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Siemens and Video Analytics as an Industrial Partner of ALERT

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Presentation is Organized around Two Questions

- **How can industry partner with a DHS COE?**
  - Present model used by **ALERT**
  - How **Siemens** ties into ALERT – what Siemens brings to the table
  - Present example of ALERT/Siemens model drawn from a successful **PBIED** project
- **How can video analytics enable multi-sensor PBIED**
  - **Multi-camera fusion** for establishing a common coordinate system and an **HMI** for **situational awareness**
  - **Video tracking of pedestrians** to enable multi-sensor targeting, data integration, **fusion**

CenSSIS-ALERT
Three level diagram

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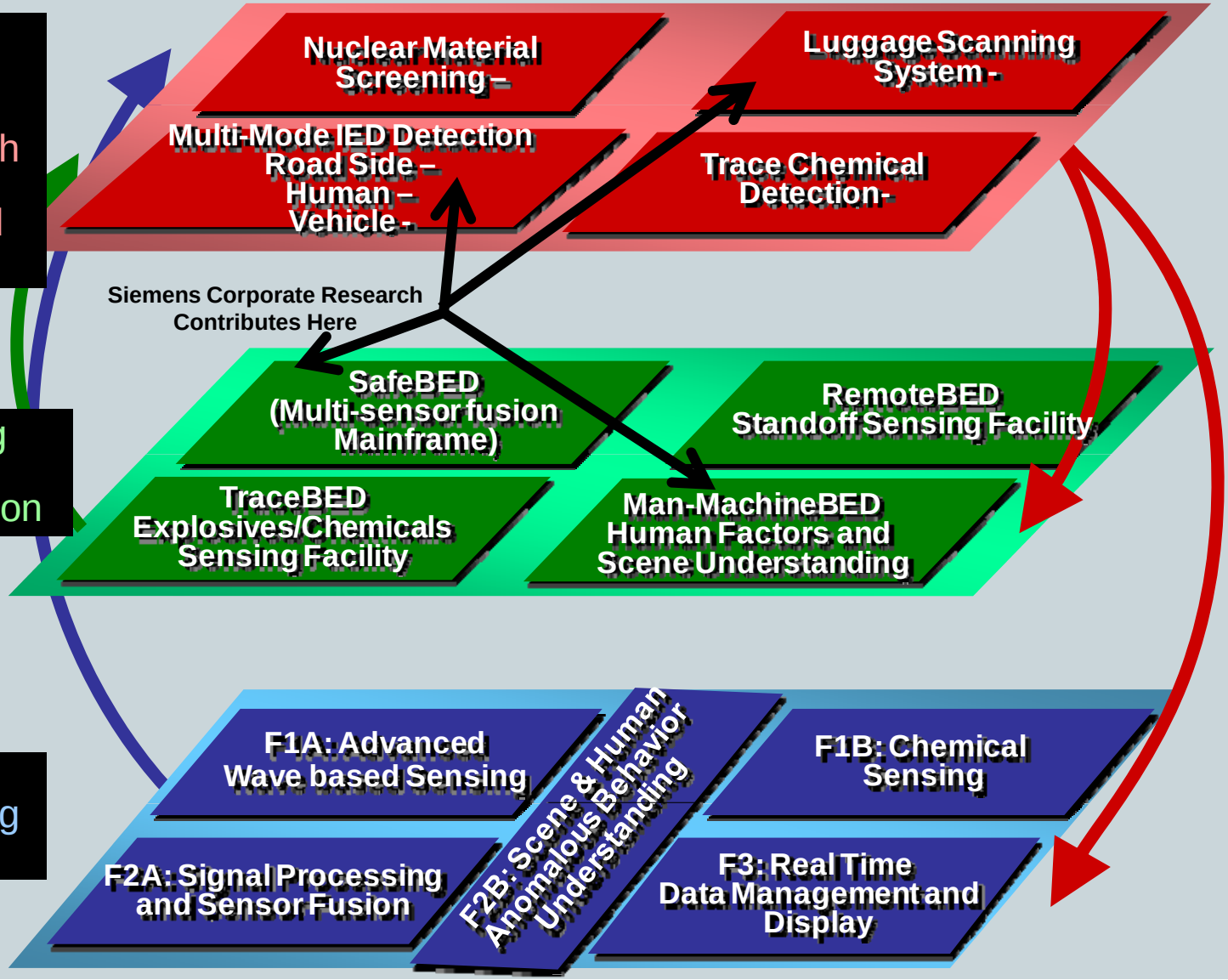
Level 3 Eng. System: Real world testbeds Collaboration with industry and national labs and DoD

Level 2 Enabling Tech: Technical Tools & Information

Level 1 Fund. Science: Sensing Modalities



Industry/COE Collaboration
ALERT MODEL

Siemens Provides: *Pathway to Deployment* and insight into real-world applications

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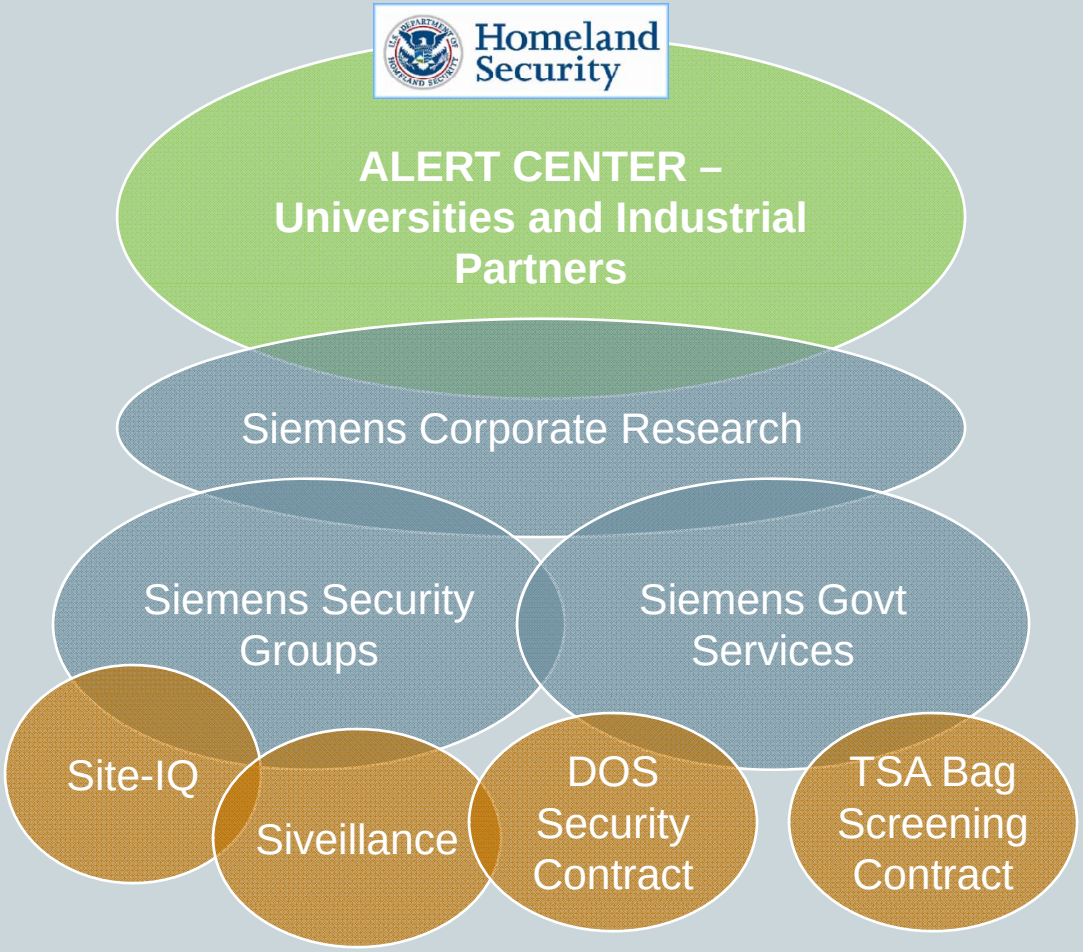

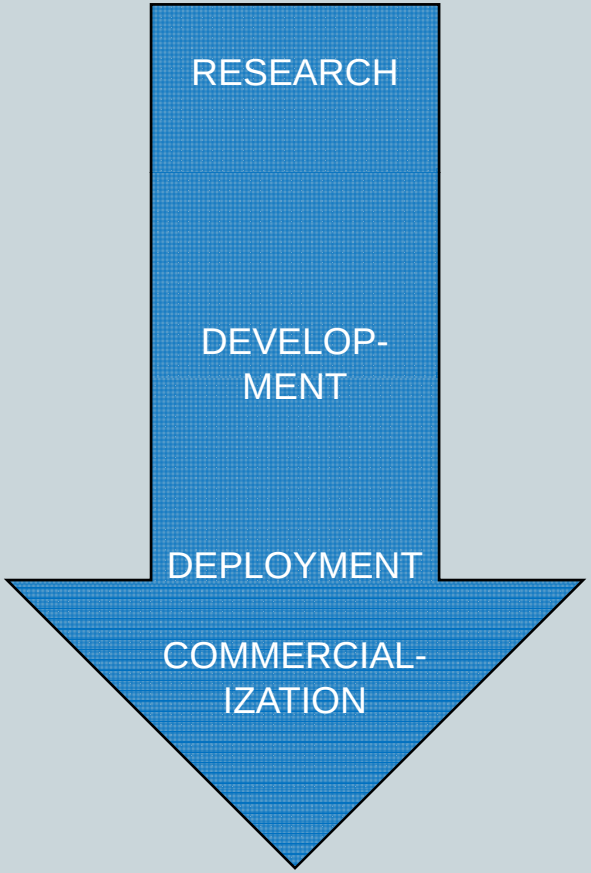

Industry/COE Collaboration
Siemens & ALERT Example

Siemens Provides: Comprehensive *Framework* for Real-World Computer Vision

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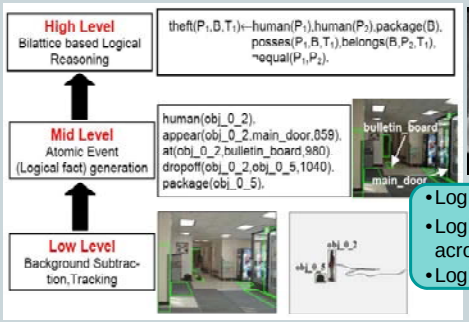
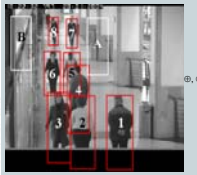
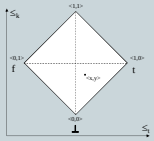
Logical Reasoning for Computer Vision/Sensor Fusion*

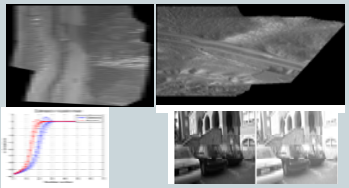


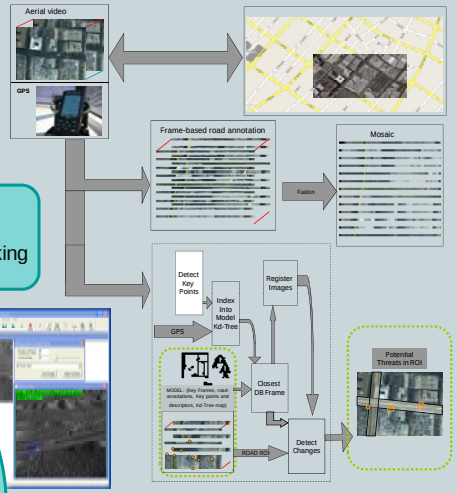




- Logic based human behavior analysis
- Logic based human identity matching across large visibility gaps
- Logic based multi-human detection.

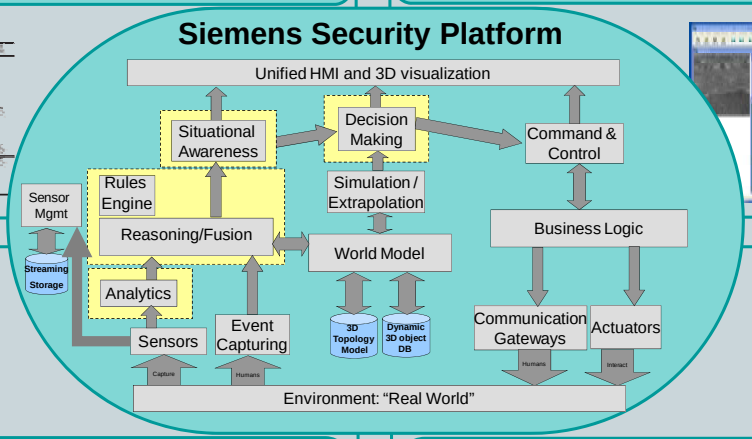
Real-Time Threat Analysis from Aerial Imagery*



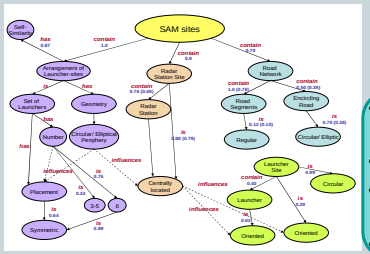


- Real-Time sequential hypothesis generation/validation from context
- Vision tools for registration and tracking in unconstrained outdoor conditions

Siemens Security Platform



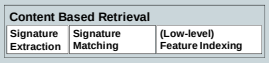
Complex Object Recognition from Aerial Imagery*



- Context: Fuse computer vision algorithm output with analyst's neuro-physiological response
- Design generic low level feature dictionary
- Perform high level inference to detect complex non-rigid visual patterns
- Flexibility to quickly adapt to new object classes

Large Scale Unconstrained Video Search

- Ongoing research with German Ministry of Science and Education
- Formalized search methodologies over high volume video data that respect user constraints over response time, accuracy and resources



Siemens Provides: Open-Architecture, Plug-and-Play Computing *Technology Platform* (Siveillance)

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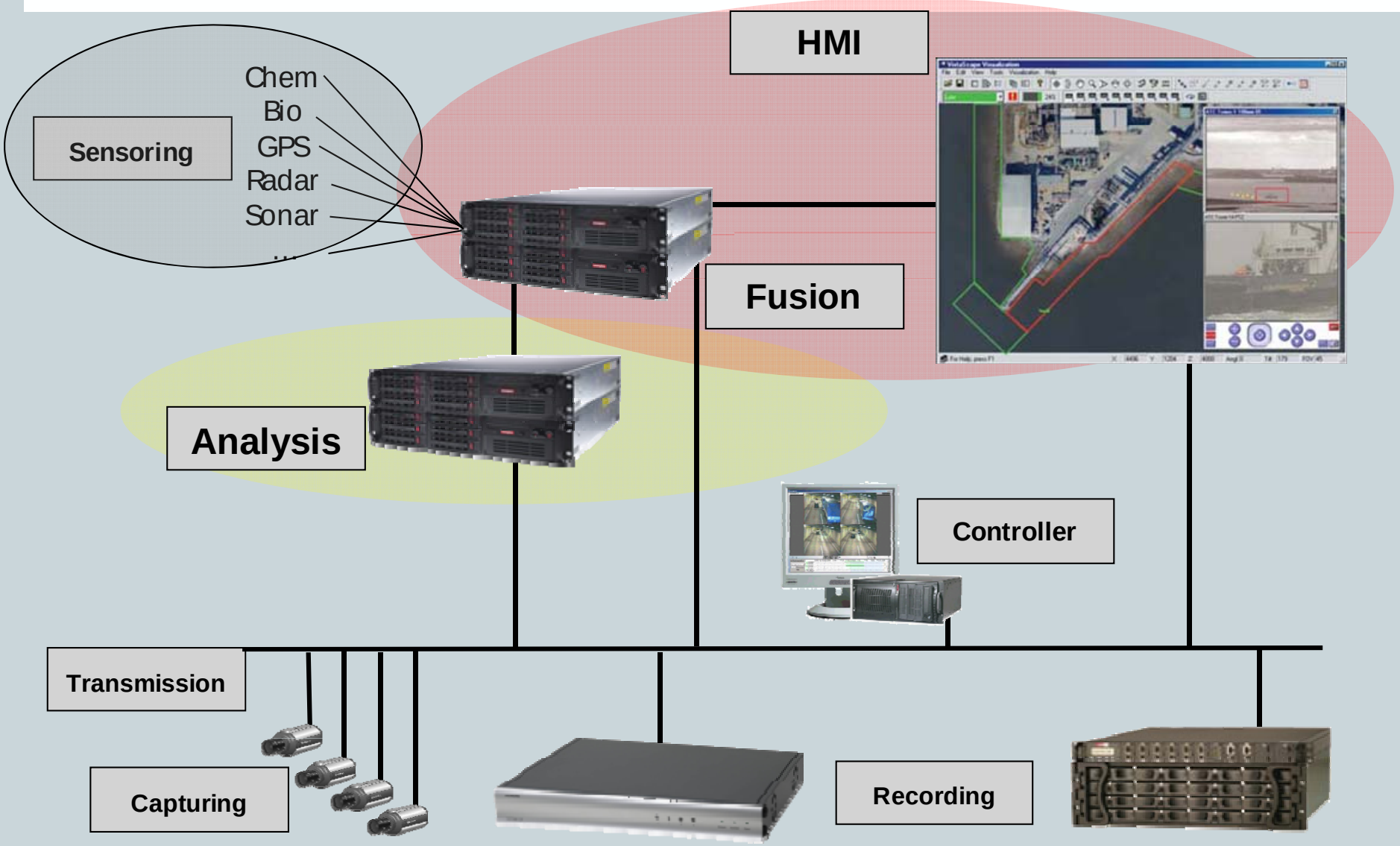

Siemens Provides: Siveillance *Plug-in Applications*

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Siveillance™ Crowd

- Estimates crowd density
- Designed for complex, crowded scenes
- General camera positions


Siveillance™ Queue

- Queue statistics estimation
- General camera position
- Multi-camera solution
- Flexible queue configuration


Siveillance™ Tunnel

- Detects stopped, slow, or wrong-way vehicle
- Detects traffic jams, lost cargo, pedestrians
- Detects smoke in tunnel.
- Proven solution


Siveillance™ Baggage

- Abandoned object detection
- Designed for complex, crowded scenes
- Detects people and baggage
- Distance and time rules for alarm


Algorithms as Plug-ins on Siveillance™ Base

Siveillance™ SiteIQ™

- Object detection, classification, tracking
- Situational awareness, integrated world view
- Consistent policy enforcement
- Intuitive graphical interface

Eagle Vision ™

- Reliable vehicle detection under all lighting conditions
- Video detector with integrated camera (single housing)
- IP communication for data and video streams
- Video streaming to central office



Second Half of Talk

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- **How can industry partner with a DHS COE?**
  - Present model used by **ALERT**
  - How **Siemens** ties into ALERT – what Siemens brings to the table
  - Present example of ALERT/Siemens model drawn from a successful **PBIED** project
- **How can video analytics enable multi-sensor PBIED**
  - **Multi-camera fusion** for establishing a common coordinate system and an **HMI** for **situational awareness**
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HSARPA BAA 05-03:

Prototypes and Technologies for Improvised Explosive Device Detection

Preliminary Design Review –

BomDetec: Sensor Fusion & Control

October 1, 2007

Presented by: John Pearson

Contributors: Hong Shen, Shuping Qing, Sam Zheng, Robert Rauschenberger, Kevin Richardson, Yanghai Tsin, Jan Neumann, Moshe Ben-Ezra, Visvanathan Ramesh

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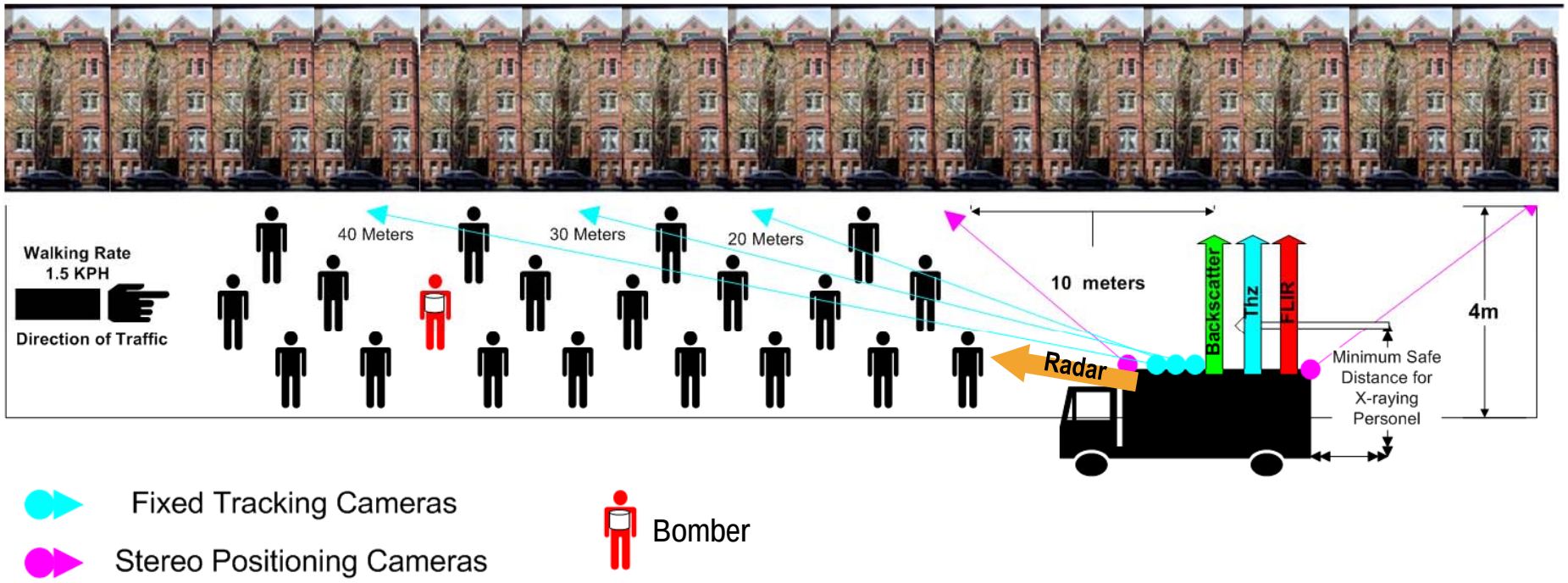
Concept of Operations

CONOPS: Streaming Pedestrian Urban Sidewalk Scenario



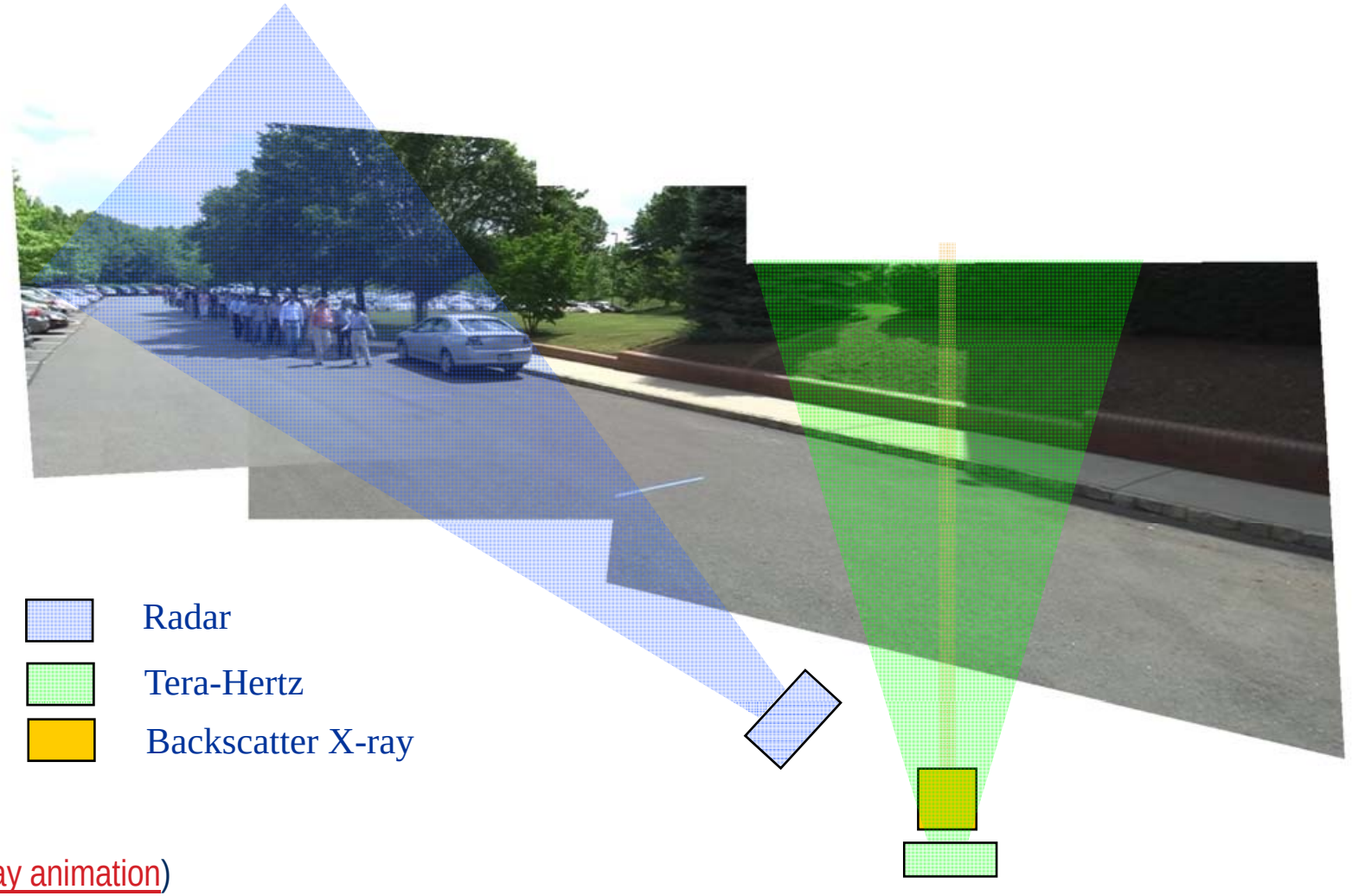
- Forward-looking video and radar used to tag suspicious pedestrians, who are scanned by Xray, THZ, FLIR when pass in front of van

CONOPS: Video key to sensor fusion

Forward Looking, Spatially Overlapping Fixed Cameras Used for Detection and Tracking

- Mosaicing creates seamless view for Operator (play)
- Automatic detection & tracking (play)
  - Generates pedestrian ID (track ID), basis for fusion
- Enables global coordinate system, 3D targeting, and intuitive pedestrian-centric threat visualization (next slide)

CONOPS: Video provides a Coordinate System for Multi-Sensor Synchronization



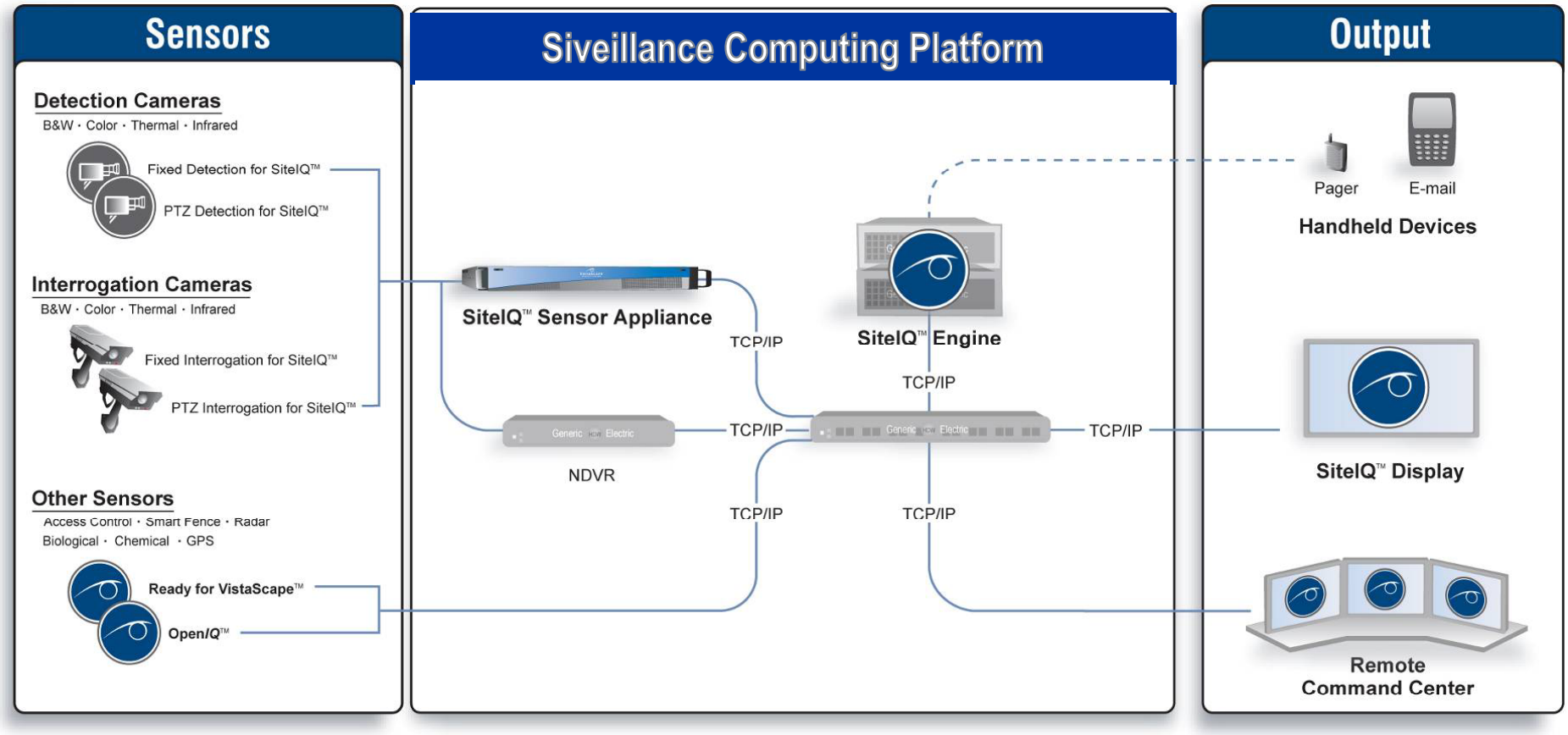
(Play animation)

CONOPS: Detailed “Suspect” Control Console

- Operator can request additional scans, watch close-up video, trigger external mitigation, dismiss from suspicion

Sensor Integration and Control Architecture and Platform

Siveillance SiteIQ as BomDetec Fusion Platform

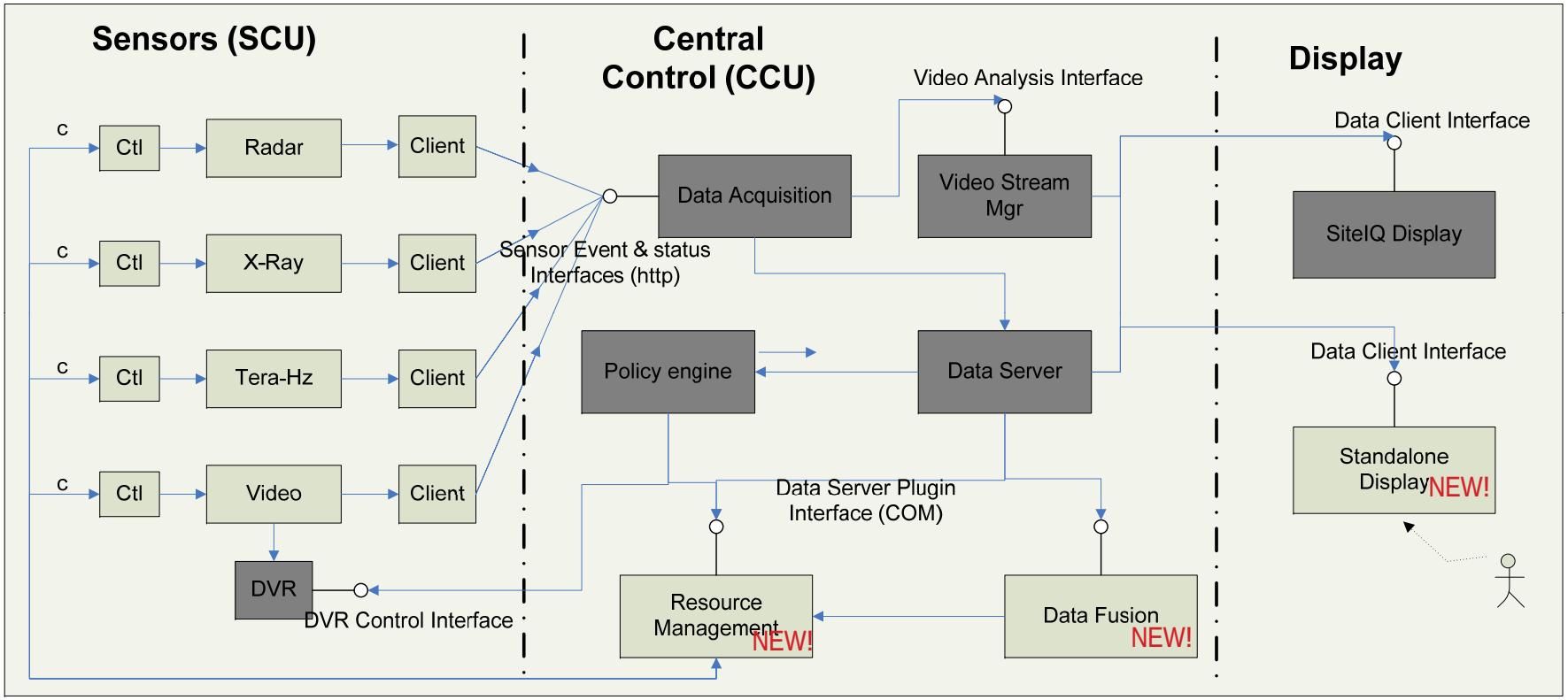


- Phase I shows feasibility of extending Siveillance SiteIQ to meet BomDetec requirements
- Building upon an extensible product should reduce development costs and speed deployment
- SiteIQ chosen because:
  + SiteIQ has well documented open and extensible architecture, with good support for customization

SiteIQ's Current Application Domain

- SiteIQ "as is" provides broad-area situational awareness, integrating inputs from sensor network, generating "alerts" for human operator
- Challenge for BomDetec is to extend SiteIQ to provide highly automated sensor control & threat analysis of a continuous stream of pedestrians

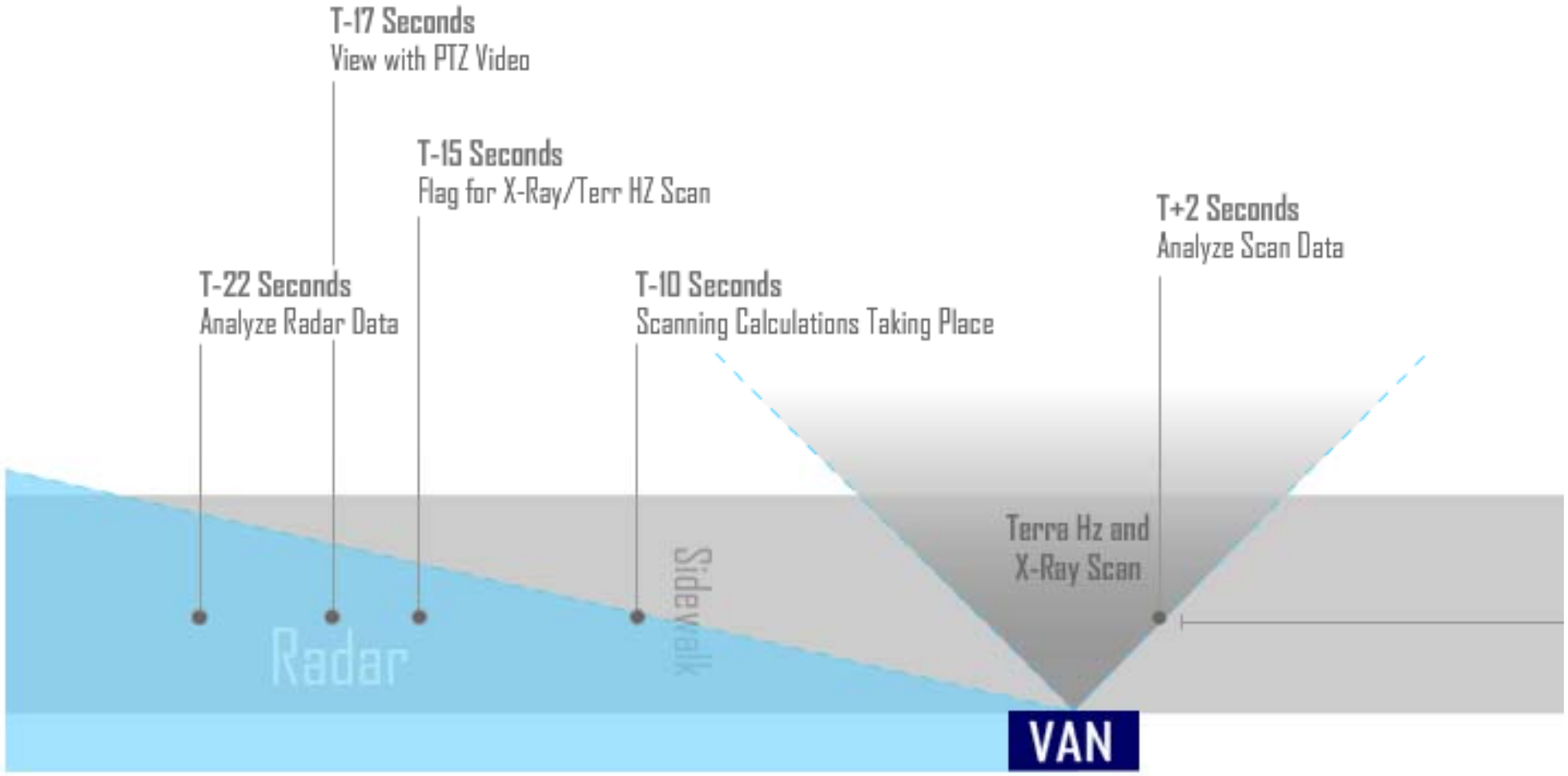
BomDetec Processing System Architecure



- Many existing modules of SiteIQ used “as is” by BomDetec
  (data input, sensor communication, archiving, policy configuration & enforcement, object tracking, alarms)
- Major new modules will need to be developed however

Human Factors Considerations

Operating Timeline Considerations



- Single pedestrian scenario (Play Animation)

Operator-intensive scenario Workflow Analysis

Time		Distance to Van	System Action Modes: Scan Present Fusion	Operator Action Modes: Perception Analysis Decision
T-24 sec	Phase 1	D-48 meters	**Fixed Video tracks new** Pedestrian	Observes **behavior**, appearance
T-22 sec		D-44 meters	Pedestrian scanned by **Radar**	
T-20 sec		D-40 meters	**Radar** derived threat info presented	Operator analyzes **radar** info *If not a threat, Operator can switch to next pedestrian*
T-17 sec		D-35 meters	**PTZ Video** acquires Pedestrian and presents **close-up view** to Operator	Operator decides to **zoom in** with PTZ Video Operator **identifies & selects** Pedestrian in fixed video feed *If not a threat, Operator can switch to next pedestrian*
T-15 sec		D-30 meters		Compares **close-up image** of Pedestrian and with **bomber profile** "Flags" Pedestrian as **suspicious** for scanning by X-Ray / THZ
T-10 sec	Phase 2	D-20 meters	Prepares for **X-Ray / THz** scan using motion data from **Video**	*During this time window* *Operator can switch to Phase 1* *Or Phase 3, or* **view close-up of PTZ Video**
T-0 sec		D-0 meters	**X-Ray / THZ** scan	
T+01 sec		D+02 meters	**All data** integrated & **threat visualization** presented	
T+02 sec	Phase 3	D+04 meters		Operator compares Fused Information to **Bomber profile**
T+12 sec		D+24 meters		Operator decides Pedestrian is a **threat** and generates alert

Pedestrian through-put based on Operator Workflow Analysis

- **One** operator scenario
  - Can sustain continuous rate with pedestrian spacing of **60m**, (30 seconds), or **120** people/hour
- **Two** operator scenario
  - Each operator specializes on Phase 1 or 3
  - Can sustain continuous rate with pedestrian spacing of **20m** (10 seconds), or **360** people/hour
- **Four** operator scenario
  - 3 operators work Phase 1, which has 3 sub-phases, 1 operator works Phase 3. They could divide the labor by pedestrian or by sub-phase (Experiment needed)
  - Can sustain continuous rate with pedestrian spacing of **5m** (2.5 seconds), or **1440** people/hour
- **Automation** of threat detection and analysis is necessary to boost through-put to deal with real-world pedestrian stream rates

Video processing for:

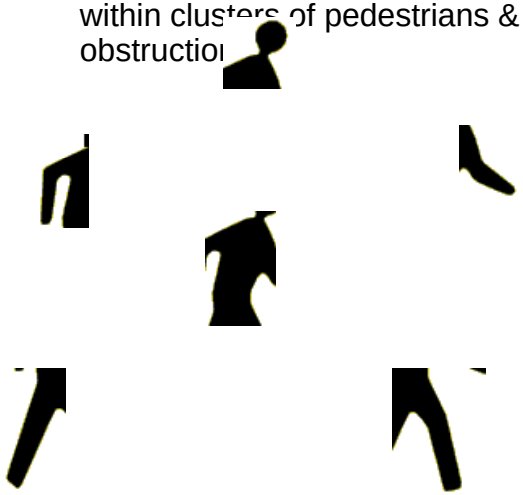
Detection,
Tracking
3D Localization

(Intelligent Video)

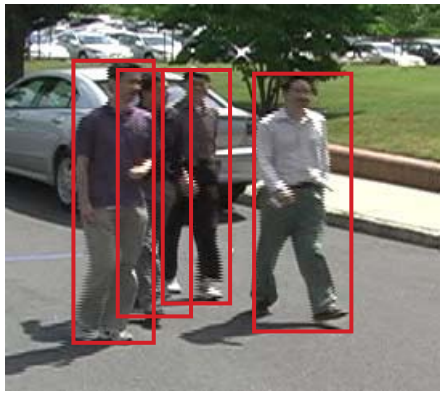
Theory of Operation – Detection

We tested two classes of algorithms

- Part-based Algorithm
  1. Search for parts or features
     - Semantically meaningful parts, such as “legs”, “torso”, “head”…
     - And “lower-level” features such as corners, edges, textures, gradient distributions
     - Searching done with multi-scale convolutional filters and histograms
  2. Group parts together into pedestrian figures
     - AdaBoost algorithm to combine evidence for pedestrian from the parts
     - Rules to reason about occlusion of individuals within clusters of pedestrians & physical obstructio



- Shape-based Algorithm
  - Define pedestrian shape-templates using camera and scene geometry
  - Search the image for people
    - Blob detection by background subtraction
    - Fit pedestrian (1 or more) shapes to blob using Markov Chain Monte Carlo (MCMC)

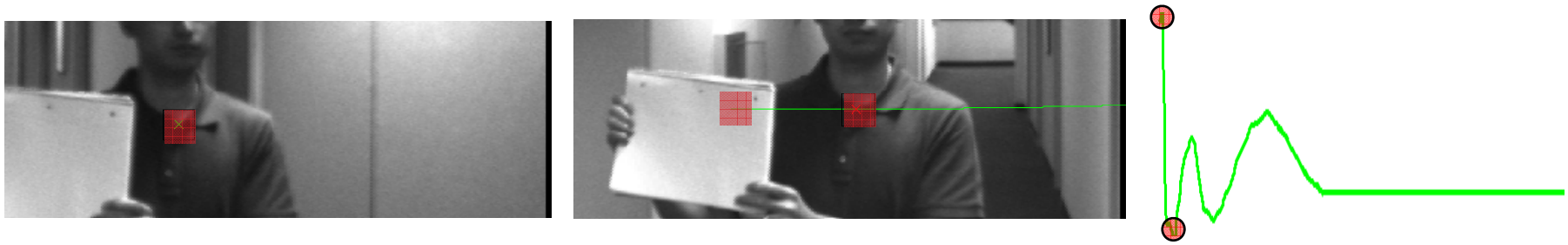


Theory of Operation – Tracking

- Develop model of each detected pedestrian
  - Color histograms [Comaniciu et. al. CVPR 2000, ICCV 2001]
    - Simplest model, not accurate but versatile
  - Multiple-part color histograms [Parameswaran CVPR 2006]
    - More complex, more accurate, more computationally expensive
    - Not tested in phase I, but may need to bring into phase 2
- Find Matching pedestrians in neighboring video frames
  - Gradient search
    - Easiest and fastest, but not the best
  - Other methods that could be brought into phase 2 as needed
    - Multiple-hypotheses particle filtering
      - Resolving possible ambiguities
    - Deformable model matching

Theory of Operation – 3D Measurement

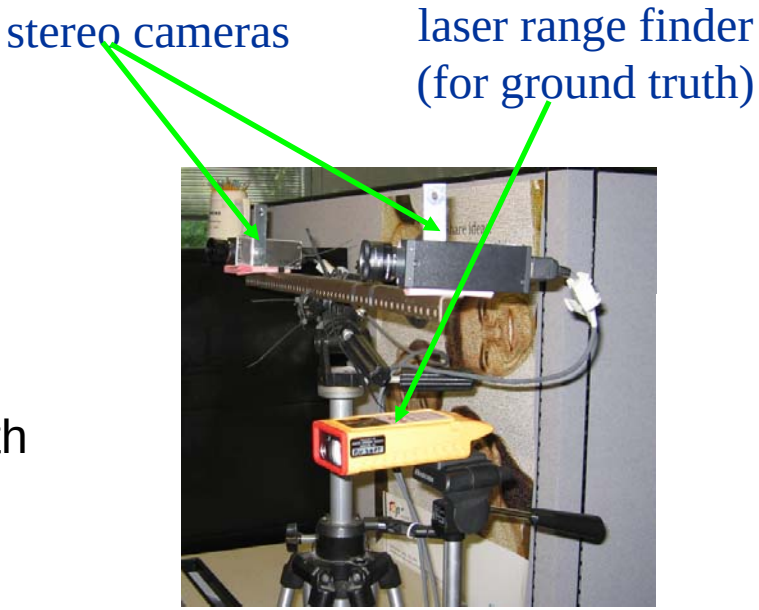
1. Calibrate Cameras
   - 4~8 internal parameters so we know how to project a 3D point to the imaging plane
   - 6 external parameters so we know how to relate a camera to the world and other cameras
2. Find position of “good features” (corners) for measurement in one image.
3. Find corresponding features in second image
   - Search constrained to a line: epipolar line
   - Find most similar feature at location of intensity difference minima



4. Use triangulation to compute 3D position of feature on pedestrian

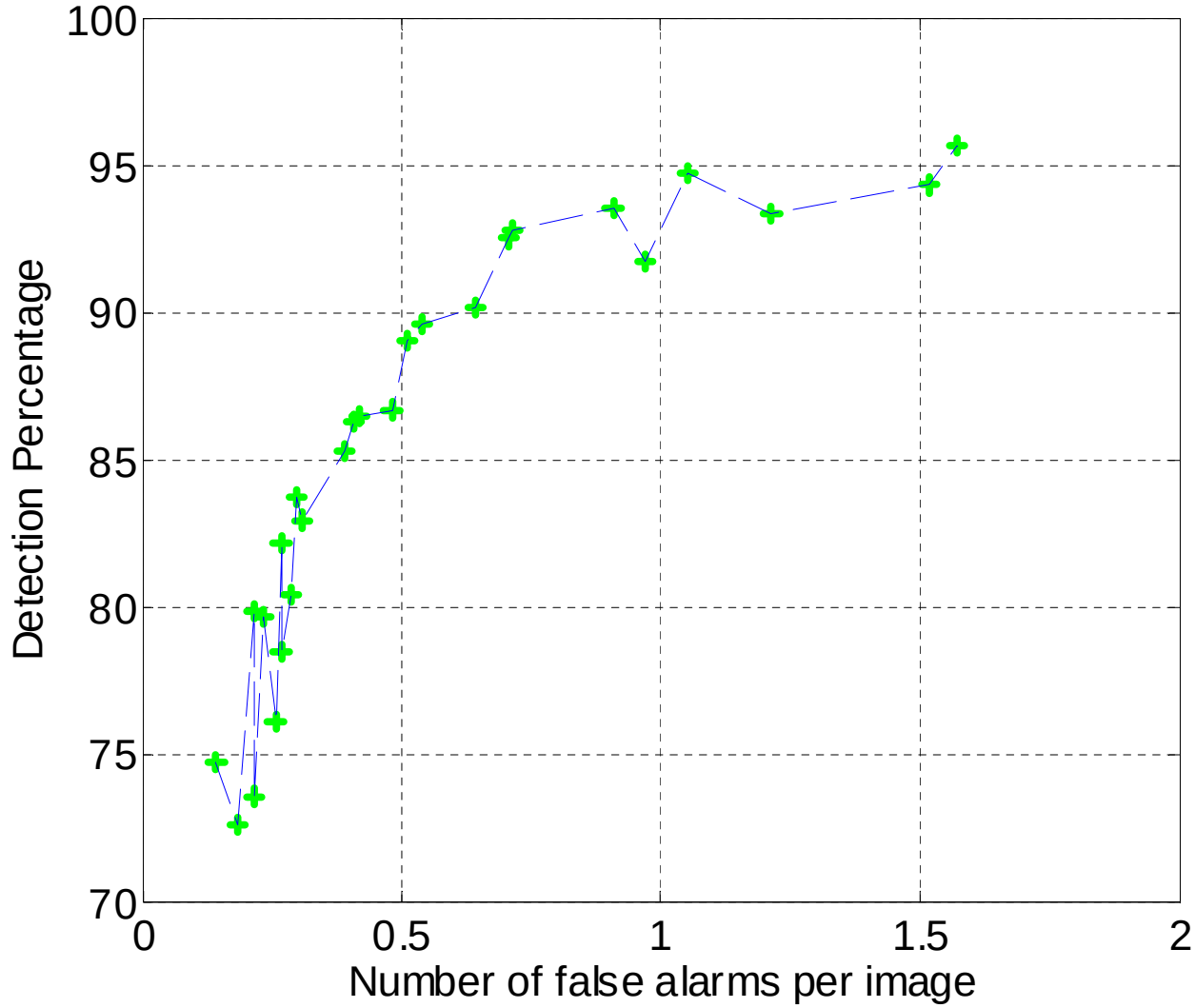
Testing Protocol – Data Collection

- Detection & Tracking
  - Subway videos
    - Dozens of cameras, hundreds of people
  - BomDetec scenario
  - Manually establish ground-truth
    - # of people and their bounding boxes
    - Initial bounding box for tracking
    - Duration for tracking
    - Degree of occlusion
- 3D position measurement
  - Calibrated stereo-rig
  - Laser range finder for ground-truth
    - Accurate to millimeter
  - 6 people, each at different locations with different range/lighting conditions



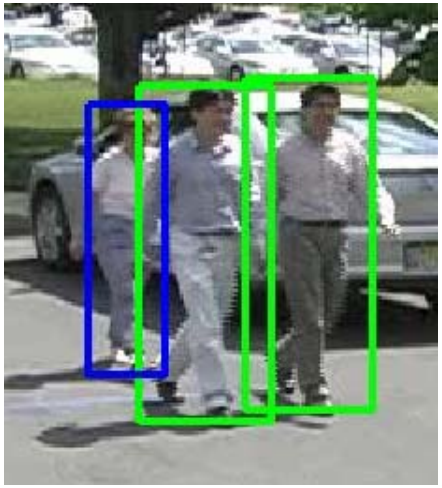
Detection Results: Qualitative

Detection Results: ROC Curve



Pedestrian Detection – Performance Summarization

- Bayesian human segmentation[1] works well for high density, heavy occlusion
- Over 95% detection rate at 1 false alarms per image
- Recommendations:
  - The tested pedestrian detection algorithm can be used as a baseline detector
  - Add temporal integration to resolve uncertainties and ambiguities
- Future work needed:
  - Adapt to BomDetec scenario (training for the specific camera settings, crowd density etc.)
  - Increase speed (currently about 1 fps) thru algorithmic & software improvements



time t

time t+1 second

1. [Zhao & Nevatia. CVPR 2003]

Experimental Setups for Pedestrian Tracking

- Algorithm tested & found sufficient for current CONOPS
  - Mean-shift tracking[1]
    - Utilizing color histogram and greedy gradient ascent search
  - Variations
    - Different color bins per channel
- Other Algorithms available for other CONOPS if necessary
  - Mean-shift with Kalman filter
  - Discriminative tracker [2]
  - Multiple-view tracking (including a PTZ master/slave system)
  - Tunable Kernel Tracking [3]
- Testing considered 3 levels of occlusion (see right)
- Performance metrics
  - Success
  - Partial failure towards the end

no occlusion (play)

partial occlusion (play)

severe occlusion (play)

1.[Comaniciu et. al. CVPR 2000, ICCV 2001] 2. [Lu & Hager CVPR 2007] 3. [Parameswaran et. al. CVPR 2007]

Tracking Results: Qualitative

(Play)

Legend for Video:
+ boxes appear on all tracked pedestrians
+ green, yellow, or pink box indicates degree of occlusion of pedestrian tracked throughout entire sequence
+ if pedestrian tracking is lost, box turns **red** shortly before tracking is lost

no occlusion partial occlusion severe occlusion

Tracking Analysis - Close Range

- Close range tracking (2-30 meters)

	No Occlusion	Partial Occlusion	Severe Occlusion	Speed
Mean-shift tracker (5-bits/channel)	91.5% (86/94)	83.8% (31/37)	61.5% (16/26)	~10 ms

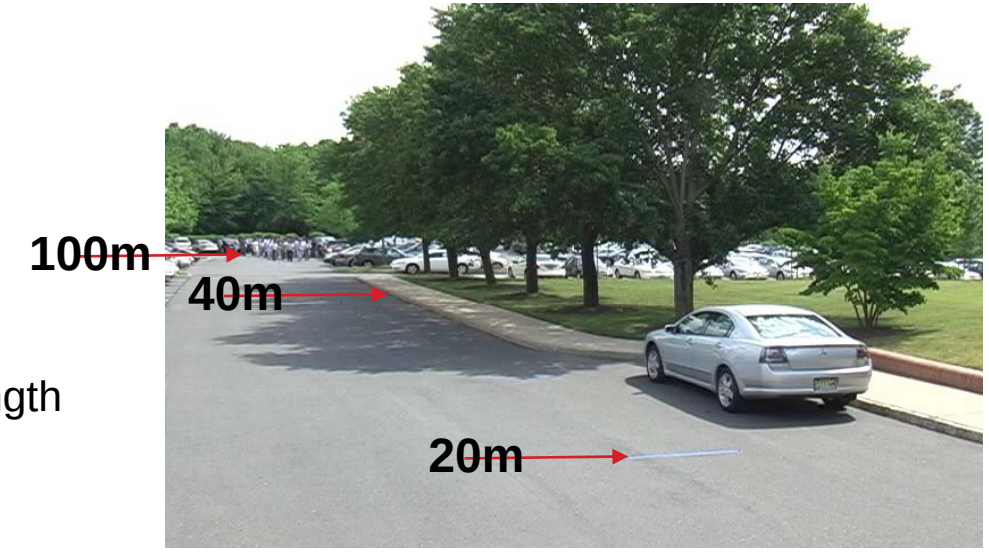
- Partial failure cases and solutions
  - Many due to close foreground/background color
  - Increase histogram bins to 7-bits/channel



	No Occlusion	Partial Occlusion	Severe Occlusion	Speed
Mean-shift tracker (7-bits/channel)	96.8% (91/94)	86.5% (32/37)	69.23% (18/26)	~250 ms

Tracking at mid/long range (>30m)

- People at 100 meters are too small for the trackers
- Tracker performance not as satisfactory as close range
- Variable resolution/focal length cameras needed
  - A lot of pixels wasted on background (sky, vegetation…)
  - A combination of short focal-length and long focal length cameras
  - Make people at long range as large as short range
  - Will be designed and tested in Phase II

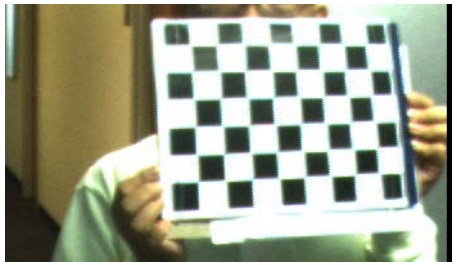


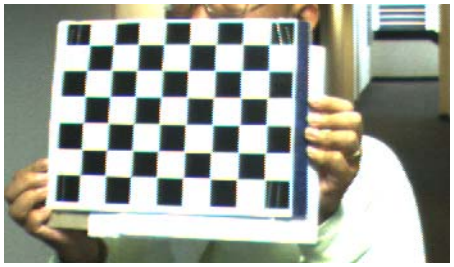
	No Occlusion	Partial Occlusion	Severe Occlusion
baseline tracker at 40m	88.0% (22/25)	80.0% (4/5)	40.0% (2/5)

Illustration of need for multi-focal length cameras

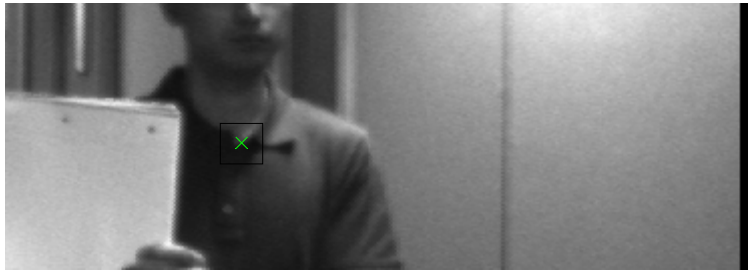
3D Localization Testing

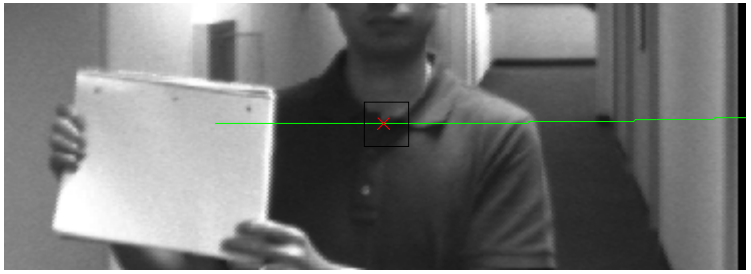
- Algorithm tested
  - Calibration [1]





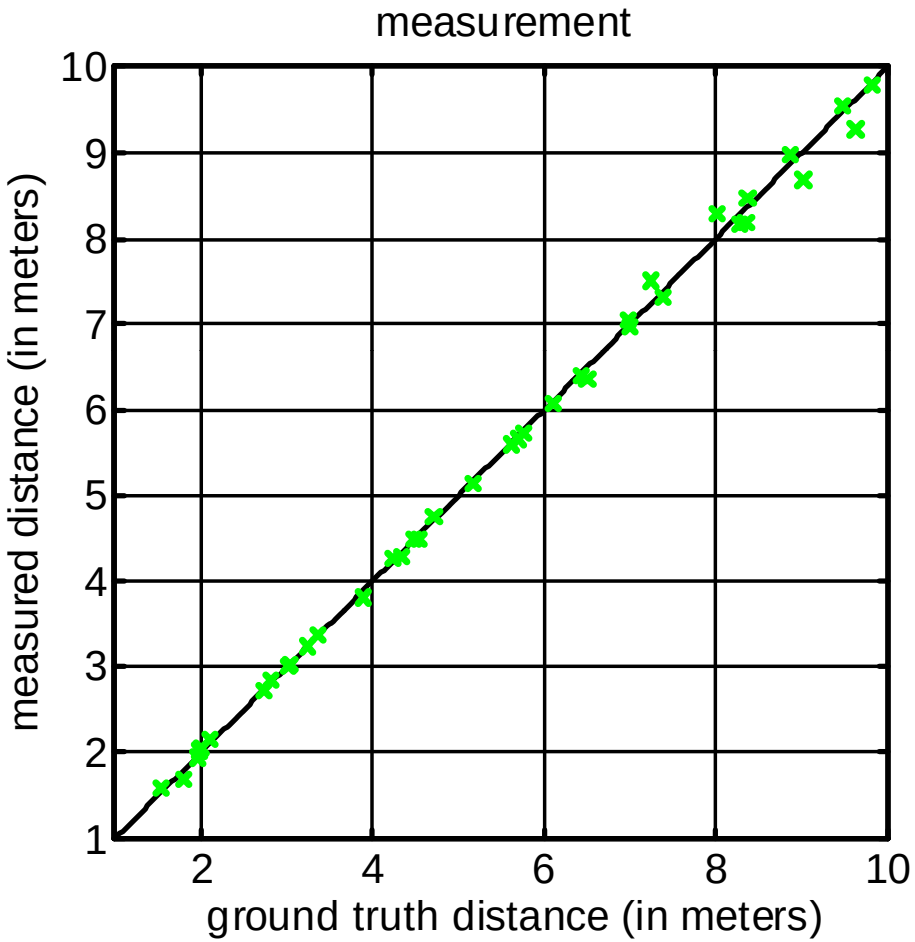
  - Matching: Sum of Absolute Difference

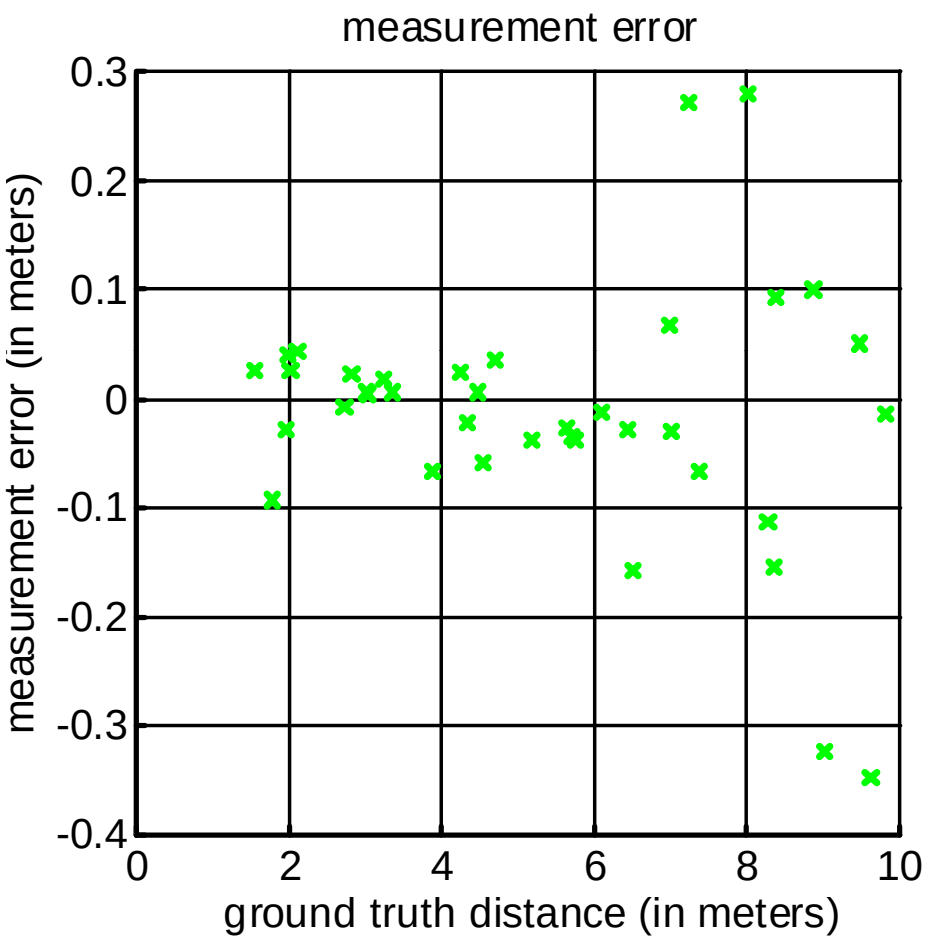




1.[Tsai 1986]

Distance (depth) measurement- results





Conclusion: Stereo accuracy sufficient for sensor targeting at 10-20m