



# Value-centered Information Theory for Adaptive Learning, Inference, Tracking, and Exploitation

[http://wiki.eecs.umich.edu/voimuri]

ARO W911NF-11-1-0391
Program manager: Liyi Dai

**Investigators**: Al Hero (PI), Raj Nadakuditi, John Fisher, Jon How, Alan Willsky, Randy Moses, Emre Ertin, Angela Yu, Michael Jordan, Stefano Soatto, Doug Cochran






# 2nd Year VoI MURI Review: Agenda

| Time | Activity |
|---|---|
| 8:00 – 8:30 | Check in at ARL visitor office |
| 8:30 - 8:35 | Welcome, Liyi Dai |
| 8:35 - 8:50 | Project overview, Al Hero |
| 8:50 - 10:15 | Thrust area I: Learning and Representation |
| | Overview, Michael Jordan |
| | PI Summaries, Michael Jordan, Stefano Soatto, Al Hero, Angela Yu |
| 10:15 - 10:30 | Break |
| 10:30 - 11:35 | Thrust area II: Information Fusion |
| | Overview, John Fisher |
| | PI summaries, Raj Rao Nadakuditi, Emre Ertin, John Fisher |
| 11:35 - 12:00 | Collaborative highlights |
| 12:00 - 12:15 | DURIP testbed, Emre Ertin |
| 12:15 - 2:15 | Lunch and poster session |
| 2:15 - 3:20 | Thrust area III: Information Exploitation |
| | Overview, Doug Cochran |
| | PI summaries: Randy Moses, Jon How, Doug Cochran |
| 3:20 - 3:30 | Wrap-up, Al Hero |
| 3:30 - 4:30 | Government discussion and de-briefing |
| 4:30 | Adjourn |

# MURI coPIs you will hear from today

Al Hero
Michigan

Raj Nadakuditi
Michigan

Randy Moses
Ohio State

Emre Ertin
Ohio State

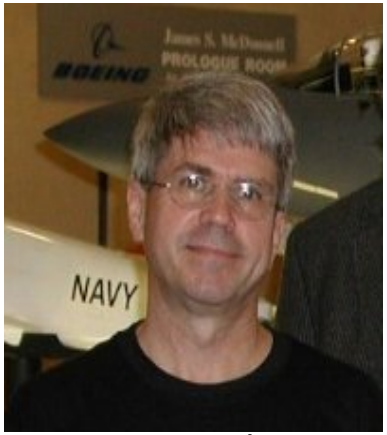
Jon How
MIT

John Fisher
MIT

Angela Yu
UCSD

Stefano Soatto
UCLA

Mike Jordan
UC Berkeley




Doug Cochran
Arizona State

# Our MURI's principal aim

- To derive a comprehensive set of principles for task-specific information extraction, distributed information fusion, and information exploitation that can be used to design the next generation of autonomous and adaptive sensing systems.

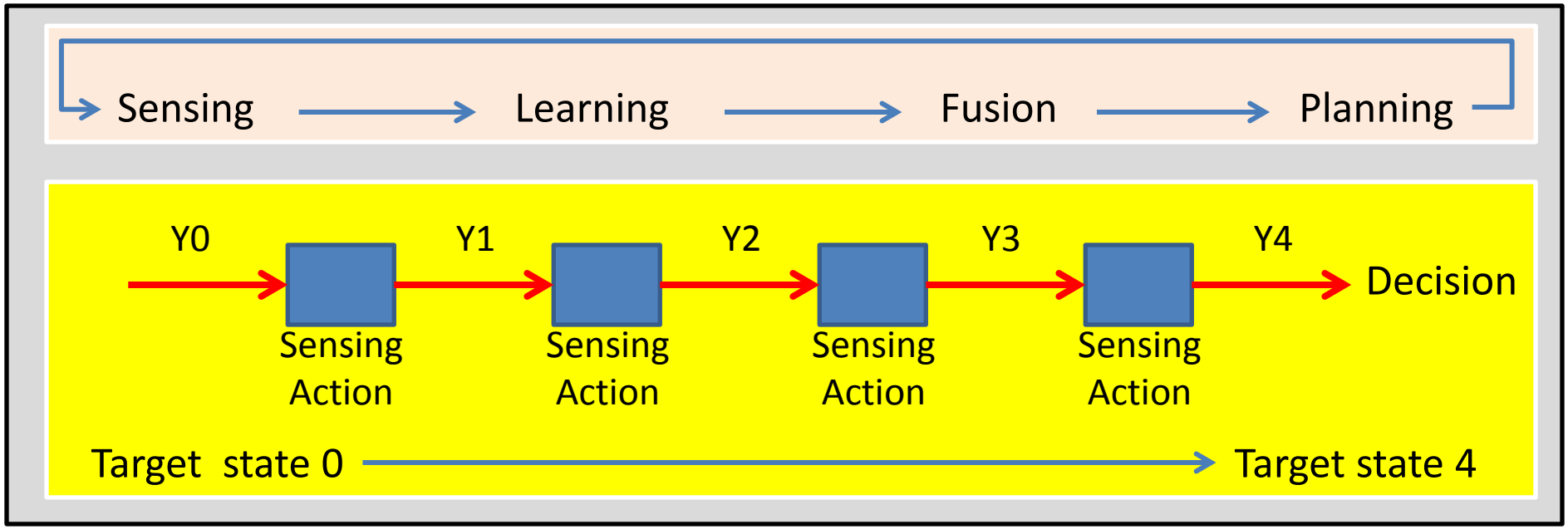
- **Specific objectives:**

  - Develop analytical frameworks for quantifying value of information.
  - Study fundamental tradeoffs for information collection and fusion
  - Develop info processing algorithms with performance guarantees
  - Validate theory and algorithms on sensing testbeds at MIT, OSU, UCSD and UCLA

- **Technical approach:** value-centered information theory, machine learning and control.

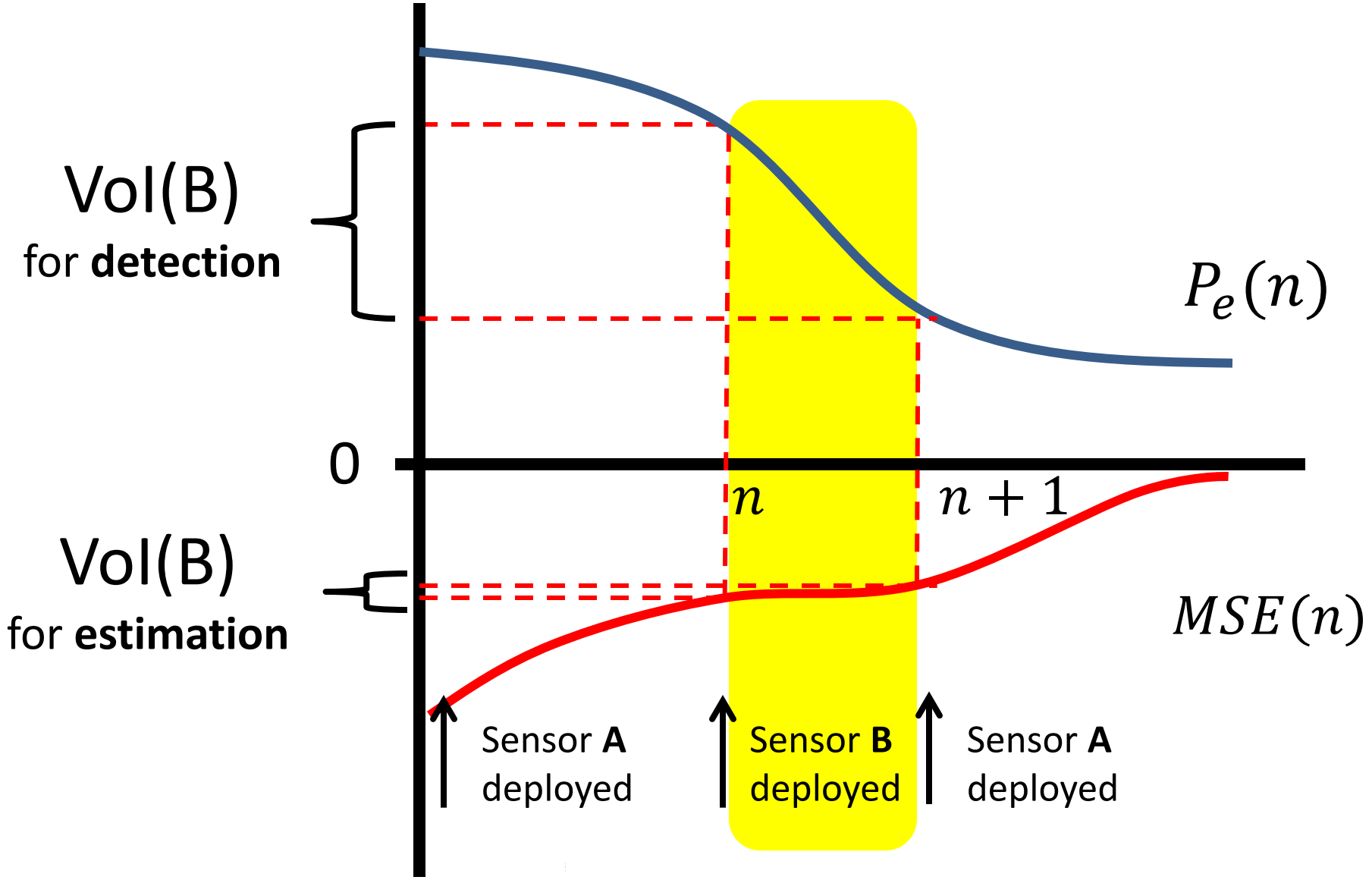
# Value-centered information theory

Adaptively measure variables Y0, Y1, … for decisionmaking



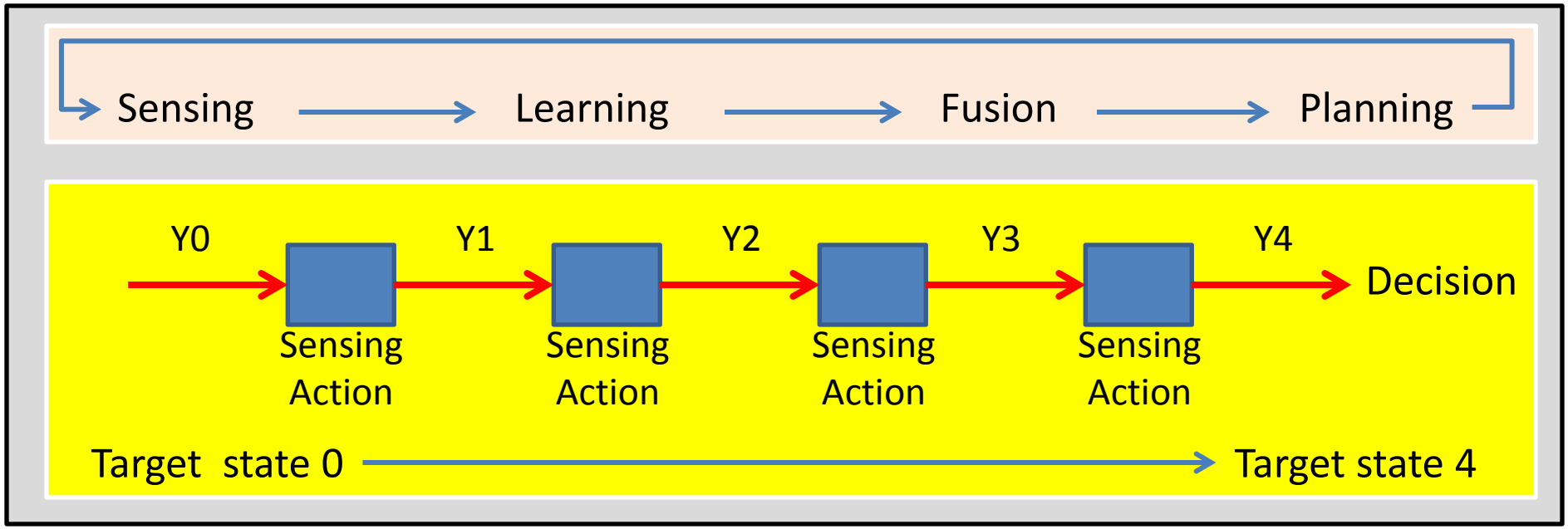

- Each sensing action acquires a sample (snapshot) Yn
- Yn contains information about target state, clutter, and sensor quality
- What is the intrinsic value of this information with respect to decision?

# Value of information accrued from a snapshot



# Value-centered information theory

Adaptively measure variables Y0, Y1, … for decisionmaking




**Our MURI has so far focused on the following:**

- Scalable information metrics that account for decision task
- Characterization of phase transitions, scaling laws, and bottlenecks
- VoI-driven fusion strategies for distributed data collection
- Applications to active vision, sensor nets, radar, human-in-the-loop

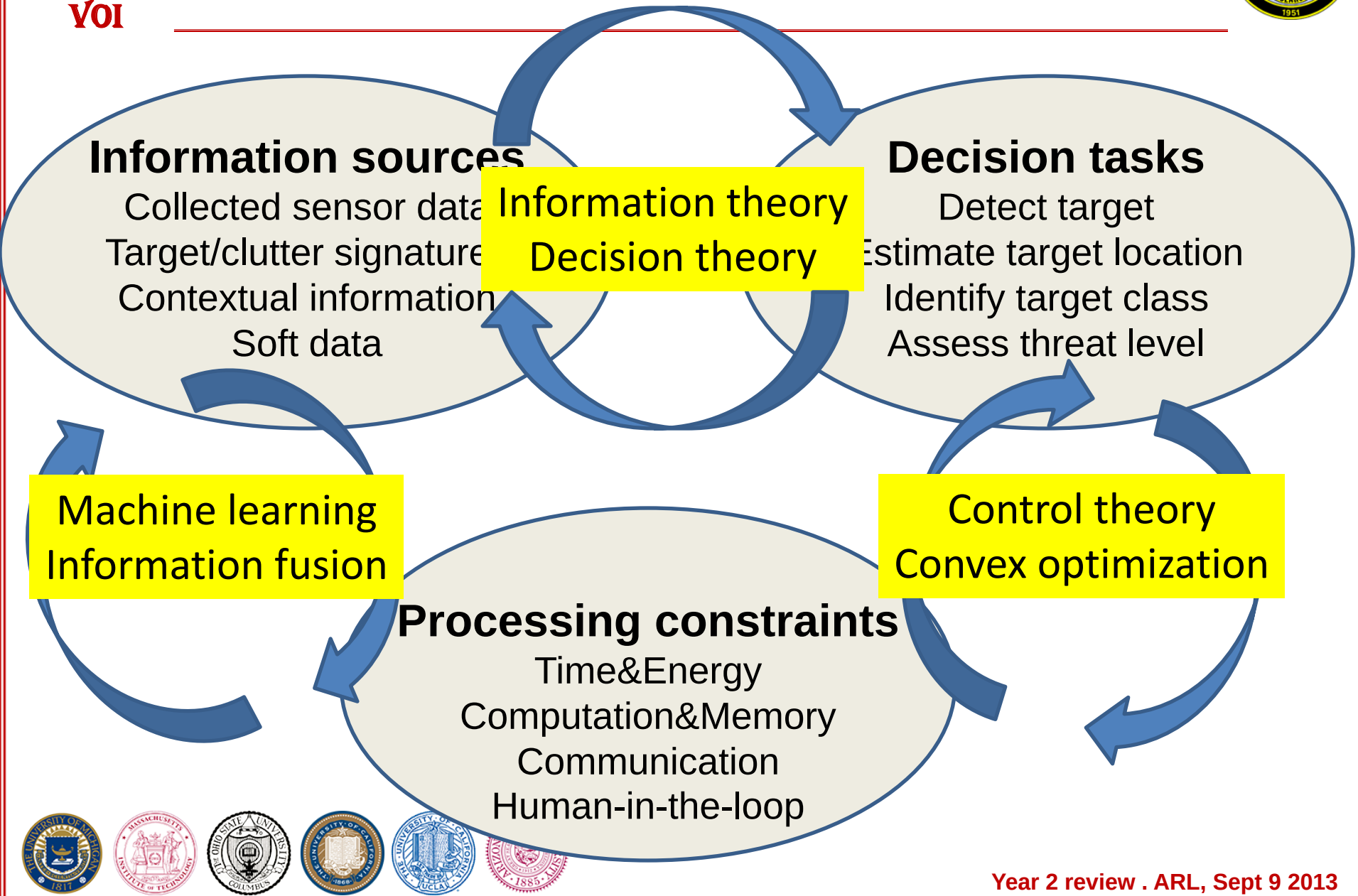
# Design space is high dimensional

**Information sources**
Collected sensor data
Target/clutter signatures
Contextual information
Soft data

**Decision tasks**
Detect target
Estimate target location
Identify target class
Assess threat level

**Processing constraints**
Time&Energy
Computation&Memory
Communication
Human-in-the-loop

# Theory applicable to design space



# Theory applicable to design space

**Central questions addressed by our MURI**

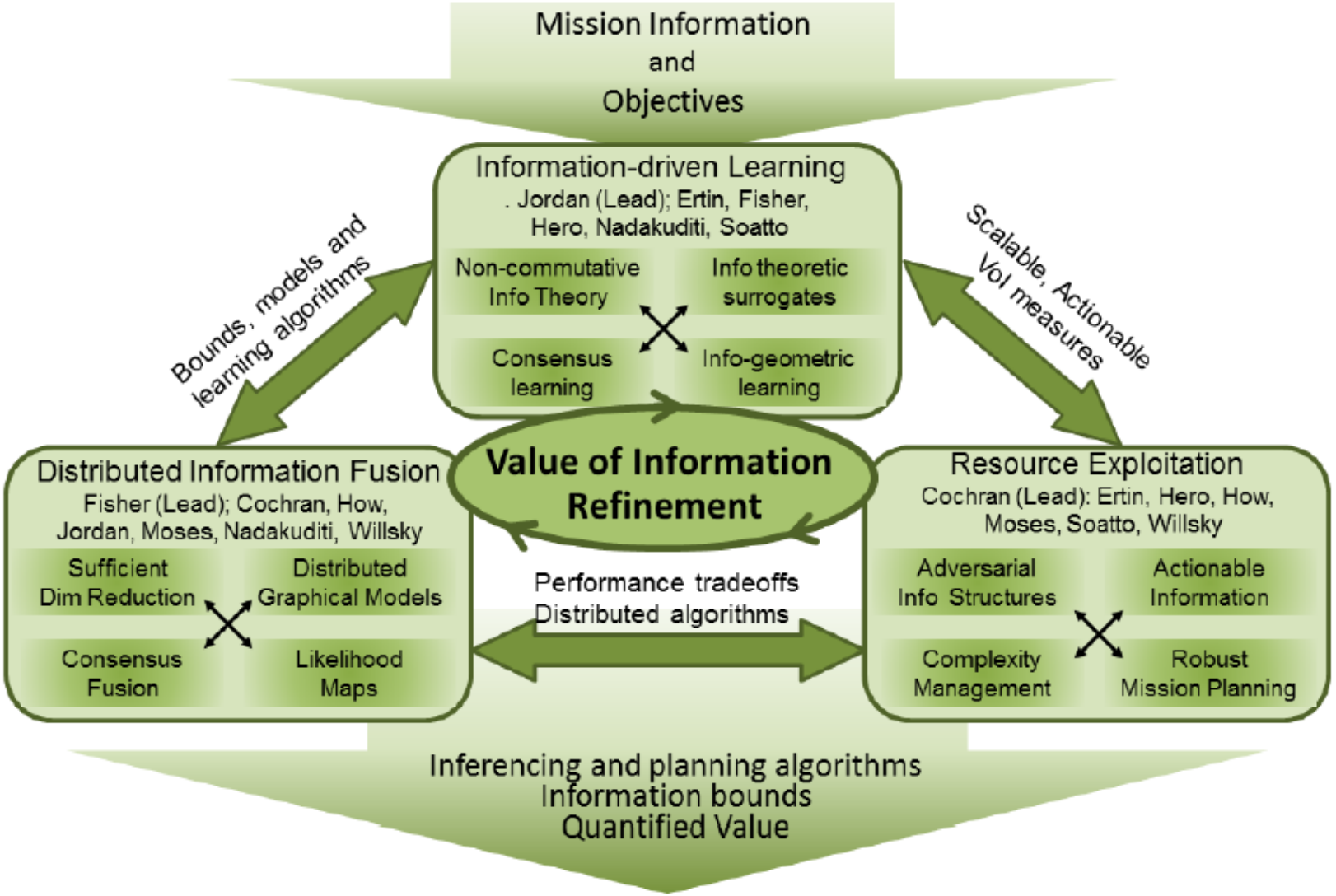
What is intrinsic value of information for a task?
How do constraints affect value?
What algorithms ensure max value?
How to overcome computational bottlenecks?

**Our technical approach to address questions**

Value-centered information theory
Information-driven data fusion
Information-aware controlled sensing/processing

Communication

# Research program: High level view



# Previous government comments

- **The government committee was pleased to see that the MURI team produces high quality, fundamental research results**
  We continue to maintain a rigorous foundational research focus

- **The poster session is an excellent idea, and should be an example for other MURI reviews**
  We have expanded the poster session this year.

- **The team has a good start with connecting research with Army laboratories…. The team is strongly encouraged to continue/expand the collaboration with ARL, AMRDEC, and other DoD laboratories**
  We have expanded our collaborations with DoD.

# Previous government comments

- **Collaborations among team members at different universities have been planned, and the team is encouraged to take actions as soon as possible to strengthen collaboration among team members**
  See today's session on collaborations and posters

- **Future research is encouraged to place more emphasis on multimodality sensors, particularly visual modality**
  We have expanded visual modality activities (video, LIDAR)

- **Experimental validation and verification is encouraged. Team responded with a pending DURIP proposal to ARO…It's desirable to have plans in place to validate and verify research results using carefully designed experiments, which is particularly important for modalities other than radar, such as visual imagers.**
  DURIP was funded. Other modalities will also be validated.

# Previous government comments

- **The committee noted that a wide range of research topics are being addressed, and encouraged the team to coordinate research efforts toward establishing a rigorous, foundational framework of value of information for distributed fusion.**

  We have made efforts to coordinate research on establishing a foundational multi-faceted framework for VoI. These include several collaborations on foundational issues and organization of two special sessions on VoI at conferences this past year.

# Today's posters

1. *N. Asendorf* and R. R. Nadakuditi, "The Performance of Deterministic Matched Subspace Detectors: Informative Versus Useful Subspace Components" Abstract
2. *T. Broderick,* N. Boyd, A. Wibisono, A. Wilson, and M.I. Jordan, "Streaming Variational Bayes"
3. *L. Crider,* R. R. Nadakuditi, and D. Cochran, "Analyze-Fuse vs. Fuse-Analyze in Multiple-channel Emitter Detection" Poster
4. *Z. Meng,", D. Wei, A. Wiesel, and A. Hero, "Distributed learning of Gaussuab graphical models via marginal likelihoods" Poster*
5. *B. Mu,* G. Newstadt, J. P. How, and A. Hero, "Heterogeneous Agent Target Assignment in an Unknown Environment"Poster
6. *B. Mu,* G. Chowdhary, J. P. How, "VoI Aware Active Task Assignment Hardware Experiment" Poster
7. *G. Papachristoudis* and J. W. Fisher, "Efficient Information Planning in Graphical Models"
8. *J. Straub* and J. W. Fisher, "Information gathering with mobile agents: sensor and model complexity tradeoffs"
9. *N. Sugavanam,* and E. Ertin, "Robust Filtering with Uncertainty in Initial State" Poster
10. *N. Sugavanam,* and E. Ertin, "Sensor Selection Problems in Adversarial Setting"

# Today's posters

11. *R. T. Suryaprakash* and R. R. Nadakuditi, "The Performance of MUSIC-Based DOA In White Noise With Missing Data" Abstract
12. *D. Teng,* and E. Ertin, "Optimal Quantization of Likelihood for Low Complexity Sequential Testing" Poster
13. *D. Teng,*and E. Ertin, "Learning Statistical Manifolds for Target Signatures" Poster
14. *T. Tsiligkaridis* and A. Hero, "Covariance Estimation In High Dimensions via Kronecker Product Expansions"
15. *T. Tsiligkaridis,* B. Sadler, and A. Hero, "Collaborative 20 Questions for Target Localization"
16. *G. T. Whipps,* E. Ertin, and R. L. Moses "Decentralized EM for a Mixture of Factor Analyzers"
17. *G. T. Whipps,* E. Ertin, and R. L. Moses "Distributed Detection with Collisions in a Single-hop Wireless Sensor Network"
18. *S. Zhang* and A. J. Yu, "Forgetful Bayes and Myopic Planning: Human Decision Making in a Bandit Setting"
19. *Y. Zeng, C. Wang,* S. Soatto, *and S.-T. Yau, "Nonlinearly Constrained MRFs: Exploring the Intrinsic Dimensions of Higher-Order Cliques"*