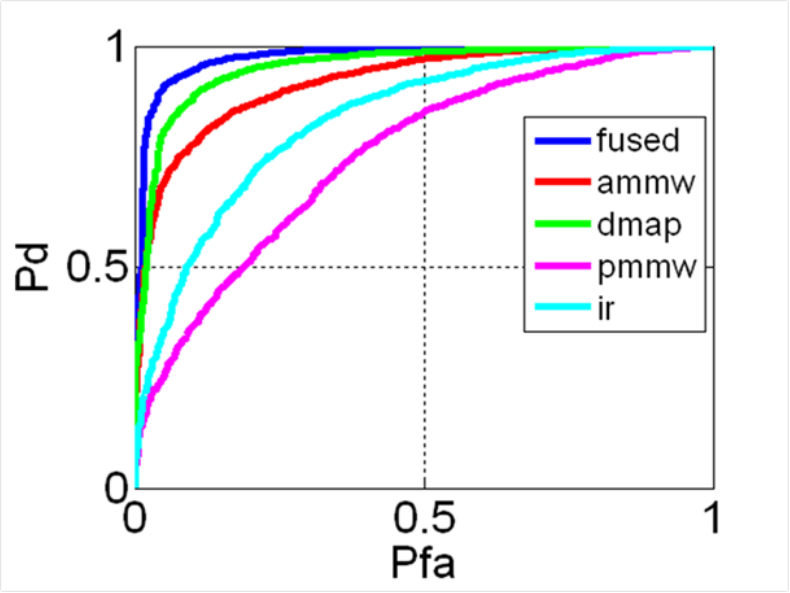
Conclusions

Multi-sensor inputs improved performance of a decision-fusion AiTR algorithm PBIED detection.

Receiver Operator Curve



Funding Agency

Work was funded under

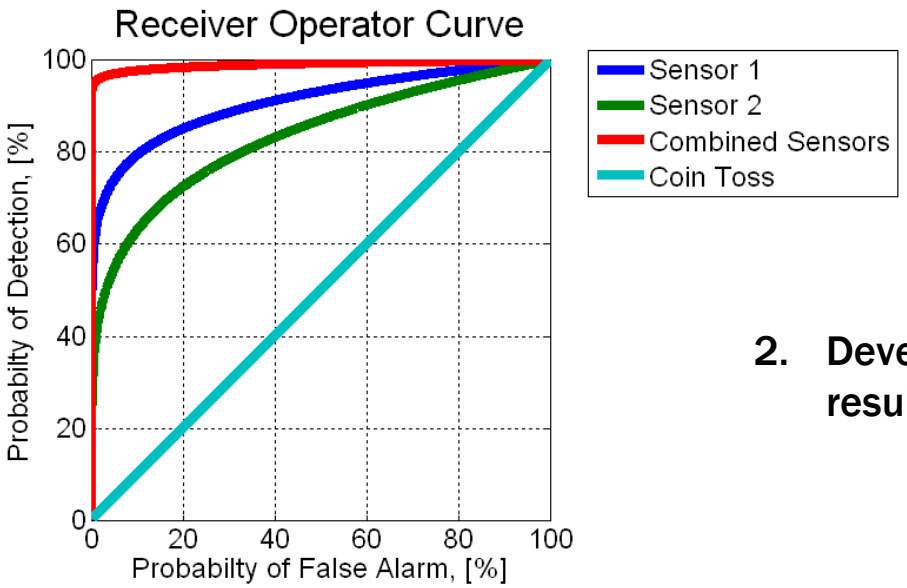
Contract: HSHQDC-09-C-00168

Agency: Department of Homeland Security Science & Technology, Explosives Division

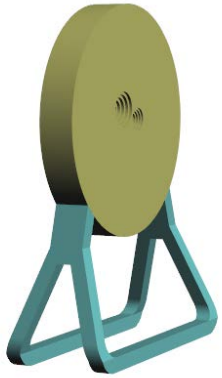
Project: Detection of Person-Borne and Vehicle Borne Improvised Explosive Devices

Background - Program Goals

1. Investigate the benefits of multiple sensors on the performance of AiTR (Aided Threat Recognition) algorithm for the detection of Person Borne IEDs



2. Develop prototype system based on results of study.



Program Overview

Phase 1
Fall 2009

- Acoustic & Multi-Frequency AMMW Imaging
- Slow Raster Scanning Laboratory System & Mannequins
- AiTR Framework
  - "Body Model"
  - Decision Fusion Concept

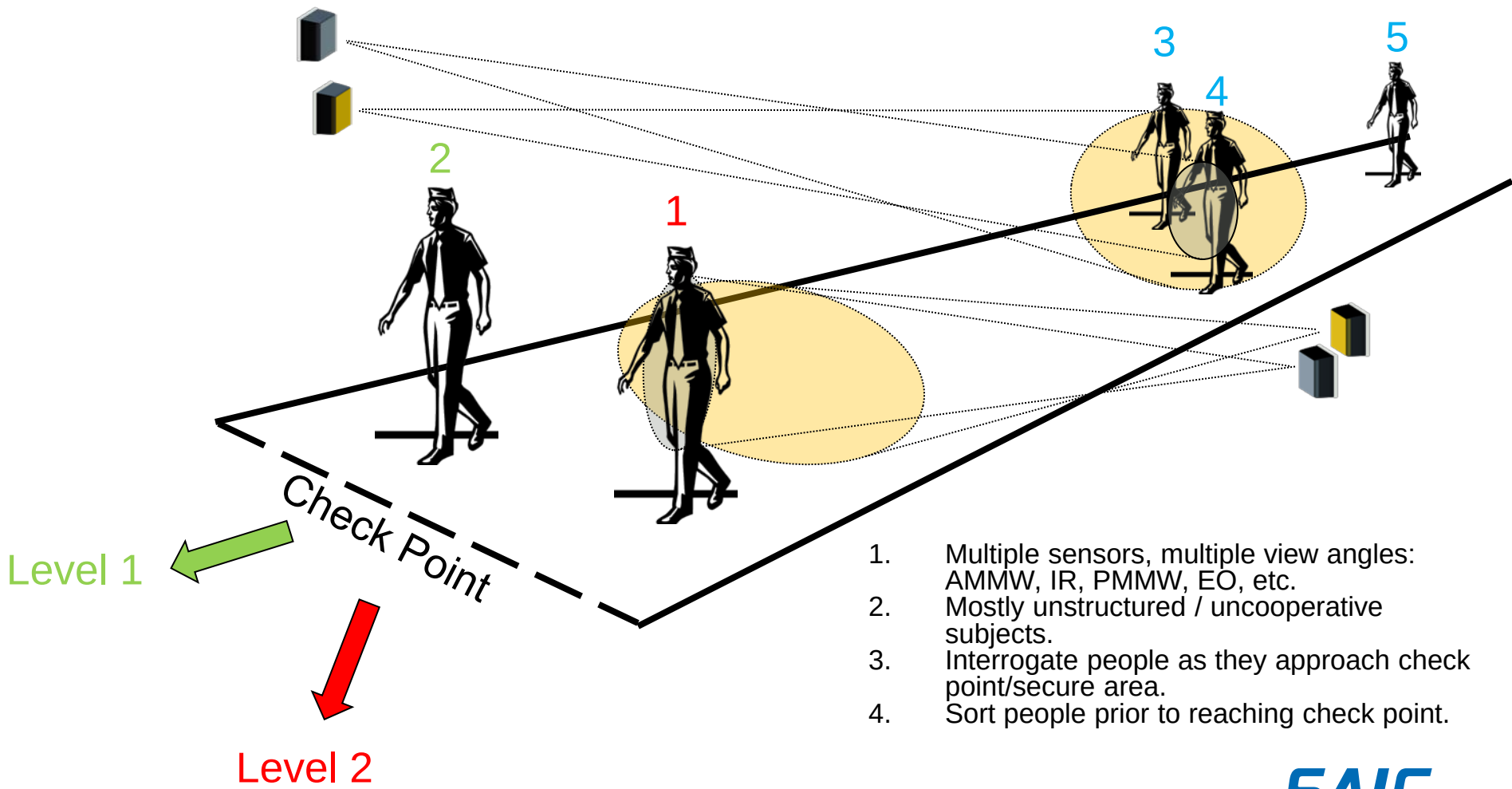
Phase 2
Spring 2010

- AMMW Imaging
  - Passive-IR
  - PMMW Imaging
  - 3D Profiling
- Human Subject Scanning
- AiTR Algorithm
- Performance Results

Phase 3
Summer 2011

- Multi-Frequency/Polarimetric Signature Study (10-100GHz)
- AiTR Algorithm Development
- Prototype System

CONOPS



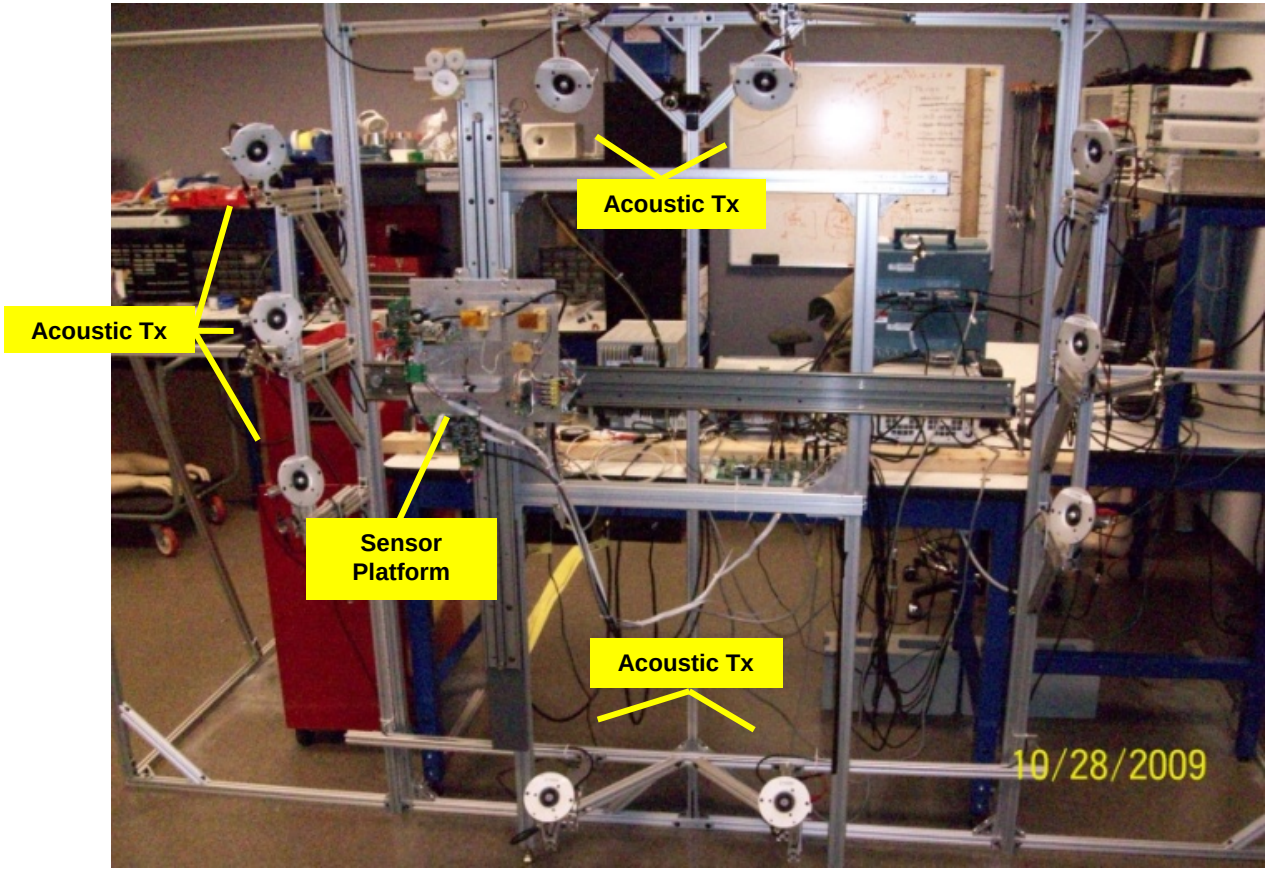
1. Multiple sensors, multiple view angles: AMMW, IR, PMMW, EO, etc.
2. Mostly unstructured / uncooperative subjects.
3. Interrogate people as they approach check point/secure area.
4. Sort people prior to reaching check point.

AMMW & Acoustic Sensor Fusion

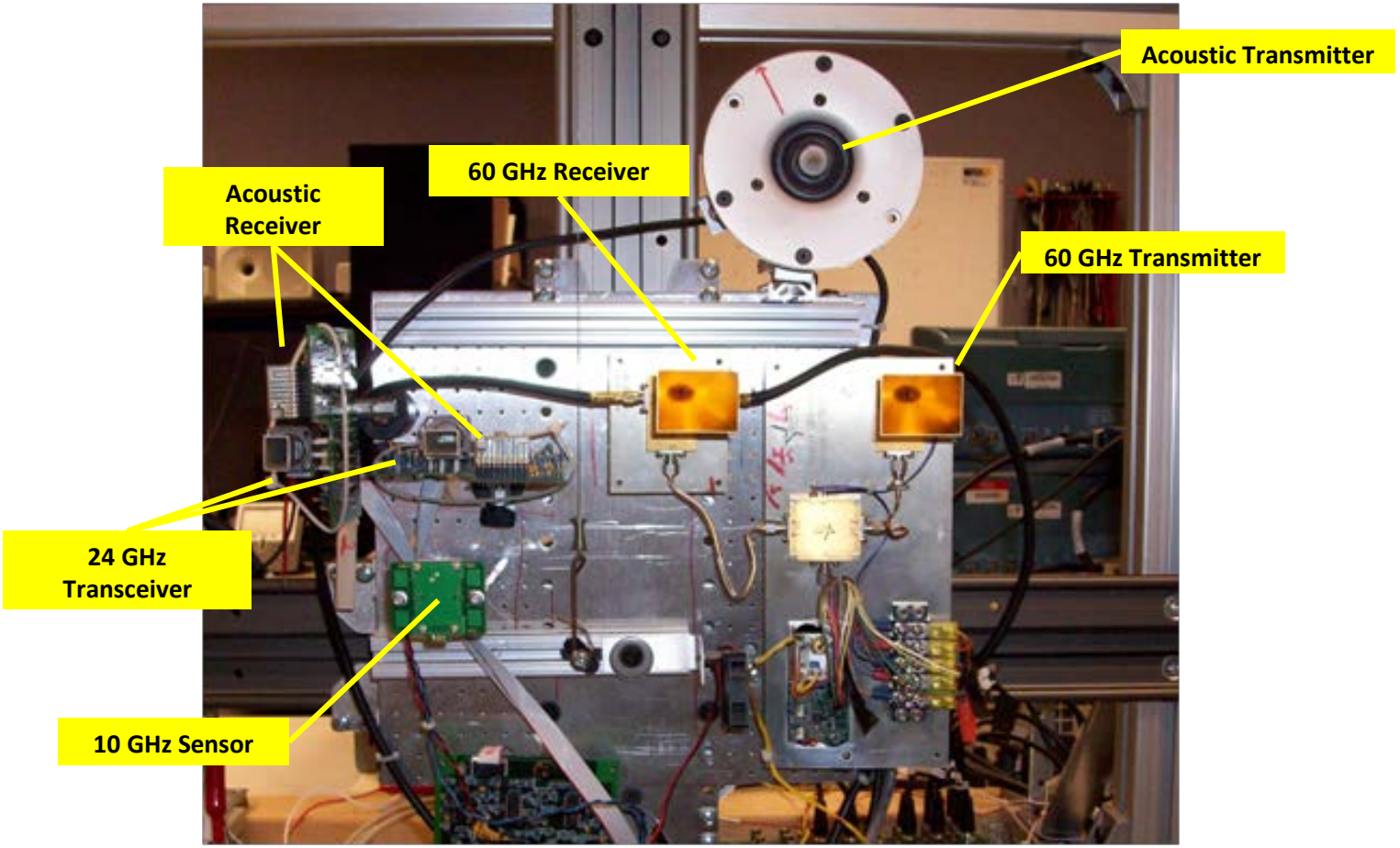
PHASE 1 FEASIBILITY STUDY

Phase 1
Acoustic and Multi-Frequency SAR Imaging – Laboratory Scanning System

Scanning Stage



Phase 1
Acoustic and Multi-Frequency SAR Imaging Sensors



Phase 1
Test Object

Bare Mannequin

Under Layer

Under Layer with First Covering Layer

Under Layer with 2 Covering Layers

Under Layer with Low Metal Content Bomb-Vest

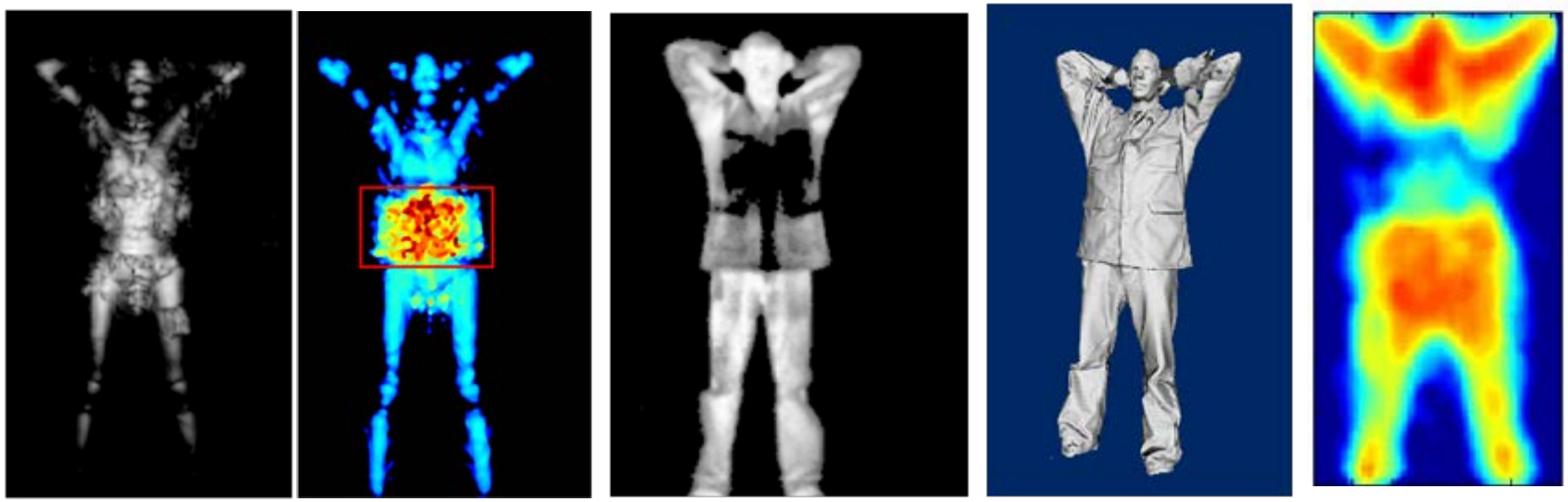
Phase 1
Fusion of Acoustic and AMMW Imaging

AMMW V -band

Acoustic

Combined

Images from 3D Viewer



Phase II

HUMAN SUBJECT SCANNING / PBIED DETECTION SYSTEM CONCEPT DESIGN

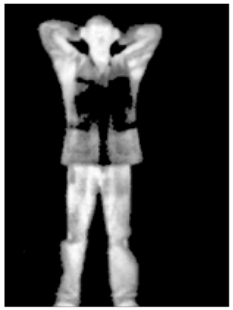
Phase 2 Sensors

Active MMW Scanner

Specifications
Freq: 12.5-18 GHz
Lateral Res: 1cm
Depth Res: 2.7cm
Spatial Coverage:
112cm x 200cm x 80cm
Scan Time: 1-2 sec

Notes
Primary detection sensor

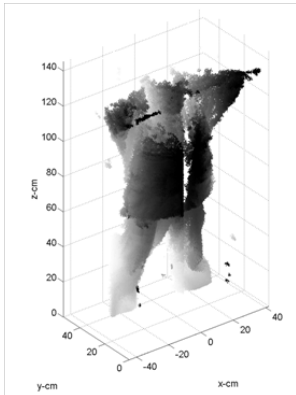
Passive IR



Specifications
Wavelength: 8-13μm
Thermal Res: 0.1°C
Spatial Res: <0.5cm
Pixels: 160H x 120V
FOV: 28°H x 21°V
Frame Rate: 8.5 FPS

Notes
•Identify body structure/model
•Assists AMMW detection
•Secondary confirmation
•Reduce FA

ToF 3-D Camera



Specifications
Lateral Res: <0.5cm
Depth Res: 1cm
Pixels: 176H x 144V
FOV: 43°H x 34°V
Frame Rate: 54 FPS

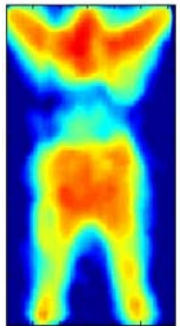
Notes
•Identify body structure/model
•Locates outer surface
•Real-time data collection
•Secondary confirmation
•Reduce FA

SWL 3-D Scanner

Specifications
Lateral Res: <<0.5cm
Depth Res: <<0.5cm
Pixels/Camera: 1280H × 1024V
Cameras Per System: 4
FOV: 28°H x 21°V
Scan Time: 1-2 sec

Notes
•Identify body structure/model
•Locates outer surface
•Excellent resolution
•Not real-time data collection

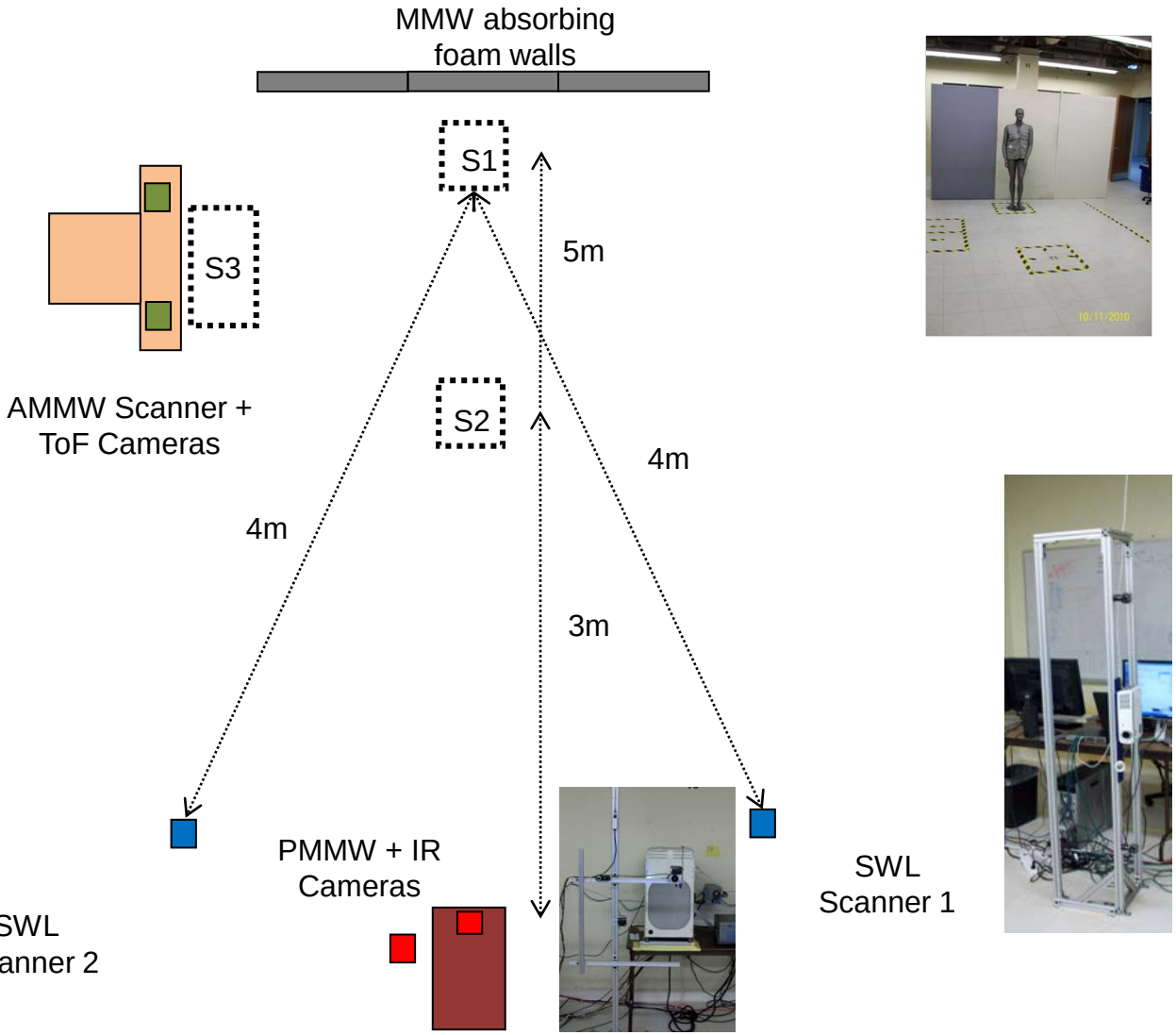
PMMW Camera



Specifications
Freq: 80-100 GHz
NEDT: 0.5°K
Focus: 2.5m
Lateral Res: <4cm
Pixels: 32 H × 60V
FPS: 5

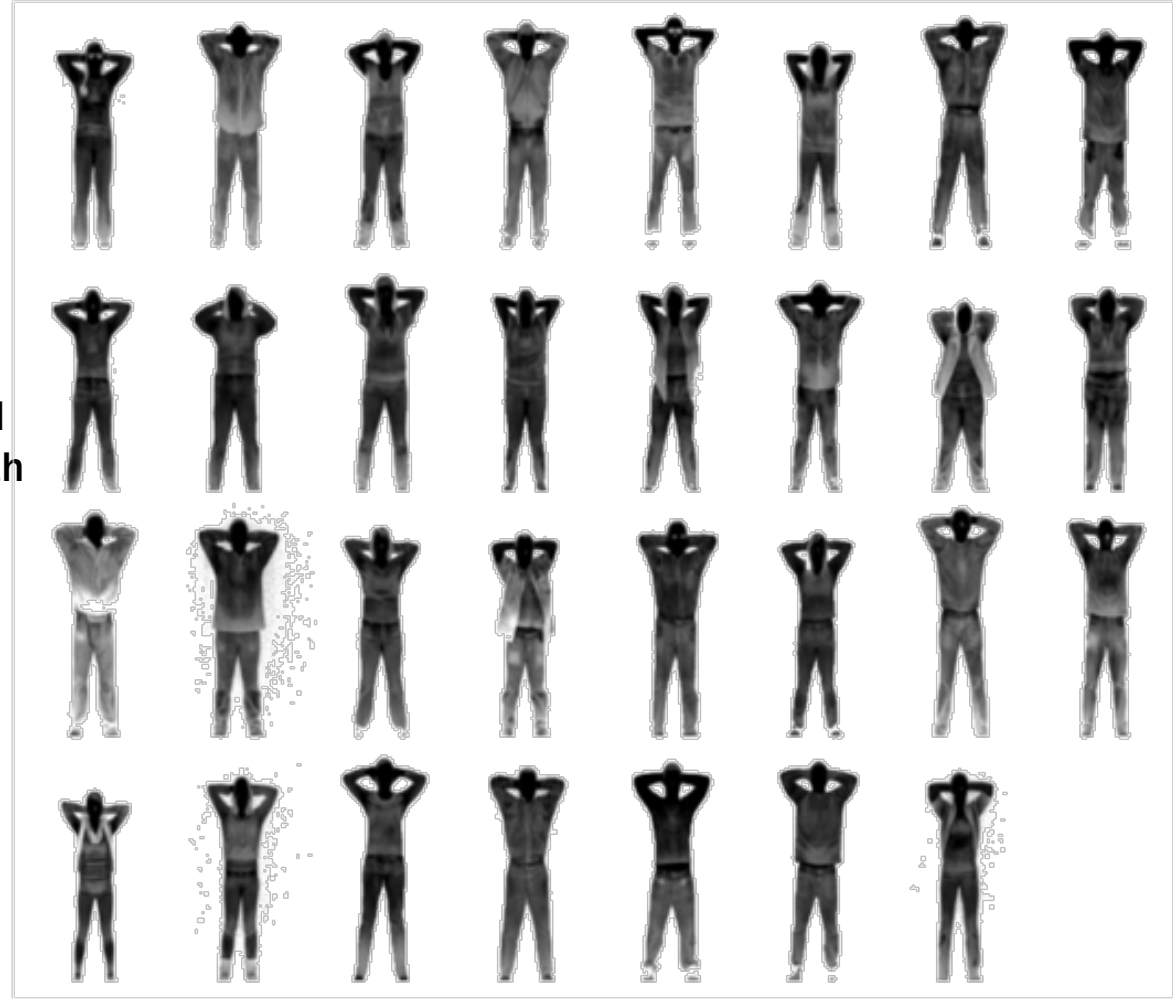
Notes
•Limited resolution
•Locate anomalous zones
•Assists AMMW detection
•Reduce FA

Experimental Setup



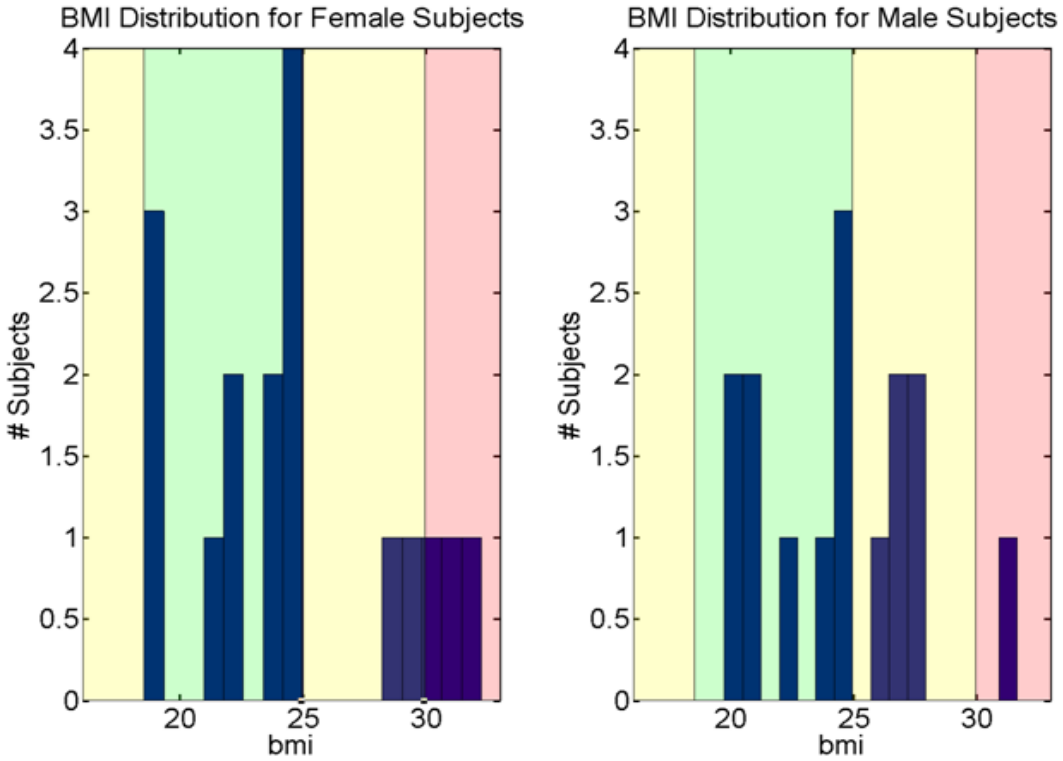
Scan Subjects

- 17 women and 16 men participated in the data collection.
- A total of 1,229 scans were collected
- Subjects were scanned with and without various simulated suicide bomb devices, and with and without common items.



Scan Subjects (continued)

- 17 women and 16 men participated in the data collection.
- A total of 1,229 scans were collected
- Subjects were scanned with and without various simulated suicide bomb devices, and with and without common items, such as cell phones, keys, wallets.
- Data was collected using smaller threat items such as handguns, knives and smaller explosive threat masses.



Simulated Bomb Devices









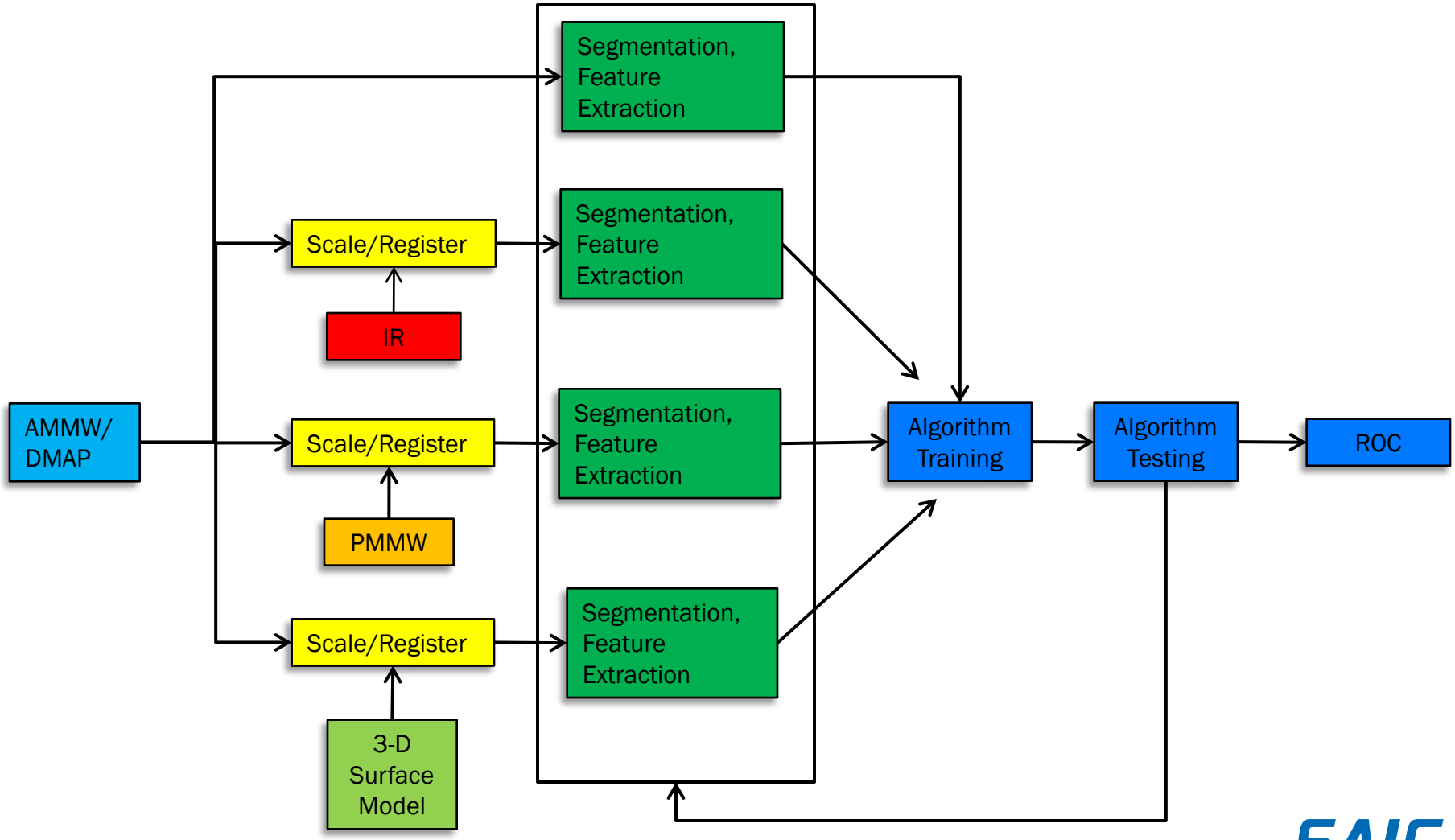









Data Processing Flow



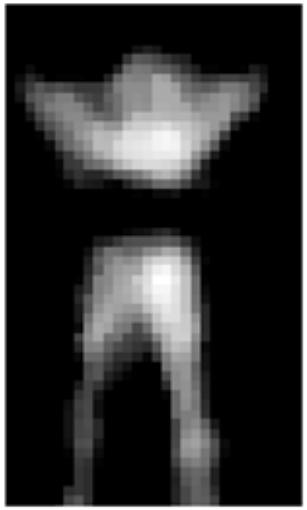
Data Registration

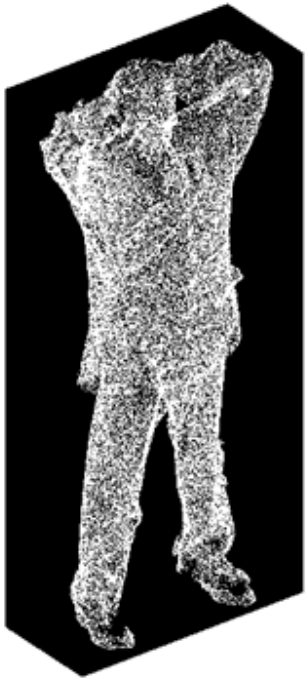
AMMW

IR

PMMW

SWL



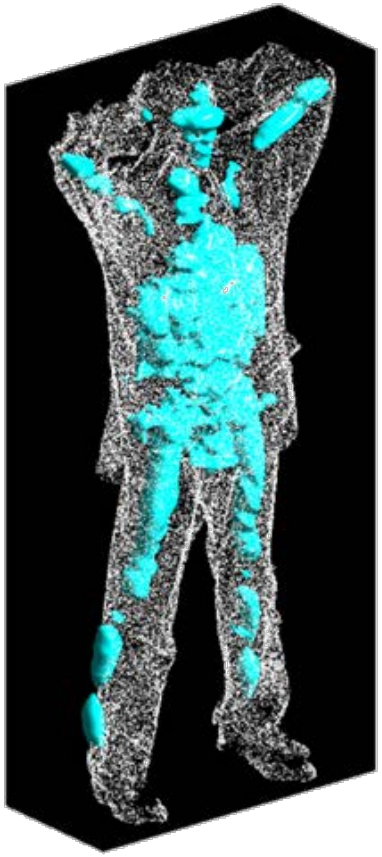


Data Registration

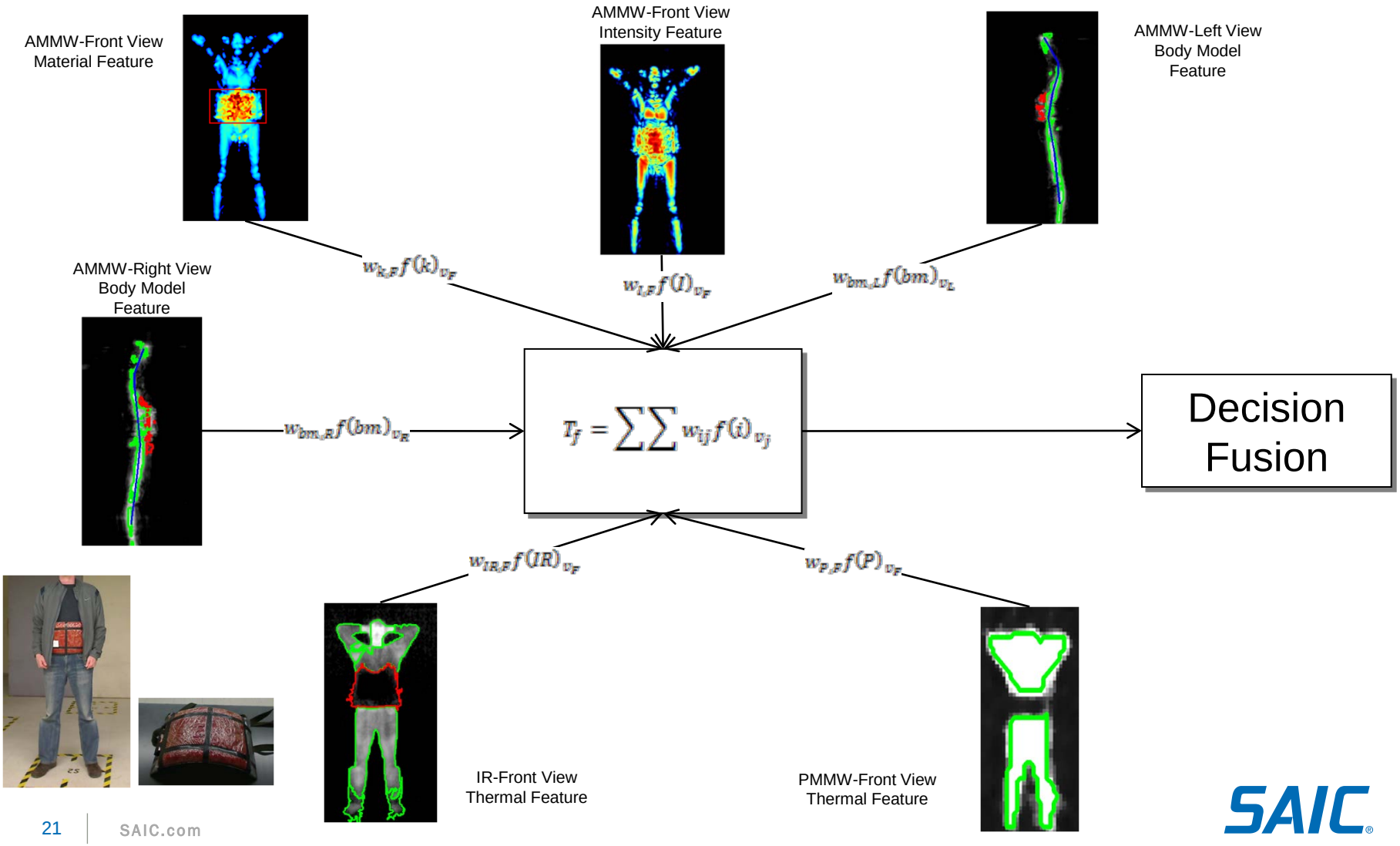
AMMW + IR

AMMW + PMMW

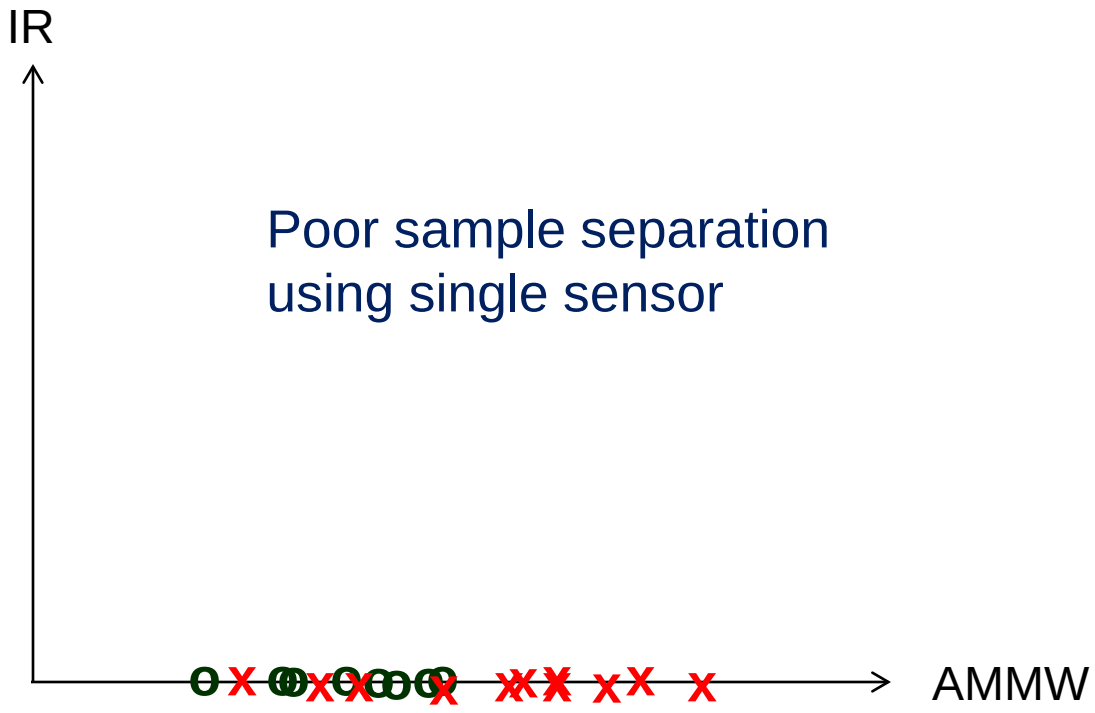
AMMW+ SWL



Decision Fusion Scheme



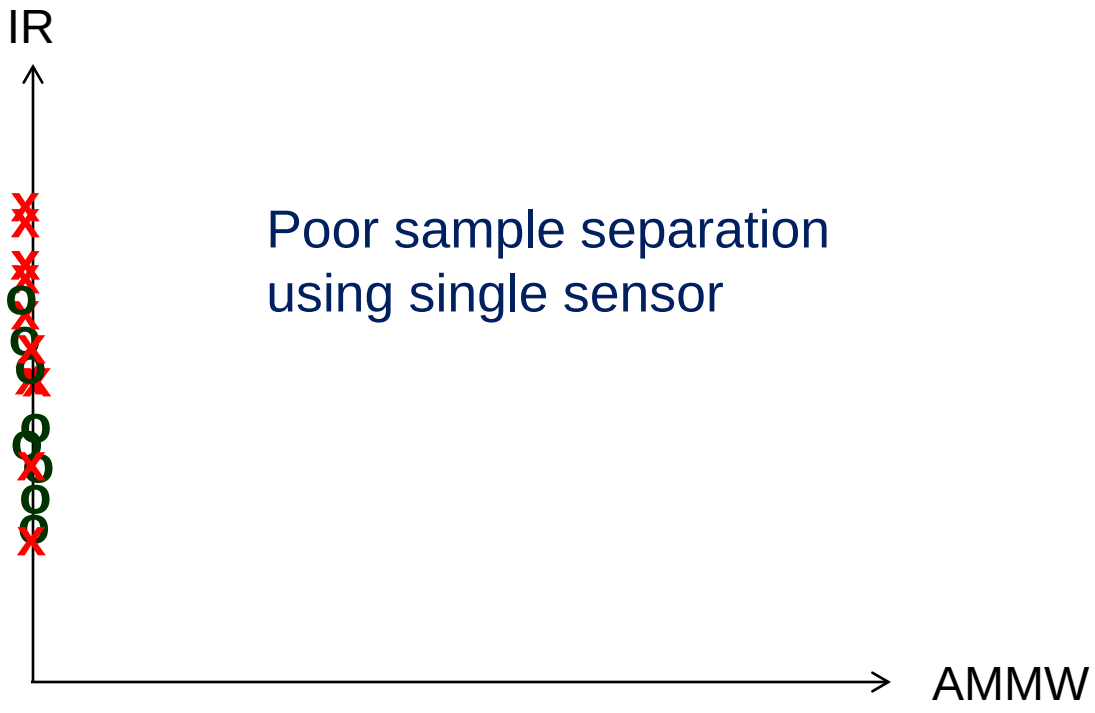
Decision Fusion Scheme (continued)



x = THREAT

o = CLEAN

Decision Fusion Scheme (continued)

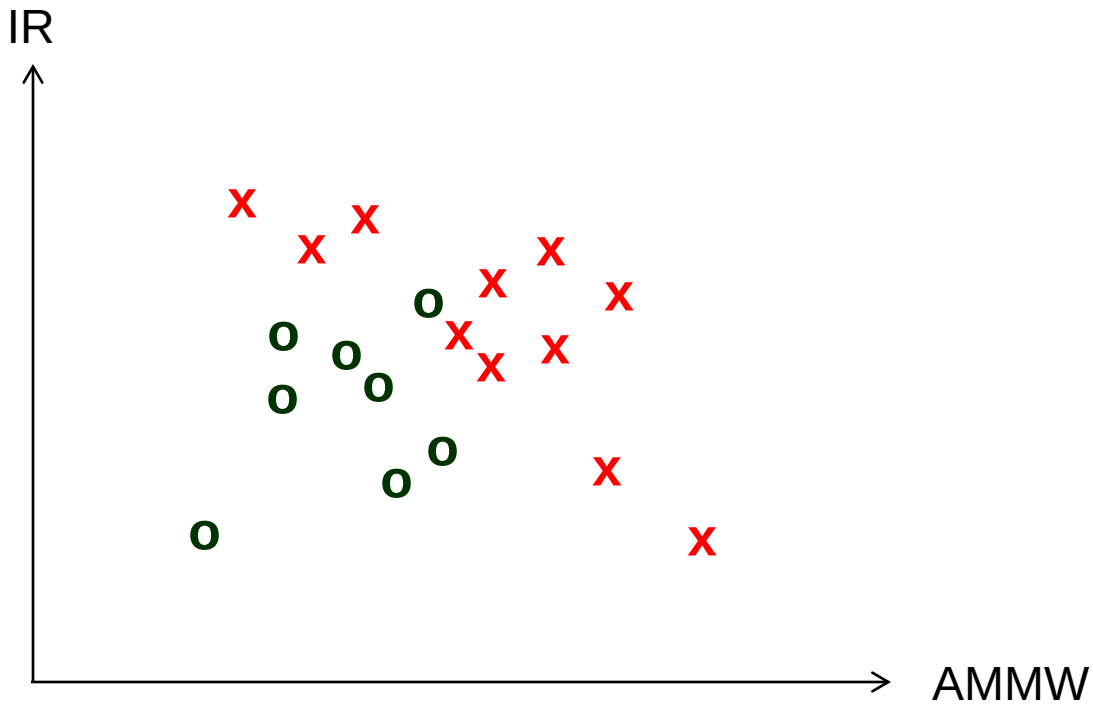


Poor sample separation using single sensor

x = THREAT

o = CLEAN

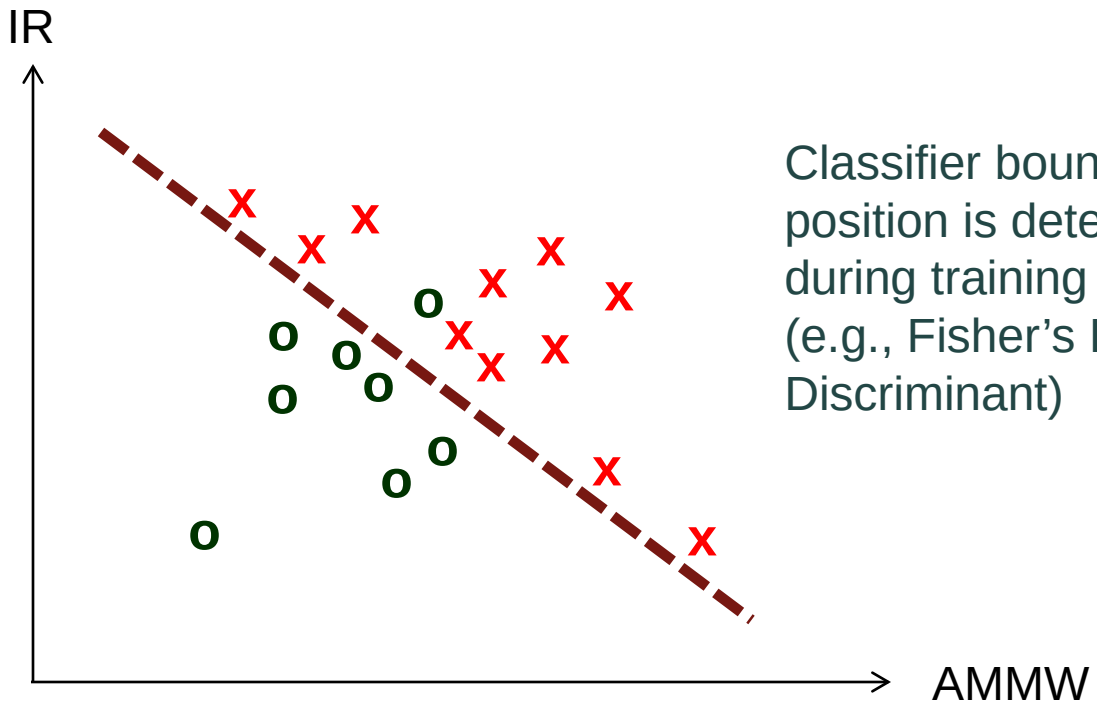
Decision Fusion Scheme (continued)



x = THREAT
o = CLEAN

Improved sample separation using sensor fusion

Decision Fusion Scheme (continued)

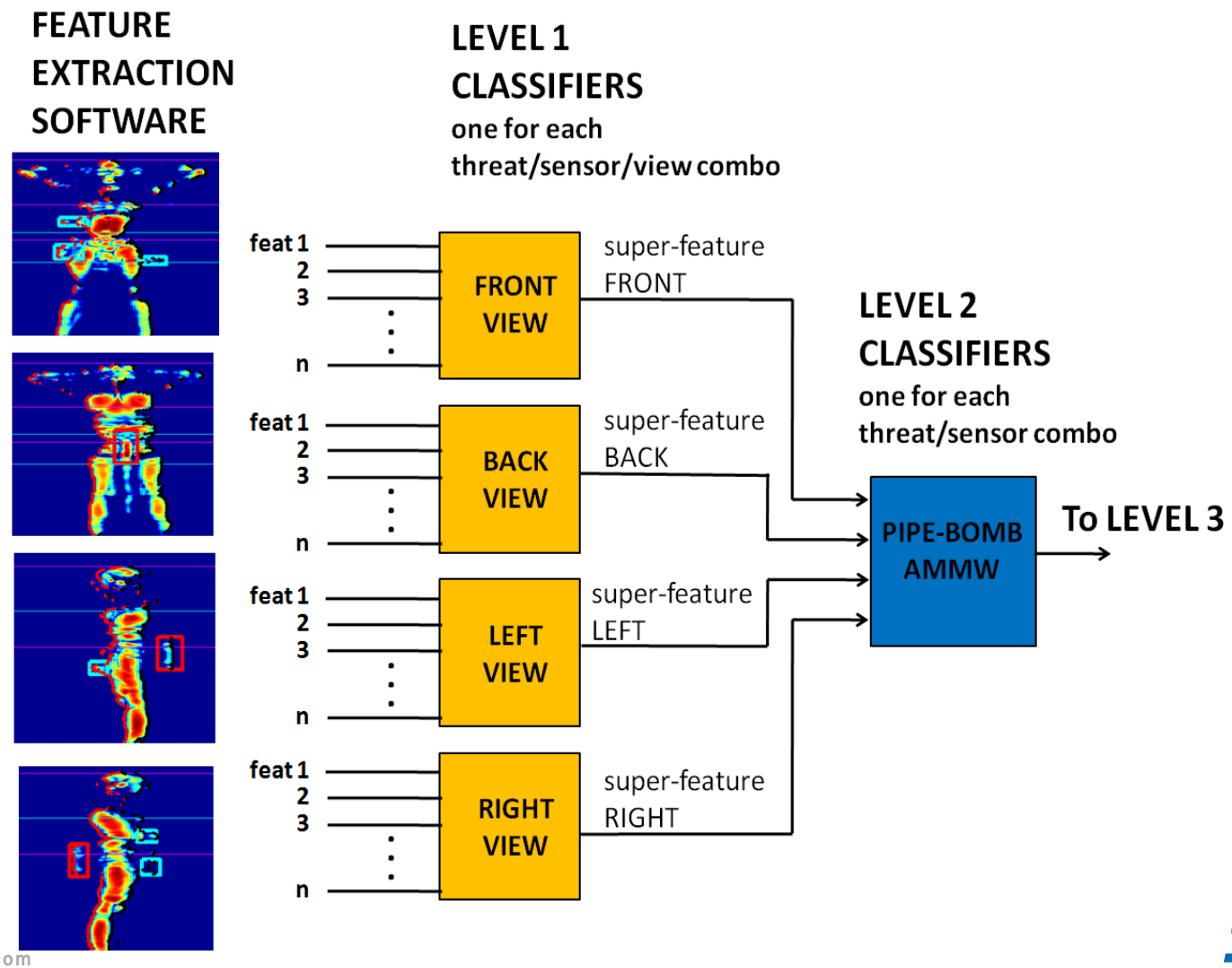


Classifier boundary position is determined during training (e.g., Fisher's Linear Discriminant)

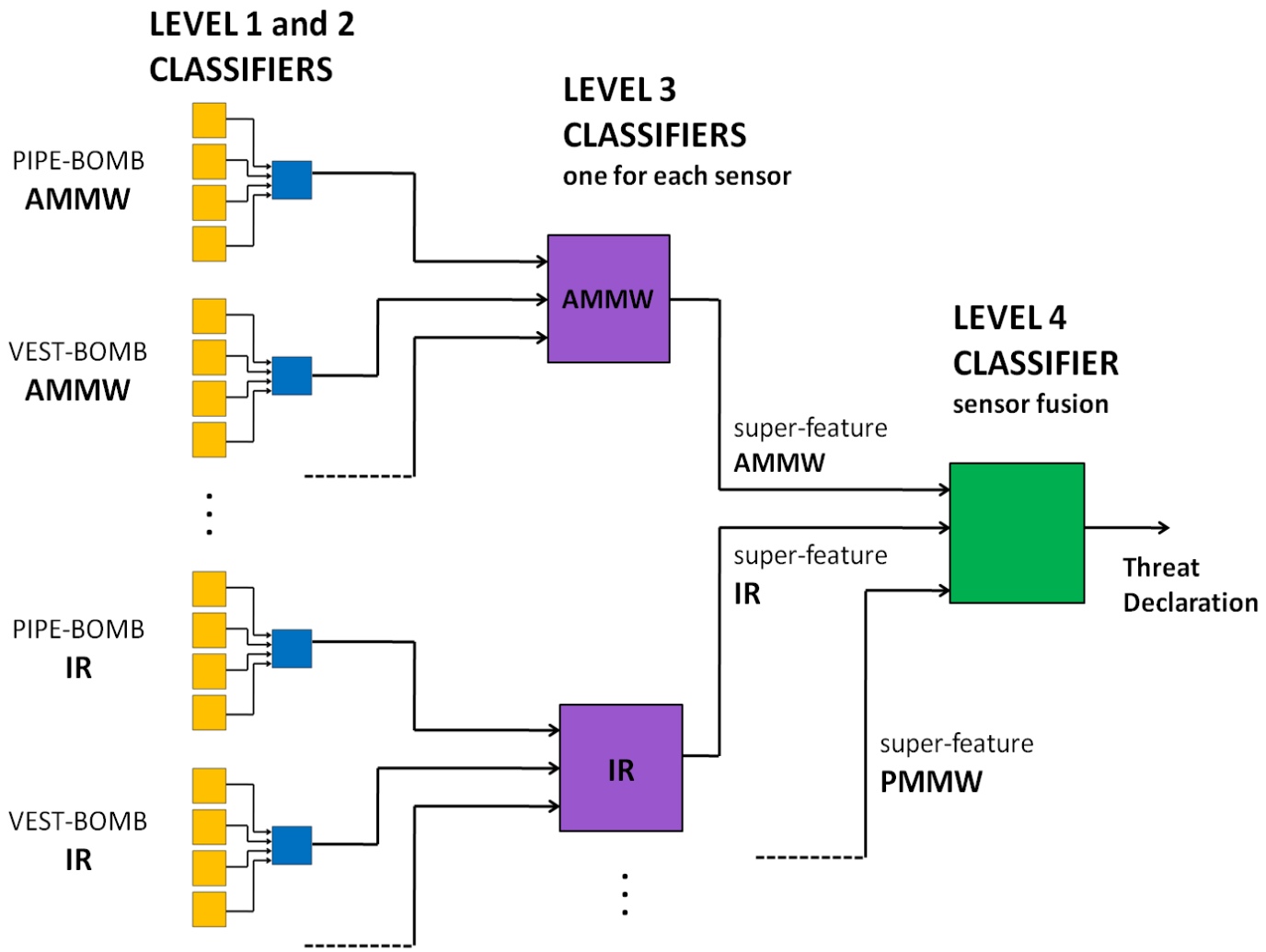
x = THREAT
o = CLEAN

Improved sample separation using sensor fusion

Decision Fusion Scheme (continued)

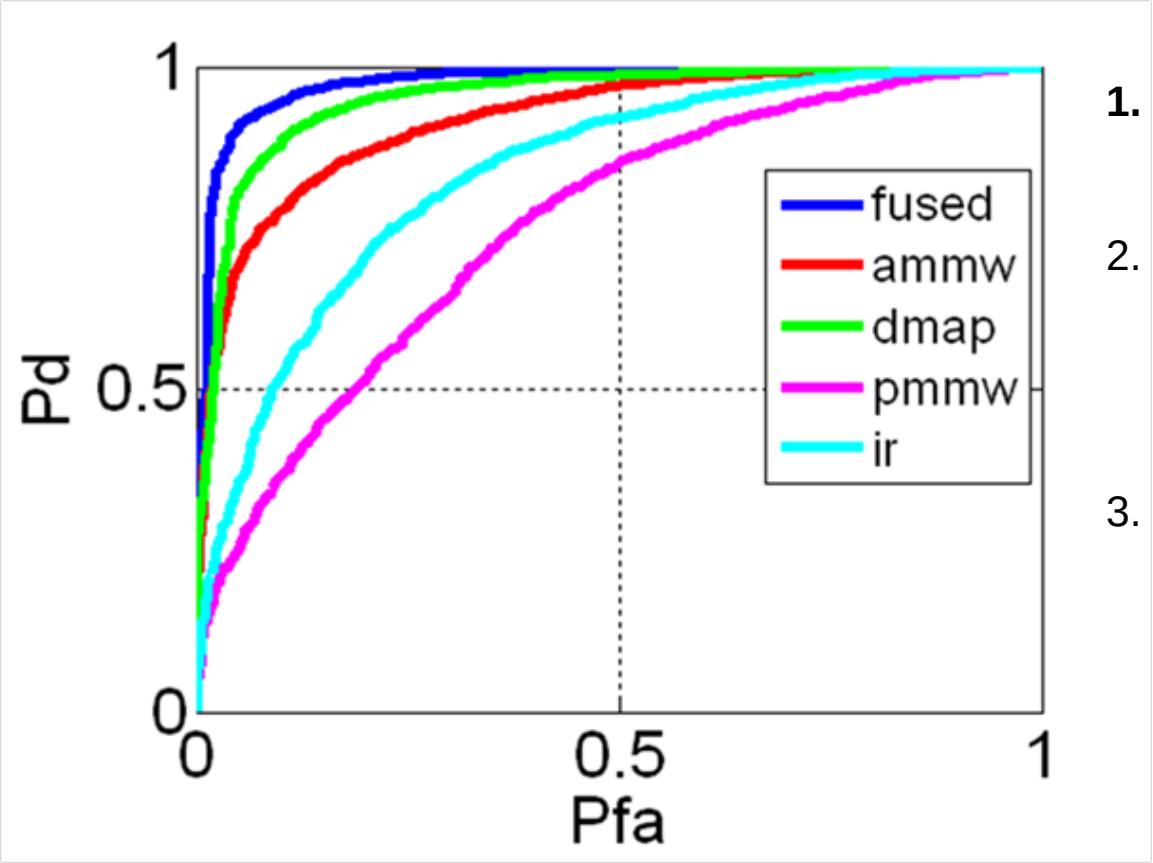


Decision Fusion Scheme (continued)



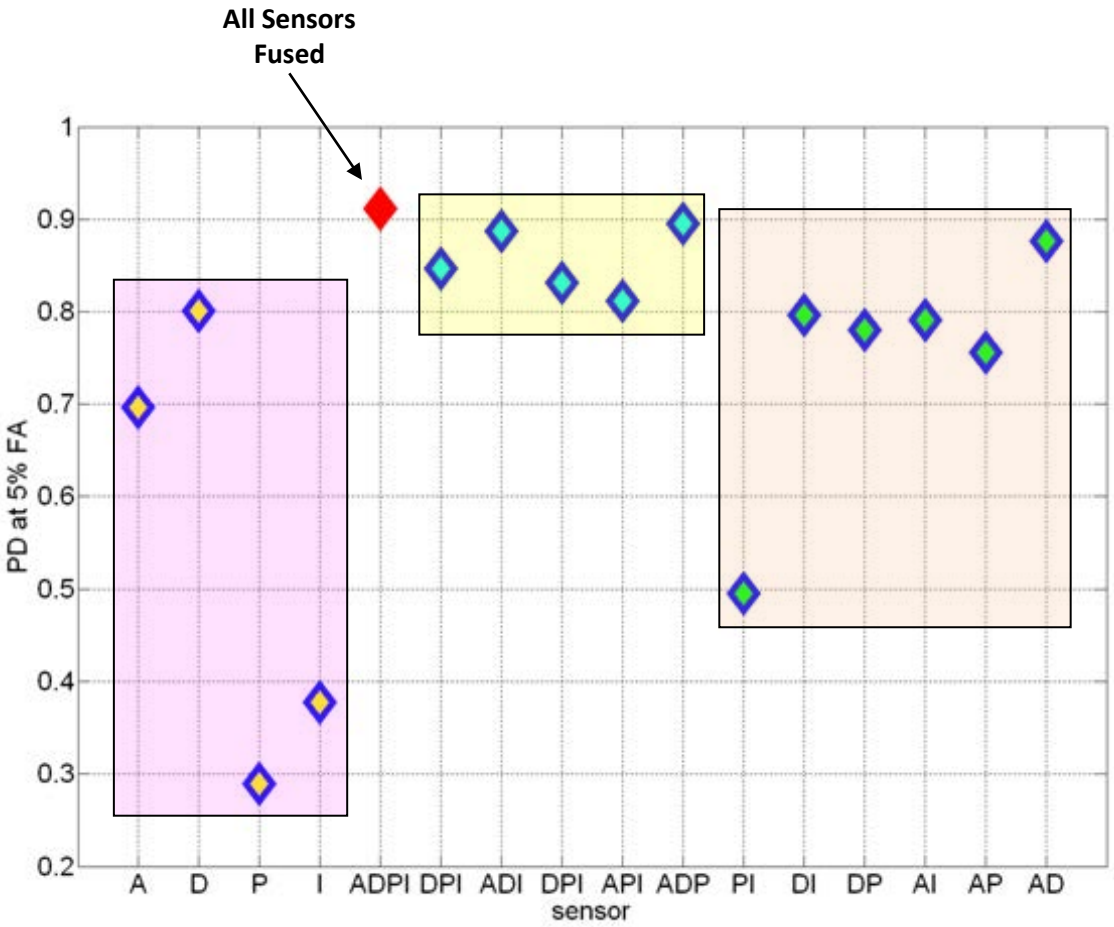
Performance Curve for Fused Sensors vs. Single Sensor, All Threats

Receiver Operator Curve



1. **Fusion of sensors increased performance of the AITR Algorithm.**
2. Sensor performance results is a function of the sensor's ability to "detect something", the quality of the features extracted and many other factors.
3. Results displayed should not be taken as a authoritative assessment on a particular sensor.

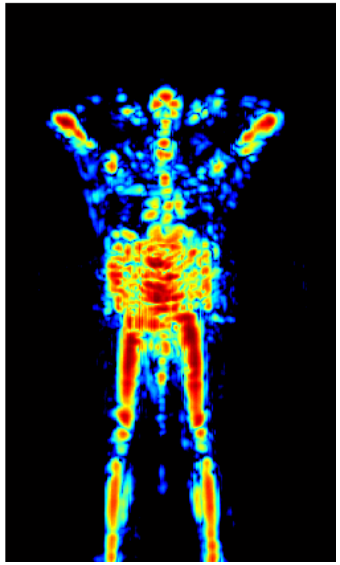
Probability of Detection at 5% False Alarm Rate for Different Sensor Combinations – All Threats



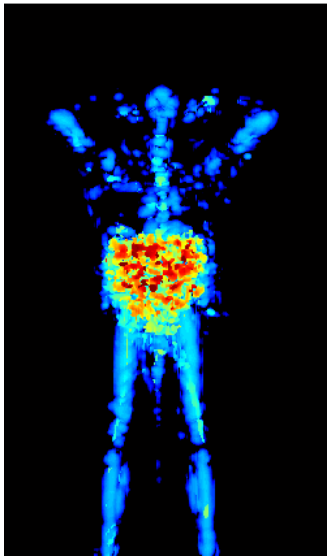
AMMW Intensity Image
Dielectric Map Image
PMMW Image
IR Image

DMAP Examples

Maximum Intensity Projection Image

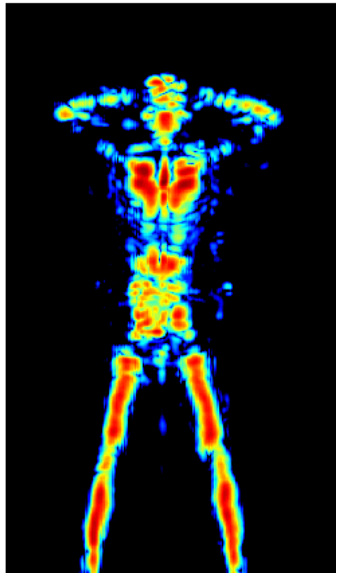


DMAP Image

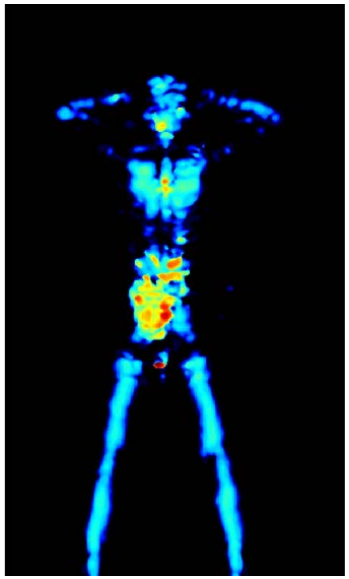


Sheet Explosive Simulant
1cm thick, with metal bb shrapnel
on steel plate

Maximum Intensity Projection Image



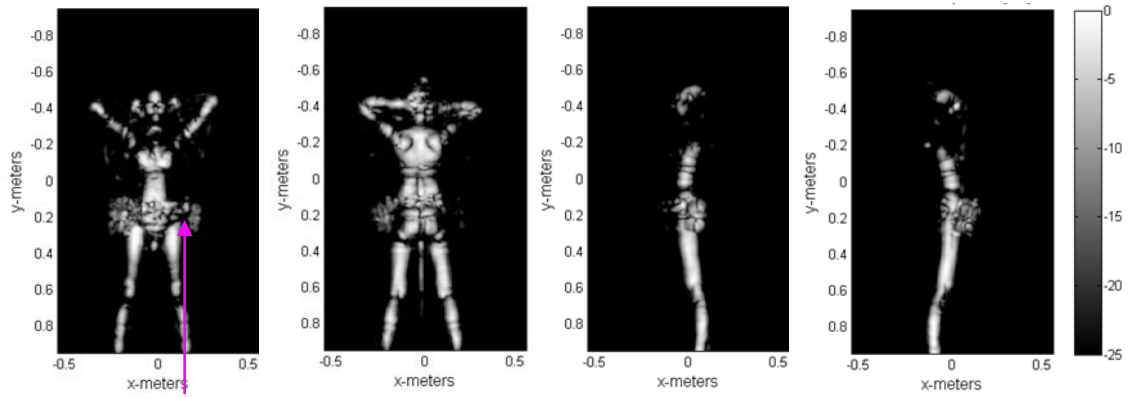
DMAP Image



Sheet Explosive Simulant
1.5cm thick, with ceramic ball shrapnel

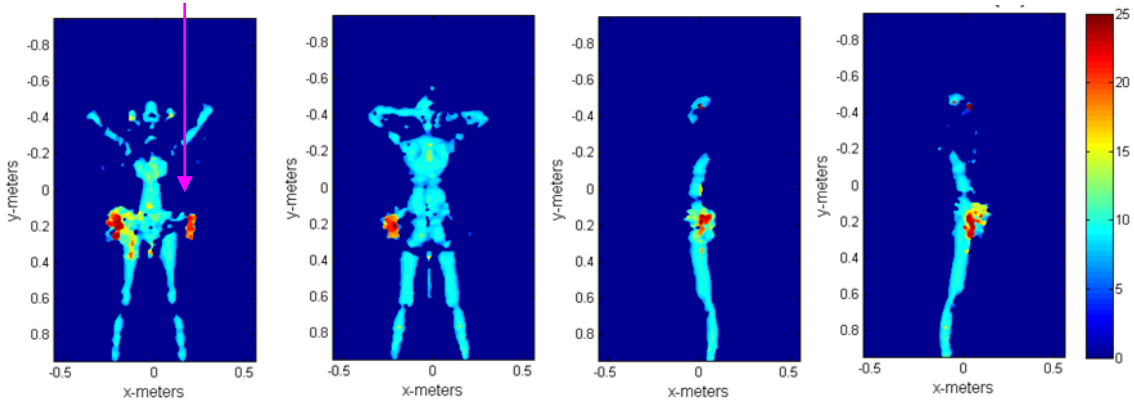
DMAP (Continued)

XY Max Projection Image [dB]



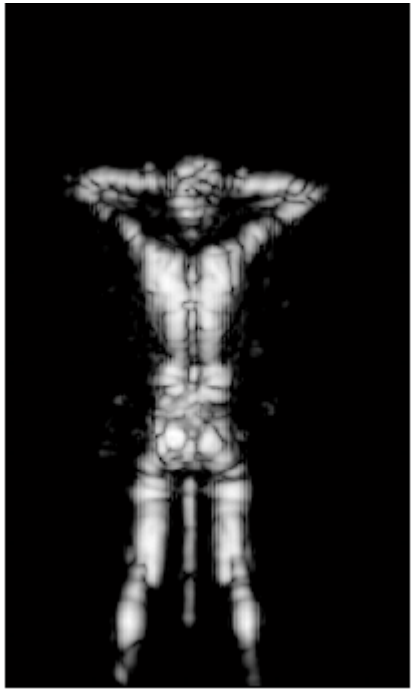
Explosive Simulant

DMAP

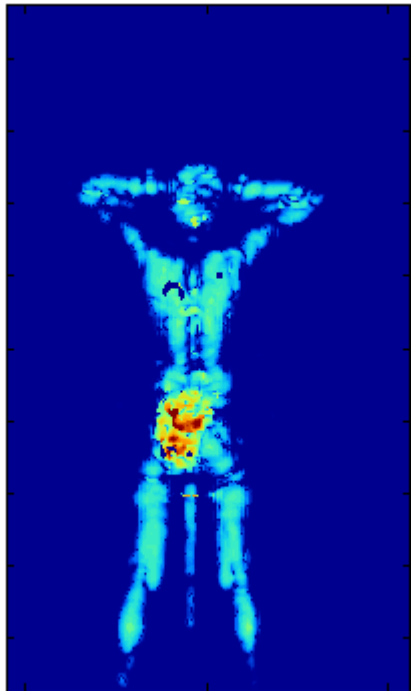


Because the DMAP effectively locates the human body in the image, this can be used to remove the human body from the image leaving only the area of interest for an operator or an algorithm

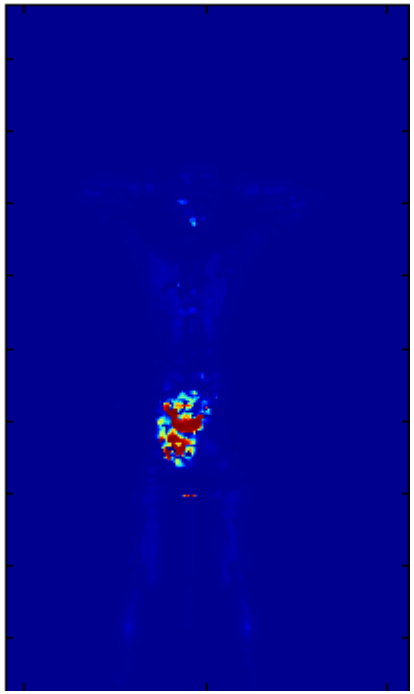
Intensity Image



DMAP



“Privacy Filter”/Regionizer



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Thank You

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