

Integrated Fusion, Performance Prediction, and Sensor Management for Automatic Target Exploitation



Overview

MURI Annual Review Meeting

Randy Moses

November 3, 2008



MURI: Integrated Fusion, Performance Prediction, and Sensor Management for Automatic Target Exploitation



Research Goal

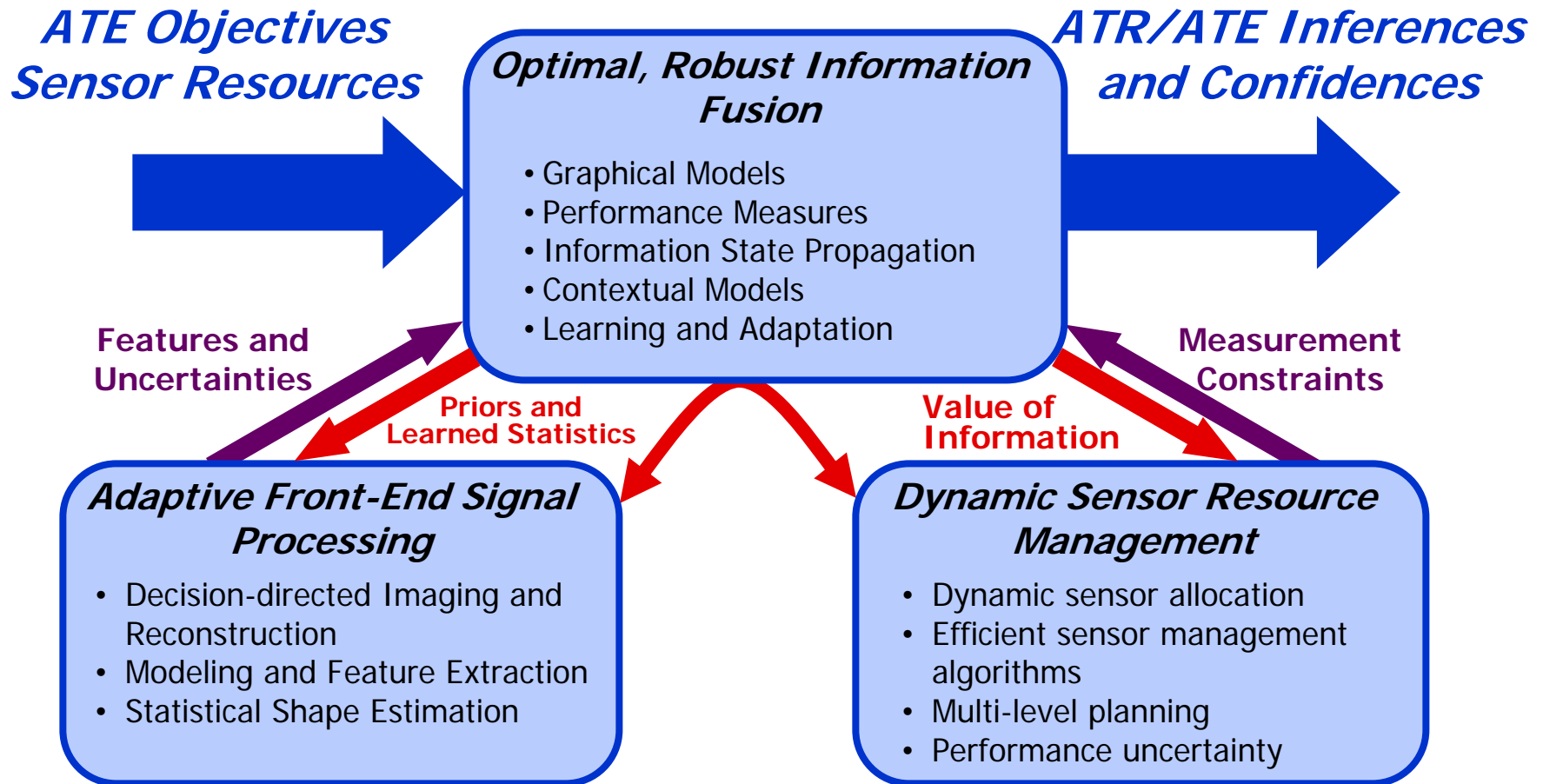
- *Develop an integrated systems theory that jointly treats information fusion, control, and adaptation for automatic target exploitation (ATE).*
 - Multiple, dynamic sensors
 - Multiple sensing modes
 - Resource-constrained environments



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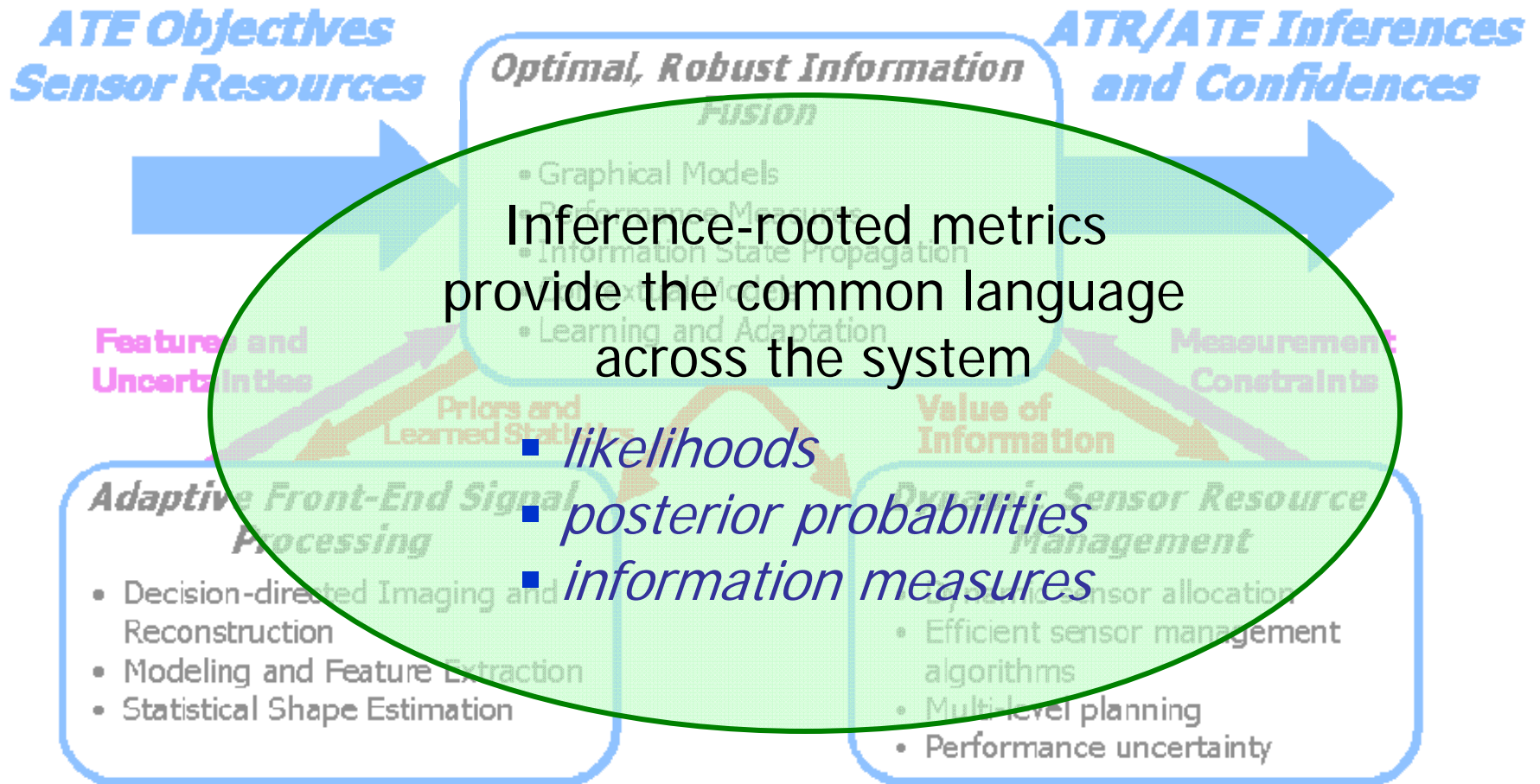
Research Framework



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Research Framework



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Information Fusion: Key Research Questions

ATE Objectives
Sensor Resources

ATR/ATE Inferences
and Confidences

Optimal, Robust Information Fusion

How to effectively direct front-end signal processing?

- Graphical Models
- Performance Measure
- Information State Pro
- Contextual Models
- Learning and Adaptat

Inference on Graphical Models:

- Structures and algorithms for fusion, tracking, identification
- Scalable algorithms
- Learning and adaptation
- Contextual Information

Features and Uncertainties

Priors and Learned Statistics

Value of Information

Constraints

Adaptive Front-End Signal Processing

- Decision-directed Imaging and Reconstruction
- Modeling and Feature Extraction
- Statistical Shape Estimation

Dynamic Sensor Resource Management

- Dynamic
 - Efficient
- level planning
performance uncertainty

What are the 'right' performance measures and bounds for FE and Sensor Mgmt?

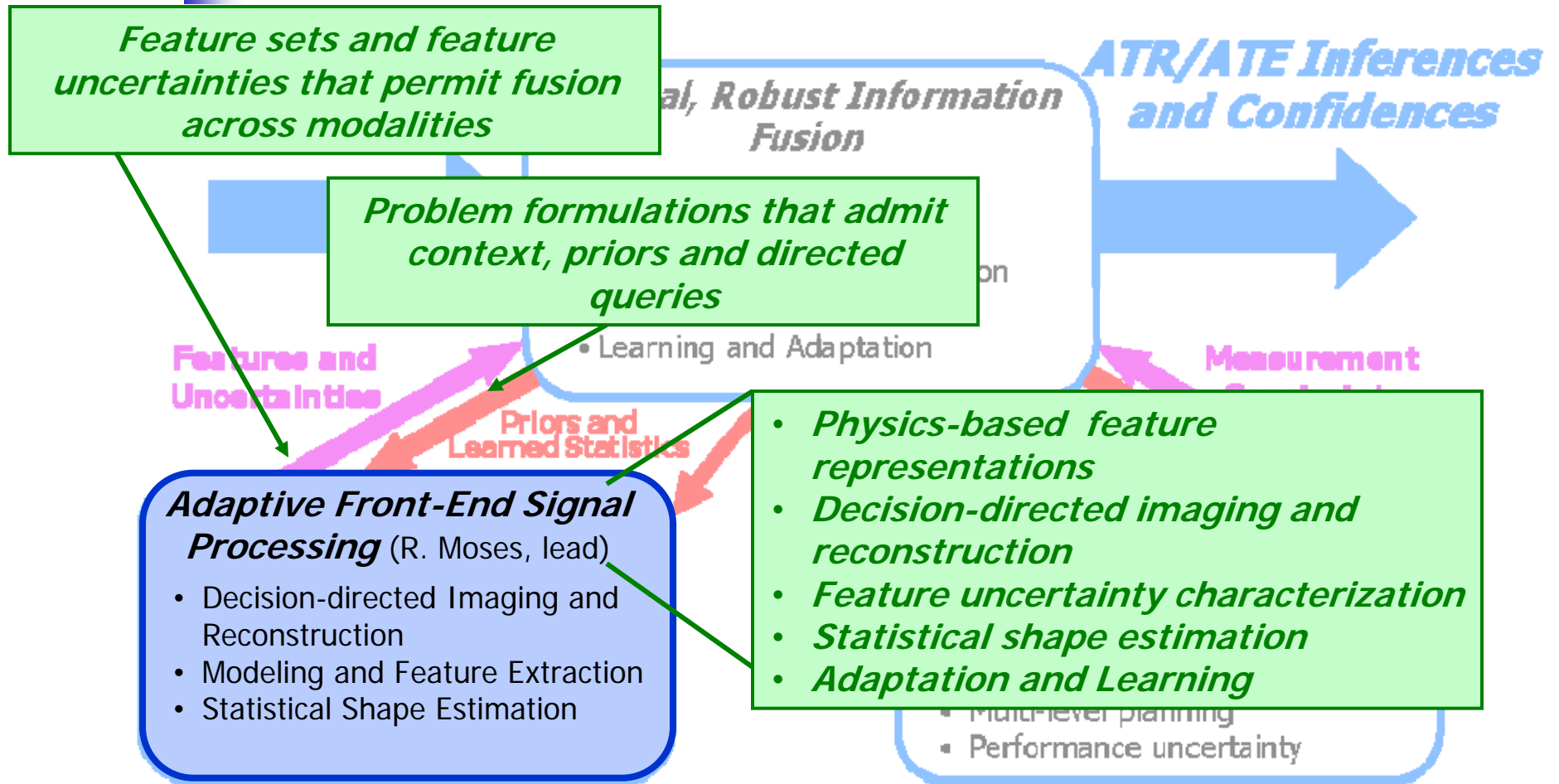
State propagation in graphical models.



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Signal Processing: Key Research Questions

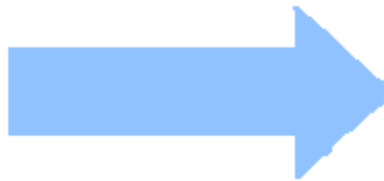


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Sensor Management: Key Research Questions

ATE Objectives
Sensor Resources



Optimal, Robust Information Fusion

- Graphical Models
- Performance Measure
- Information State Propagation
- Contextual Models
- Learning and Adaptation

- *Integrate ATE performance based on graphical models*
- *Manage evolution of "information state" in support of ATE missions*

- *Active sensor control that incorporate ATE performance metrics*
- *Multi-modal, heterogeneous platforms*
- *Scalable real-time algorithms for theater-level missions*
- *Robust to inaccurate performance models*

- Modeling and Feature Extraction
- Statistical Shape Estimation

Value of Information

Measurement Constraints

Dynamic Sensor Resource Management (D. Castañón, lead)

- Dynamic sensor allocation
- Efficient sensor management algorithms
- Multi-level planning
- Performance uncertainty



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MURI Payoff

Goal: Develop an integrated theory for ATE systems that combines information fusion, platform control, signal processing, and adaptation.

Research Outcomes:

- *An integrated theoretical framework for dynamic information exploitation systems.*
- *Theoretical foundations for adaptivity and learning in complex inference systems.*
- *New algorithms and performance metrics for coupled signal processing, fusion, and platform control.*

Payoff:

- *Systematic design tools for end-to-end design of multi-modal, multi-platform ATE systems.*
- *Active platform control to meet ATE objectives.*
- *System-level ATE performance assessment methods.*
- *Adaptive, dynamic ATE systems.*



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MURI Team

UNIVERSITY TEAM:

- Ohio State University (lead)
 - Randy Moses (PI)
 - Lee Potter
 - Emre Ertin
- Massachusetts Institute of Technology
 - Alan Willsky
 - John Fisher
 - Mujdat Çetin (also Sabanici U.)
- Boston University
 - David Castañón
 - Clem Karl
- University of Michigan
 - Al Hero
- Florida State University
 - Anuj Srivastava

AFOSR: David Luginbuhl → Doug Cochran

AFRL POC: Greg Arnold



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Year 1 Meeting Feedback

- Strongly positive on team expertise and interactions.
- Strongly supportive of research plan
- Maintain emphasis on fundamental research.
 - Assumptions that maintain relevance.
- Maintain research continuity and relevance
 - Complementary research problem statements, compatibility across the team.
 - Scalability
 - Performance Prediction



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Year 2 Advances

- Regularized Tomography for Sparse reconstruction
 - Sparse apertures – monostatic and multistatic
 - Sparse 'objects' (targets or scenes)
 - Anisotropy characterization
 - 3D Reconstruction for wide angle and circular SAR
 - Decision-directed reconstruction
 - Lots of cross-pollination
- Shape Statistics for Curves and Surfaces
 - Shape Analysis
 - Shape distribution; not just point estimates
 - Bayesian classification from shapes
 - Bayesian shape estimation from EO/IR images



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Year 2 Advances II

■ Sensor Management

- Multiplatform information-theoretic dynamic sensor management using integer optimization
- Adaptive dynamic sensor management algorithms and performance bounds for radar search, detection and classification
- Multi-Radar resource management with guaranteed uncertainty metrics

■ Scalable Inference

- Lagrangian relaxation and multiresolution methods for tractable inference in graphical models
- New graphical model-based algorithms for multi-target, multi-sensor tracking
- Learning Graphical Model structures directly for discrimination
- GM-based distributed PCA and hyperspectral image discrimination
- Graphical models to extract dynamic behavior modes



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MURI Students

- 11 graduate students and 1.5 postdocs supported by the MURI.
- 14 graduate students and 1 postdoc working on the MURI team with outside support (e.g. fellowships) or partial funding.
- 7 PhD and 8 MS degrees awarded



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ATE MURI Web Page

Main Page - Atemuri http://projects.csail.mit.edu/atemuri/wiki/index.php/Main_Page

Main Page

From Atemuri



Integrated Fusion, Performance Prediction, and Sensor Management for Automatic Target Exploitation
A Multidisciplinary University Research Initiative (MURI) Research Program

Contents

- 1 MURI Team
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 - 2.1 Executive Summary
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- 4 Publications
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- 8 Gain access
 - 8.1 Internal
 - 8.2 FrequentlyAskedQuestions

MURI Team

- **The Ohio State University:** Randy Moses (PI), Lee Potter, Emre Ertin
- **Boston University:** David Castanon, W. Clem Karl
- **Massachusetts Institute of Technology:** Alan Willsky, John W. Fisher III, Mujdat Cetin
- **Florida State University:** Anuj Srivastava
- **University of Michigan:** Al Hero

A complete roster and web page links may be found at MURIPeople.

Overview

The goal of the research is to develop an integrated systems theory that jointly treats information fusion, control, and adaptation for automatic target exploitation (ATE) that addresses:

- Multiple, dynamic sensors
- Multiple sensing modalities
- Resource-constrained environments

Executive Summary

1 of 2 8/16/2007 2:08 PM

- People
- Publications
- On-line research collaboration space
- Resources



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Synergy Examples: Joint Data Collections

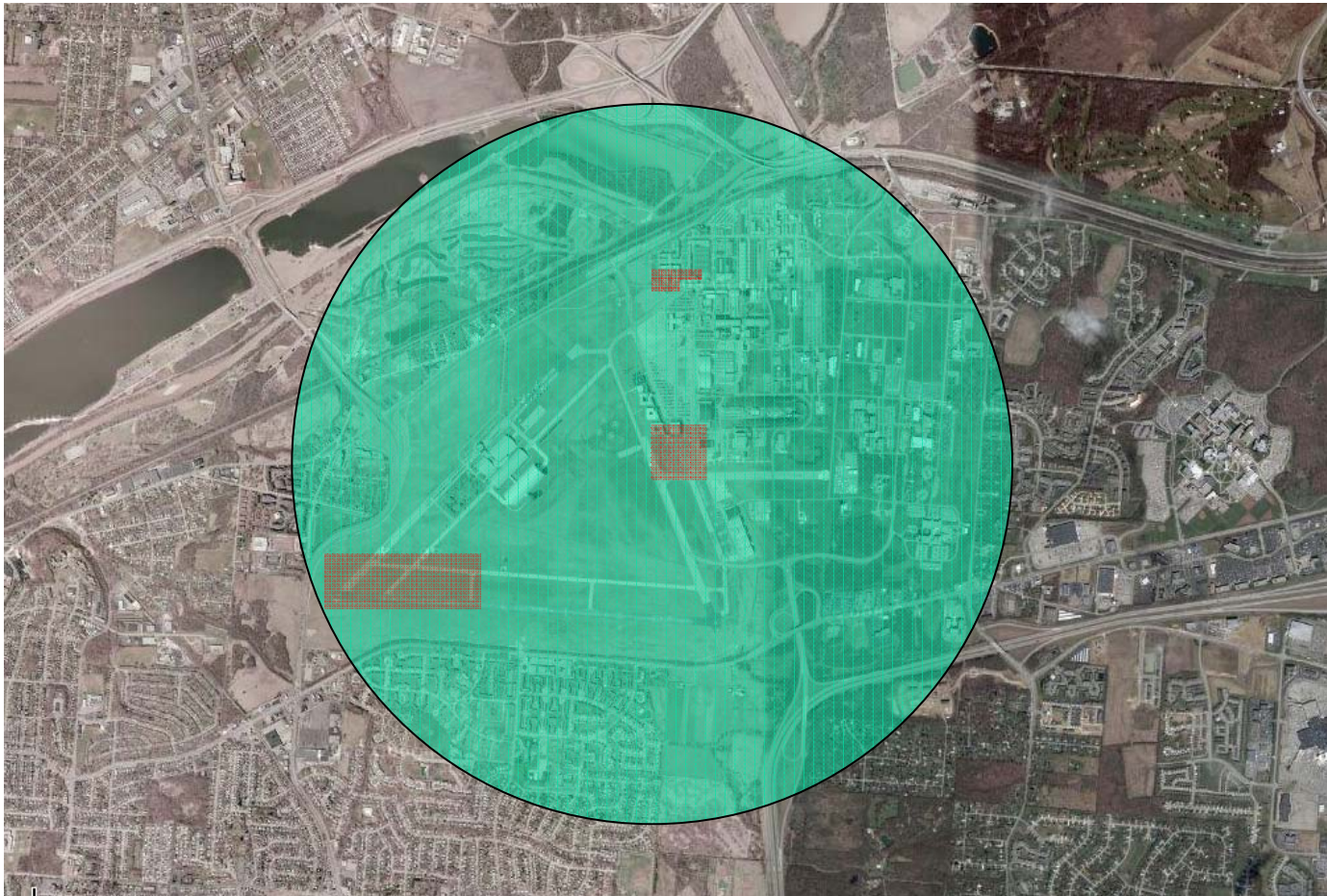
- October 2007: Layered Sensing over OSU Campus
 - AFRL: 3 airborne imaging sensors
 - AFRL and OSU: rooftop sensors
 - OSU: acoustic, seismic, microsensor radar ground sensors
- November 2007: Follow-up layered sensing collection
 - Rooftop and Ground sensors
 - Richer set of people tracking scenarios
- August 2008: AFRL Radar/EO sensing
 - Our MURI provided
 - test targets, stationary and moving vehicles, “sweat equity”
 - INS measurements of moving targets; Location ground truthing
 - Acoustic and Seismic ground sensing
 - Moving vehicle test plans
 - Data to benefit multiple university programs
 - MURI, AFOSR DCT program, ATR Center research



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Gotcha Collection, August 2008

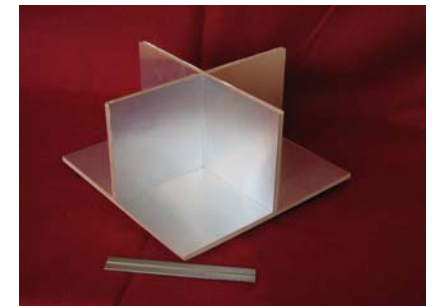


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Test Reflectors

- Urban propagation measurements
 - Top hats
 - Isotropic even bounce return
 - 11.1 dBsm (48 inch base; 16x12.5 cylinder)
 - Quad corners
 - Quasi-isotropic odd bounce return
 - 10.0 dBsm (5 inch squares)
 - Bruderhedral at 45 degrees
 - Wide beam cross-polarization return
 - 5 dBsm
 - Loan from SET Corp



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Phase Alignment Reflectors

- 14 Quad-corners
 - 37.2 dBsm



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Civilian Vehicles



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Today's Presentations

**ATE Objectives
Sensor Resources**

**ATR/ATE Inferences
and Confidences**

**Optimal, Robust Information
Fusion**

**Optimal, Robust Information Fusion in
Uncertain Environments (Willisky)**

- Information State Propagation
- Contextual Models
- Learning and Adaptation

**Graphical Models for Resource-
Constrained Hypothesis Testing and
Multi-Modal Data Fusion (Castañón,
Fisher, Hero)**

**Features and
Uncertainties**

**Priors and
Learned Statistics**

**Adaptive Front-End Signal
Processing**

**Inference-Aware Feature Extraction
and Reconstruction (Çetin, Ertin,
Karl, Moses, and Potter)**

- Statistical Shape Estimation

**Front-End Processing Research on Shape
Analysis (Fisher, Srivastava, Willisky)**

**Dynamic Sensor Resource
Management**

- Dynamic
- Efficient
- algorithms
- Multi-sensor
- Performance uncertainty

**Progress in Sensor Management
for Integrated Surveillance
(Castañón, Fisher, Hero)**



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Agenda

8:30 - 9:00	Intro and Overview (Moses)
9:00 - 9:40	Optimal, Robust Information Fusion in Uncertain Environments (Willsky)
9:40 - 10:25	Inference-Aware Feature Extraction and Reconstruction (Potter)
10:25 - 10:45	Break
10:45 - 11:15	Shape Analysis Research (Srivastava)
11:15 - 11:55	Graphical Models for Resource-Constrained Hypothesis Testing and Multi-Modal Data Fusion (Fisher)
11:55 - 12:50	Lunch - Blackwell Ballroom
12:50 - 1:30	Progress in Sensor Management for Integrated Surveillance (Castañón)
1:30 - 2:00	Summary (Moses)
2:00 - 2:30	Government caucus
~2:30	Feedback and Discussion



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