

# Internet of Battlefield Things

## COLLABORATIVE RESEARCH ALLIANCE



IoBT  
REIGN



# IoBT CRA Research Management Board (RMB) Review

## Program Overview

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DEVCOM, Army Research Laboratory

Tarek Abdelzاهر, Consortium Manager  
University of Illinois Urbana-Champaign

March 18, 2022





# IOBT CRA RMB REVIEW



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**Objective: Provide an overview of the current research within the Internet of Battlefield Things (IoBT) Collaborative Research Alliance (CRA), discuss accomplishments and describe proposed research plan for the optional period of the CRA**

Start	Topic	Presenter
1300	Welcome – Introductions	Kott
1310	Program Overview	Wigness/Abdelzaher
1350	Research Focus 1: Efficiency & Timeliness	Verma/Fragouli
1420	Research Focus 2: Resiliency	Kaplan/Tabuada
1450	<b>Break</b>	
1500	Research Focus 3: Intelligence at the Point of Need	Panneton/Shenoy
1530	Experimentation Overview	Wigness/Shenoy
1550	IoBT – Way Ahead	Swami/Abdelzaher/Wigness
1610	<b>Break</b>	
1620	RMB Caucus (Government Only)	All Government
1700	Adjourn	



# BOTTOM LINE UP FRONT



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**The IoBT CRA is the only ARL fundamental research program addressing challenges of ubiquitous computing and sensing as an intelligent and adaptive common operating environment**

- **Seeking Approval of Extension for 5-year Option Period and Guidance on Future Research Direction**
  - Are we asking the right scientific questions?
  - Are there research areas that we should expand or deemphasize?
  - Are there additional opportunities for early transition?
  - Do we have the right balance of experimentation and foundational research?



# IOBT CRA OVERVIEW



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## Collaborative Research Alliance:

- 6.1 Basic Research Program
- University Led Consortium
- Collaboration is Executed Across the Alliance
- 5 year program with option for 5 year renewable (FY23)

	FY18	FY19	FY20	FY21	FY22	Total
6.1 Funds	\$1.7	\$3.7	\$4.8	\$4.9	\$2.7	\$17.8M

## Current Consortium Partners



## Current Government Partners



UNITED STATES MILITARY ACADEMY  
WEST POINT.



## Operating Model:

- Joint leadership and execution
- BPP for continuous refresh in research directions
- Regular engagement among researchers to develop rich collaboration



# IOBT CRA TEAM

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## Test of Time Awards

- ACM MOBICOM
- ACM Int. Symposium on Wearable Computers
- ACM/IEEE Int. Conf. on Software Engineering

## Faculty Awards


- Honorary Professorship at UIUC
- Tau Beta Pi Daniel C. Drucker Eminent Faculty
- Distinguished Professor, Umass-Amherst
- Grainger Distinguished Chair in Engineering
- Outstanding Teacher Award from the College of Information and Comp. Sciences
- Jack Kilby/Texas Instruments Endowed Faculty

## Research Awards


- Many Awards from Google, Amazon, Sandia National Labs, Adobe, Facebook, J.P. Morgan
- Healthy Longevity Award, Interstellar Initiative
- Healthy Longevity Catalyst Award, U.S. National Academy of Medicine
- IEEE Internet Award
- USC Stevens Center Commercialization Award
- Honorary Doctorate, KTH Royal Inst. of Tech.
- National Academy of Science

## Alumni Awards

- Wilbur Cross Medal, Yale University




**Wigness, ARL**  
Collaborative Alliance Manager



**Abdelzaher, UIUC**  
Consortium Manager




**Swami, ARL**  
Chief Scientist




**Verma, ARL**  
Research Area Lead



**Krishnamachari, USC**  
Research Area Lead




**Kaplan, ARL**  
Research Area Lead




**Tabuada, UCLA**  
Research Area Lead



**Panneton, ARL**  
Research Area Lead



**Shenoy, UMASS**  
Research Area Lead




**Fragouli, UCLA**




**Wang, Texas Austin**




**Jha, SRI**




**Thomas, UMASS**



**Veeravalli, UIUC**




**Srivastava, UCLA**




**Vaidya, Georgetown**



**Ramdas, CMU**



**Brunskill, Stanford**




**Towsley, UMASS**



**Ravikumar, CMU**




**Varshney, UIUC**




**Diggavi, UCLA**



**Roy, SRI**



**Nahrstedt, UIUC**



**Basar, UIUC**



**Jiang, UIUC**

## Efficiency

## Resiliency

## Edge Intelligence

● New PI (in this BPP)

● New Govt Leads (in this BPP)

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# IOBT STRATEGIC GUIDANCE

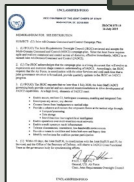
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## Joint All-Domain C2 Campaign Plan



**converge service and partner capabilities across all-domains interoperability, C2 flexibility, and hyper-connectivity needed between all sensors to all shooters**  
**robust, protected, and resilient network**

flexible integration of emerging technologies (AI, Machine Learning, Self-healing networks)

## National Defense Strategy



**information superiority**  
**resilient, survivable, federated networks and information ecosystems**  
**autonomy, artificial intelligence, and machine learning**

## Army Cyberspace and EW Operations



**machines make decisions for themselves on the battlefield**  
**fail-safe technologies**  
**collect, process and disseminate information**

IoT data collection and management

## DoD IoT Policy Recommendations



**improve situational awareness**  
**security with inexpensive and precise monitoring devices**

## Army Science Board IoT Study



**meaningful situational awareness on the status of Soldiers and equipment, on the battlefield and in the logistics pipeline**  
**enhance autonomous vehicles, to exploit IoT proficiency in exploiting adversaries' smart cities and defending from attacks**  
**requirements for the acquisition community to integrate IoT**  
**understand risks associated with IoT**

## Multi-Domain Operations



**accelerated and likely highly automated decision making from devices**  
**enable collection, analysis, and display of multi-domain data**  
**mechanical sensors enable intelligence collection**

**Influencing Future Concepts**

## Army Concept Framework 2040

- The IOBT CRA contributed as research SMEs for a Focused Excursion (FE) that investigated IOBT implications on select learning demands of this new framework
- Used FE discussions and feedback to validate and refine the future research direction of the IOBT CRA

## Army Mission Command



**Army information network links leaders, Soldiers...and sensors to help create a synergistic, globally-connected total Army force**

sensors coupled with deep-learning technologies  
**interoperability, collaboration, and uninterrupted mission command**  
require sensors linked by a **tailorable suite** of mission command applications, information services, and communications

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# THE “WHY”? MACHINE INTELLIGENCE IS REDEFINING FUTURE WARFARE

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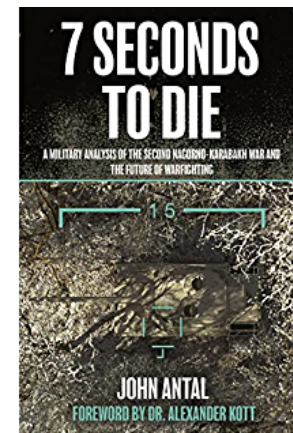
Value proposition:

Develop the scientific foundations for *Efficiency and Resilience (of Edge-AI Services) for the Tactical Edge*



The Future is Here:

- *Nagorno-karabakh War, Fall 2020:* Featured early use of drones to stimulate, find, and strike anti-aircraft (Armenian) defenses.
- *Israeli anti-Hamas Operation, Spring 2021:* Featured early use of AI to identify and prioritize key targets in real-time (e.g., missile launchers aimed at Tel Aviv and Jerusalem).



Computational Challenges:

- Push intelligence to the edge
- Support faster sensing-to-effects loops

~~Future~~ Intelligent battlefield systems require autonomic behaviors with efficient closed-loop (safety) controls to ensure reliable and resilient operation at machine-speed in contested environments

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# THE "WHY"? MULTI DOMAIN OPERATIONS INCREASE COORDINATION NEEDS

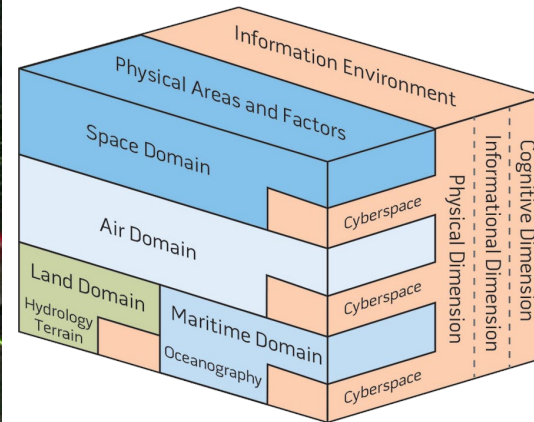
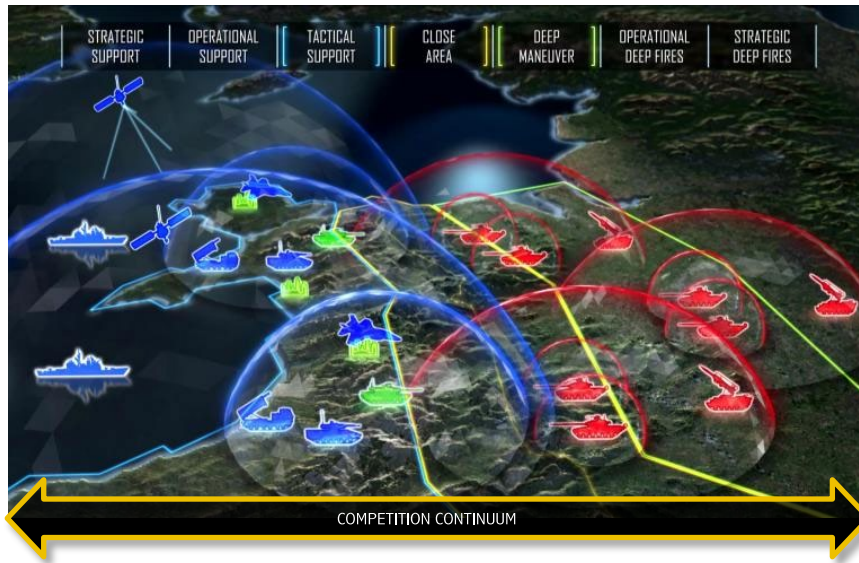


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Value proposition:

Support coordination at scale in *Contested High-tempo, Heterogeneous, and Distributed Environments*



**Future command & control information-networks require tighter (cyber-physical) integration across heterogeneous assets in multiple domains**

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# THE IOBT INNOVATION SPACE



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## IOBT:

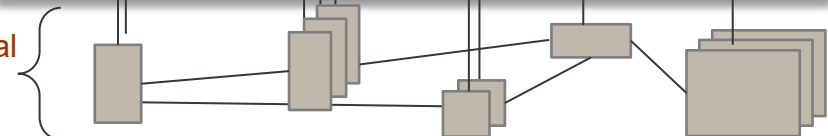
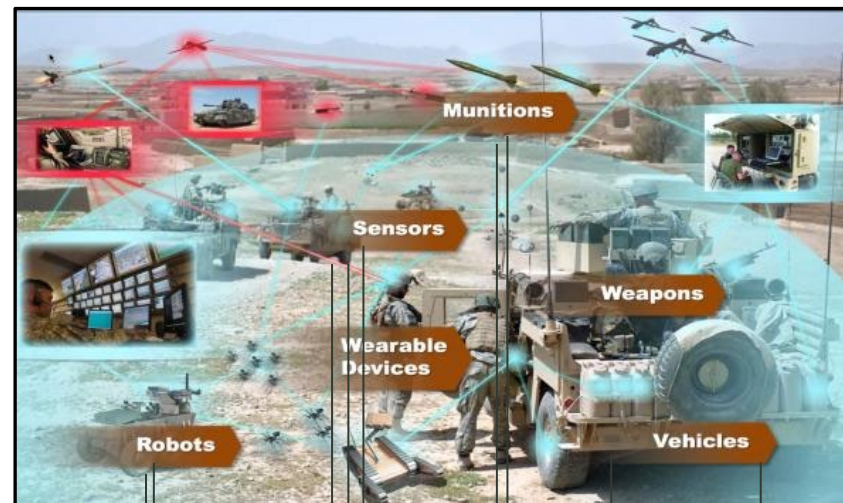
**Endows** a set of interdependent and interconnected entities at the tactical edge (the “*battlefield things*”)

- Smart devices (e.g., sensors, actuators, weapons, vehicles, robots)
- Computing infrastructure (e.g., networks, storage, processing)
- Intelligent analytics (on-node, in-network, de-centralized or centralized)

with the capabilities to:

- **Operate in real time at the point of need** to form a collectively-intelligent complex system-of-systems intended to meet multiple missions, tasks, or goals in contested environments
- Exhibit self-\* characteristics (Self-\* = *SELF* organizing, configuring, adapting, maintaining, protecting) **resilient to a wide array of attacks against the computational elements in the system**
- **(In order to) accelerate the sensor-to-effects loop** and impact the physical world

Computational  
Elements



**IOBT Services**  
for Intelligent Edge Efficiency and Resilience



# DECISION ADVANTAGE WITHIN THE MDO EFFECT LOOP

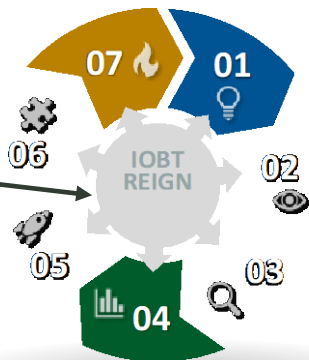
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Intelligent real-time technologies must operate **at the point of need** as a highly **resilient** system-of-systems, dynamically composed to **accelerate the MDO Effect Loop**



Two sides to this concept

- *Red side*: Adversarial engagement in the MDO phases (i.e., **threat** recognition)
- *Blue side*: Cross domain utilization of Joint or Coalition assets (i.e., **asset** recognition)

Critical high-level research challenges for AI-enabling MDO Effect Loop

- Improve efficiency, reduce latency
- Mitigate risk, reduce false positives

Automation will reduce full cycle time from **hours/minutes to seconds/sub-minutes**



## 1. Assess & Detect

Conduct reconnaissance and detect entities



## 2. Identify

Identify threat/asset and relate threat/asset capabilities



## 3. Locate & Track

Determine location and maintain situation awareness



## 4. Aggregate & Synthesize

Collect and communicate sensor data



## 5. Distribute

Distribute information and actuation recommendations (Capability COAs) in COP updates



## 6. Decide

Commander's decision enabled and enacted by automated orders



## 7. Effect / Actuate

Affect the physical world and assess decision outcomes

Threat Recognition  
Asset Recognition

Intelligent Decision Support

Engage



# WHAT DISTINGUISHES THE BATTLEFIELD

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## What is challenging about supporting battlefield functions (putting the “B” in “IoBT”)?

### The Environment

1. Rapid dynamics
2. Presence of adversaries
3. Contested, constrained, predominately wireless environment



### The System

4. Significant heterogeneity
5. Ubiquitous scale in multiple dimensions
6. Resource distribution

**Advantage = the ability to outpace/disrupt/degrade peer-adversary’s decision cycles**

- Competing decision cycles: *Who can best connect their sensors and shooters?*
- Converging distributed sensors/data/effects from ALL domains, at capacity to achieve commander’s intent; agnostic to domain, platform, and Service

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# THREE KEY DIRECTIONS



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## Concepts driving IoBT evolution:

Value proposition: **Efficient and Resilient Tactical Edge Analytics** for the Sensing-to-Decision (MDO Effect) Loop

### 1. **Efficient** → Time is a weapon

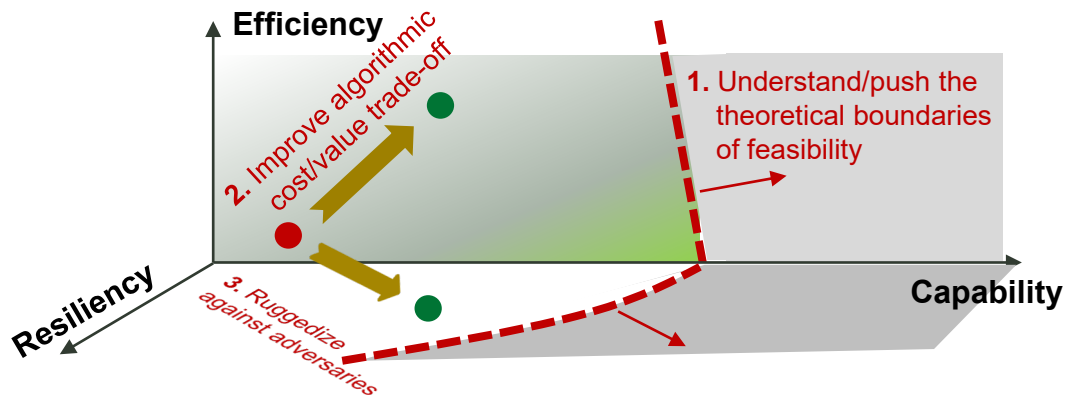
Design for timeliness and efficiency of intelligent processing and network communication on edge devices

### 2. **Resilient** → IoBT is a fighting network

Offer strong assurances of correctness in the face of adversarial disruption

### 3. **Edge AI** → Tailored intelligence at the point of need

Tailor multimodal services for the distributed tactical edge





# EXAMPLE INNOVATIONS



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## Rapid Sensing

- Submodular optimization for network synthesis: **Fast approximations to NP-hard network synthesis** problems
- Statistical theory of **quickest change detection**

## Rapid Communication

- Communication efficient compressed distributed learning: **Over 1000x improvement** in distributed learning cost
- Compressive offloading: **Beating state-of-the-art compression by 2x-4x** (e.g., JPG)

## Rapid Inference

- Criticality-based attention prioritization **for fast inference**
- Adaptive execution of DNN inference: **Controllable speed/quality trade-offs**
- Theory of model compression: **Fundamental storage bounds**

**Focus #1:  
Edge Efficiency  
(Time is a weapon)**

**Focus #2:  
Resiliency  
(of Decision Loop  
Analytics)**

**Focus #3:  
Tailored Intelligence  
(at the Point of Need)**

## Intrinsically Resilient Edge Systems

- New neural **network architectures for improved edge resiliency** and interpretability
- **Robust inference** despite distribution shifts
- **Secure deep learning** inference for IoT devices

## Safe Resource Allocation

- Risk-aware resilient task placement: **Tolerance to resource outages** via risk-aware placement
- Safe reinforcement learning

## Adaptation to Contextual Shifts

- Robustness to adversarial inputs: **Deep learning robustness** to out-of-distribution data
- Detection and **mitigation of attacks on sensors**
- Detection and mitigation of data attacks on distributed learning

## Opportunistic & Unconventional Sensing

- **Opportunistic and unconventional sensing** exploiting common radios (WiFi, LoRa, LTE) for sensing purposes

## Adaptive, Distributed Prediction

- Adaptive distributed inference: **Splitting tactical edge analytics across heterogeneous devices**

## Theory of Uncertainty Quantification

- Theory of **uncertainty quantification at the point of observation**
- Novel learning paradigms: **Learning in the frequency domain** to reduce inference cost





# TECHNICAL ACCOMPLISHMENTS

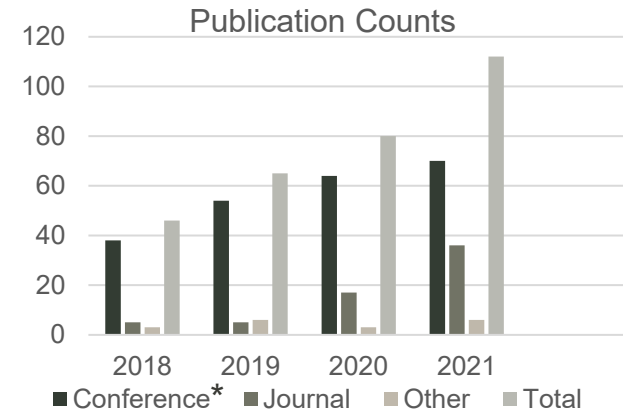


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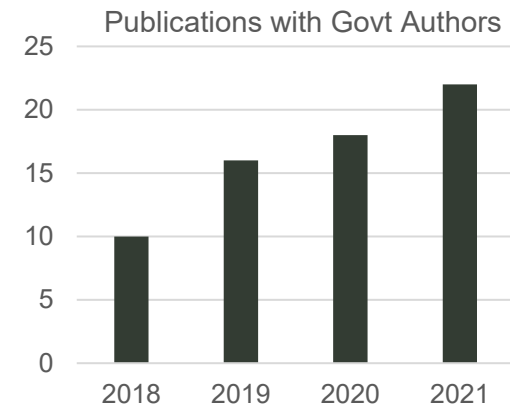


## Recent Distinguished/Best Paper Awards:

- **Krishnamachari: Best Paper Award**, “DEFER: Distributed Edge Inference for Deep Neural Networks,” Workshop on Machine Intelligence in Networked Data and Systems (MINDS), held in association with COMSNETS 2022.
- **Krishnamachari: Best Paper Award**, “Revealing a Hidden, Stable Spectral Structure of Urban Vehicular Traffic,” IEEE Vehicular Networking Conference (VNC), 2021
- **Xiong: Distinguished Paper Award**, “Exploring LoRa for Long-range Through-wall Sensing,” IMWUT '20 (UbiComp '21)
- **Abdelzاهر: Best paper award**, “On Removing Algorithmic Priority Inversion from Mission-critical Machine Inference Pipelines,” IEEE RTSS, 2020
- **Nahrstedt: Best Paper Award**, “SEAWARE: Semantic-Aware View Prediction System for 360-degree Video Streaming,” IEEE International Symposium on Multimedia, 2020
- **Abdelzاهر: Best paper award**, “Deep Compressive Offloading: Speeding Up Neural Network Inference by Trading Edge Computation for Network Latency,” ACM Sensys, 2020
- **Srivastava: Award for 2nd Runner Up**, Activity Recognition Challenge, International Conference on Activity and Behavior Computing, 2020
- **Shenoy: Best Paper Award**, IEEE International Green and Sustainable Computing Conference (IGSC), 2020
- **Abdelzاهر: Distinguished Paper Award**, “SenseGAN: Enabling Deep Learning for Internet of Things with a Semi-Supervised Framework,” IMWUT Vol. 2
- **Tabuada: Best New Application Paper Award**, “Correctness Guarantees for the Composition of Lane Keeping and Adaptive Cruise Control,” IEEE Transactions on Automation Science and Engineering 2019
- **Abdelzاهر: Top 3 paper award**, “Unsupervised Fact-finding with Multi-modal Data in Social Sensing,” Fusion 2019.
- **Shenoy: Best Paper Award**, “Combining Renewable Solar and Open Air Cooling for Greening Internet-Scale Distributed Networks,” 10th ACM International Conference on Future Energy Systems (ACM e-Energy), 2019



\*Note: Computer Science conferences are as competitive as journals (usually 15-25% acceptance rate)





# WELL-CITED AND OTHER IMPACTFUL PUBLICATIONS

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Fully Decentralized Multi-Agent Reinforcement Learning with Networked Agents

Kaizheng Zhang, Zhongyuan Liu, International Conference on Machine Learning

Abstract  
We consider the fully decentralized multi-agent reinforcement learning with networked agents in a continuous-time setting.

Output Range Analysis for Deep Feedforward Neural Networks

Souradeep Dutta, Susmit Jha, Sriram Sankaranarayanan, and Ashish Tiwari

Qsparse-local-SGD: Distributed SGD with Quantization, Sparsification, and Local Computations

Debraj Basu, Deepesh Data, Can Karakus, Suhlas Diggavi

USA Colorado.edu

com

Abstract

Communication bottleneck has been identified in large-scale learning models. Recent problems have been proposed, including different local models and mixing them iteratively. In this algorithm, which combines aggressive sparsification along with error compensation, by keeping compressed gradients. We propose both synchronous Qsparse-local-SGD. We analyze convergence for Qsparse-local-SGD and compare objective function. SGD converges at the same rate as vanilla distributed SGD and quantizers. We use Qsparse-local-SGD show that it results in significant savings over the transmitted to reach target accuracy.



Deep Learning for the Internet of Things

Shuohe Yao and Yiran Zhao, University of Aston Zhang, Amazon AI  
Shaohan Hu, IBM Thomas J. Watson Research Center  
Huijie Shao and Chao Zhang, UIUC  
Lu Su, State University of New York, Buffalo  
Tarek Abdelzaher, UIUC

How can the advantages of deep learning be leveraged to improve the emerging world of embedded systems?

PMLR Proceedings of Machine Learning Research (320+ citations since 2018)

NASA Formal Methods Symposium (190+ citations since 2018)

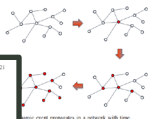
IEEE Computer Cover Feature (100+ citations since 2018)

IEEE Trans. Information Theory (25+ citations since 2020)

Quickest Detection of Dynamic Events in Networks

Shaofeng Zou, Member, IEEE, Venugopal V. Veeravalli, Fellow, IEEE, Jun Li, Member, IEEE, and Dan Towles, Life Fellow, IEEE

Abstract—The problem of quickest detection of dynamic events in networks is studied. It is assumed that an event occurs, and a number of nodes in the network are affected by the event so that they undergo a change in the statistics of their observations. It is assumed that the event is dynamic, in that it can propagate along the edges in the network and affect more and more nodes with time. The event propagation is modeled as a random walk on the network.



Fast to false alarm constraints (see [33]–[46] for e.g., Internet of Battlefield Things) [10], detection in code spreading in computer networks [11], or locally induced flow networks with certain topologies. Following the occurrence of an event, the network dynamically and stochastically affects nodes, and changes their data generating behaviors (see Fig. 1). The propagation dimension is usually dynamic, and depends on the underlying network.

Fast to false alarm constraints (see [33]–[46] for e.g., Internet of Battlefield Things) [10], detection in code spreading in computer networks [11], or locally induced flow networks with certain topologies. Following the occurrence of an event, the network dynamically and stochastically affects nodes, and changes their data generating behaviors (see Fig. 1). The propagation dimension is usually dynamic, and depends on the underlying network.

IEEE JSIT (80+ citations since 2020)

Tightening Mutual Information-Based Bounds on Generalization Error

Yuheng Bai, Member, IEEE, Shaofeng Zou, Member, IEEE, and Venugopal V. Veeravalli, Fellow, IEEE

Abstract—An information-theoretic upper bound on the generalization error of supervised learning algorithms is derived, based on the mutual information between the training and test data. The bound is derived under more general conditions than the previous ones, and provides a tighter characterization of the generalization error. Examples of learning algorithms are provided to demonstrate the tightness of the bound, and to show that it has a range of applicability. Application to noisy and correlated data, e.g., stochastic gradient descent (SGD), is provided, where the constructed bound provides a tighter characterization of the generalization error than existing results. It is demonstrated that, unlike existing bounds, which

Classical statistical learning approaches for analyzing the generalization capability of supervised learning algorithms can be mainly categorized into two groups. The first set of methods are based on measures of the complexity of the output hypothesis space, e.g., VC dimension and Rademacher complexity [7], [8]. However, these complexity measures usually scale exponentially with the depth of deep neural networks [9]. Moreover, these approaches do not take into consideration the regularization implicitly imposed by the algorithms used to train the neural networks, e.g., stochastic gradient descent [10], [11]. Thus, the generalization error bounds based on these complexity measures tend to be loose and do not explain

Associate Editorships



arXiv, IEEE JSAC (140+ citations since 2019)

MILCOM (45+ citations since 2018)

The Internet of Battlefield Things: The Next Generation of Command, Control, Communications and Intelligence (C3I) Decision-Making

Stephen Russell<sup>1</sup> and Tarek Abdelzaher<sup>2</sup>

<sup>1</sup> U.S. Army Research Laboratory, Adelphi, MD 20783  
<sup>2</sup> University of Illinois at Urbana-Champaign, Urbana, IL 61801

Abstract – As a key component of the 3rd offset strategy, information and related networks have changed the landscape of military operations. This

systems are considered the brain, then battlefield sensors and actuators, the Internet of Battlefield Things (IOBT), are the eyes and ears; and military maneuver,

FCC Co-Authored Papers

The Multi-Domain Operations Effect Loop: From Future Concepts to Research Challenges

Tarek Abdelzaher, Univ. of Illinois (United States), Adam Tzafros, U.S. Army Futures and Concepts Ctr. (United States), Paul Sullivan, U.S. Army Combat Capabilities Development Command (United States), Stephen Russell, U.S. Army Combat Capabilities Development Command (United States)

Abstract  
In a defense landscape driven by increasing automation, larger system scale, higher op-temps, and tighter integration across multiple domains, how do emerging advances in computing technology impact future defense concepts and operations? The paper addresses the notion of a multi-domain operations (MDO) effect loop as an emerging paradigm for military operations and information-driven decision processes. It also highlights recent advances in artificial intelligence, automation theory, distributed sensing, and decision optimization that significantly leverage the capabilities of different key components, as illustrated by potential defense scenarios.

I. INTRODUCTION  
It is widely acknowledged that, in modern military operations, a data deluge is essential to inform fast and efficient response. Since a dynamic and sensitive process. Recent concepts [1] envision networked military decision processes across, within, and between key domains. Systems of systems (SoS) brought together by new networks, it is advanced artificial intelligence further enable such systems to adapt. The accuracy of such operations systems is inextricably connected to timely, low-latency access and faster operating tempo. The combination of that recent human capacity to digest of information and support in data collection, analysis, and decision processes.

In an attempt to offer structure that organizes the required capabilities, it is necessary to consider the multi-domain effect loop. An adaptation of a previous figure, we call it the multi-domain operations effect loop (MDOE) to convey military activities with theoretically-grounded decision-making (DM). This concept breaks down necessary military capabilities into DM. This concept breaks down necessary military capabilities into DM.

SPIE, 2020 (2nd most downloaded/viewed brief, according to press release)

PROCEEDINGS OF SPIE



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# KNOWLEDGE PRODUCTS AND APPLICATIONS



Technical Research Focus

**Focus #1: Edge Efficiency (Time is a Weapon)**

**Focus #2: Resiliency (of Decision Loop Analytics)**

**Focus #3: Tailored Intelligence (at the Point of Need)**

Accomplishments

Rapid Task-driven IoBT Asset Synthesis

Compressed Learning and Inference at the Distributed IoBT Edge

Resilience to Surprise

Robust Estimation/Learning in Non-stationary and Adversarial Settings

Uncertainty Estimation

Unconventional, RF, and Multimodal Sensing

Applications and Tools

IoBT Digital Twin (with Boeing)

DARTS

ACROPOLIS

MedEvac Systems

Trinity

URSA Bench

Urban Operations, Triage

Concept Evaluation

Distributed Virtual Proving Ground (DVPG) Testbed





# KNOWLEDGE TRANSITION & INTEGRATION SUMMARY

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UQ software for edge computation



IoBT FE to support Army Concept Framework

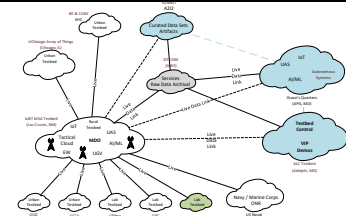


AFC Deep Dive on IoBT

DoD



Multimodal AI technology integration for TATE pillar experimentation



DVPG: distributed experimentation at IoBT relevant scale

**IoBT Special Session & Panel**  
**MILCOM, December 2021**

**Special Session Topics**

- ML & Optimization
- Computation at the Edge
- Security

**Panel: The IoBT: From Research Priorities to Decision Overmatch**

Scientific Community



ARL

Connections to Competencies

**Military Information Sciences**  
Use of information to maximize effectiveness of information systems and decision-making

**Network, Cyber & Computational Sciences**  
Unifying approaches for highly adaptive network-cyber-computing to achieve decision dominance

Pathway to PC and EDGE Events



DARTS and ARL Experiment Excursion: ACROPOLIS



The IoBT CRA has trained over 50 students who have gone on to academia and industry



Industry



IoBT digital-twin implementation to simulate multi-domain operations involving Navy drone/UAS carriers.

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# PROGRAM PLANNING & REVIEW



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## 6: Bootcamps & Workshops

Collective meetings to present research; strategic topic focus and involving stakeholders; incorporate feedback to adjust research and define demos

## 5: RMB / CRA Review

CRA review engages ARL and selective strategic stakeholders for feedback in non-RMB years

## 4: BPP Approval

Revise BPP and adjust budget to account for feedback and approve tasking for execution

## 1: TMG Strategic Planning Meeting

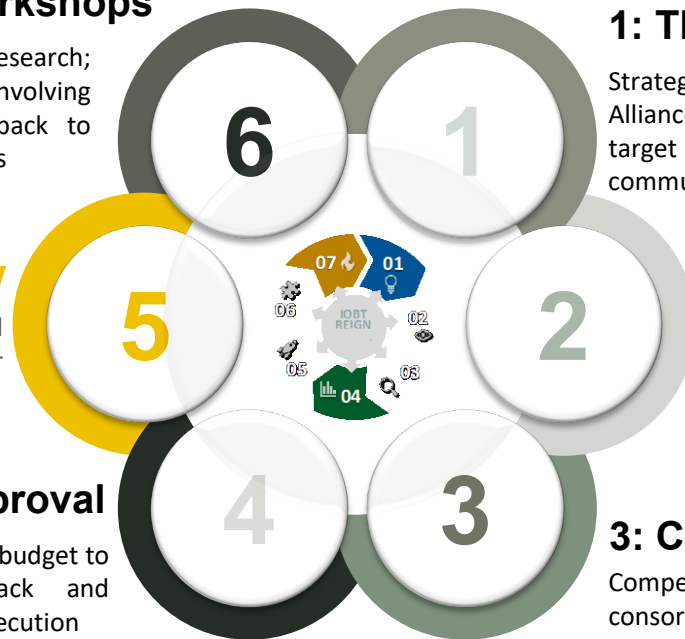
Strategic planning meeting to adjust for Army & Alliance dynamics and plan for BPP landscape; target transition opportunities, and strategic communications

## 2: Annual Tech Review

Review CRA status & progress in context of approved BPP; assess performance metrics

## 3: Competitive BPP

Competitive BPP proposal solicitation, open to broad consortium member orgs and reviewed by internal and external stakeholders





# SUMMARY OF ACTIONS SINCE LAST RMB

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## What we heard...

### Programmatic Guidance

1. Some similarity to the Distributed and Collaborative Intelligent Systems and Technology (DCIST) CRA
2. What is the plan for *early* transition?
3. "Didn't claim enough credit for collaborative work."
4. How many students has IoBT graduated and how many government-collaborative publications were made?

## What we have done...

### Programmatic Adjustments

1. Refactored research to concentrate on "enabling the common operating environment," putting greater emphasis static assets and the full MDO decision cycle
2. Identified early transition opportunities via experimentation (e.g., Project Convergence, AISC); Added 3 new agency collaborations (AI2C, JAIC, USMA)
3. Reporting collaboration efforts regularly in briefs
4. Continued to collect metrics quarterly and incorporated into review briefs

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# SUMMARY OF ACTIONS SINCE LAST RMB



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## What we heard...

### Technical Guidance

1. Continue/increase emphasis on the challenges of scale, heterogeneity, dynamics, and adversarial threats
2. Should address issues of a fighting network, not just one that optimally places sensors or addresses distributed inference/learning
3. Focus on non-combatant (gray) resources/assets should include further emphasis on securing the channels
4. Would be great to demonstrate technology in a larger empirical demonstration context, such as Project Convergence (PC)

## What we have done...

### Technical Adjustments

1. Reorganized research areas into major knowledge product themes: Efficiency, Resiliency, and Edge Intelligence
2. Added emphasis on the Resiliency theme, which specific focus on detection of adversarial manipulation and safety decision making
3. Reduced the emphasis on gray assets, thus minimizing concentration on securing channels (securing channels is research area in Cyber CRA)
4. Identified ways to inject technology into larger experimentation and demonstration efforts e.g., PC and TTCP exercises, and redesigned CRA integrated experimentation to align with full decision cycle execution



# MAJOR EVENTS SINCE LAST RMB

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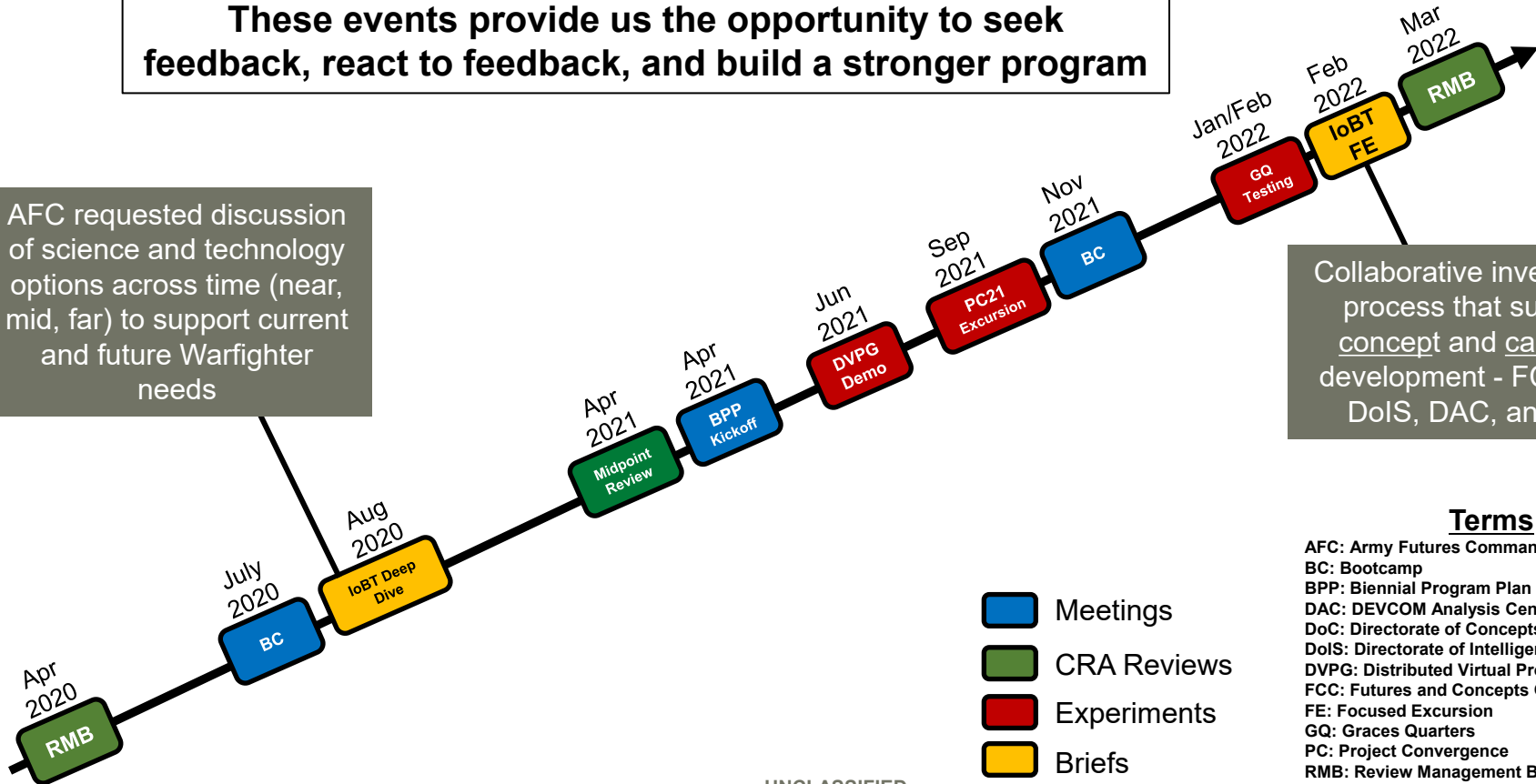
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These events provide us the opportunity to seek feedback, react to feedback, and build a stronger program

AFC requested discussion of science and technology options across time (near, mid, far) to support current and future Warfighter needs

Collaborative investigative process that supports concept and capability development - FCC DoC, DoIS, DAC, and ARL



- Meetings
- CRA Reviews
- Experiments
- Briefs

### Terms

- AFC: Army Futures Command
- BC: Bootcamp
- BPP: Biennial Program Plan
- DAC: DEVCOM Analysis Center
- DoC: Directorate of Concepts
- DoIS: Directorate of Intelligence and Security
- DVPG: Distributed Virtual Proving Ground
- FCC: Futures and Concepts Center
- FE: Focused Excursion
- GQ: Graces Quarters
- PC: Project Convergence
- RMB: Review Management Board

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# IOBT FOCUSED EXCURSION

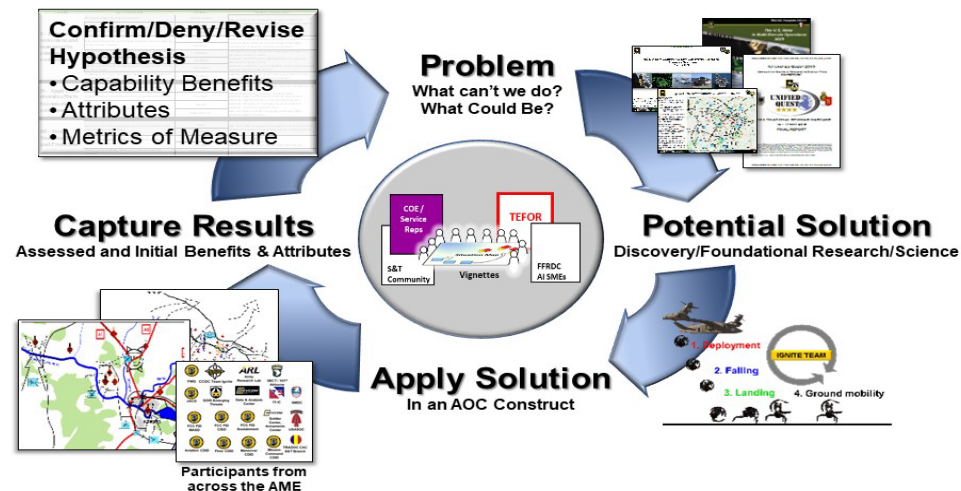


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- **Focused Excursion:** a deliberate investigative process that supports concept and capability development through a collaborative examination of a particular research area across the technical, concepts, threat, and analytic communities
- **IoBT Focused Excursion:**
  - Collaboratively hosted by DEVCOM & FCC
  - IoBT CRA leadership team (ARL and academia) represented the technical SMEs
  - Initial Hypotheses centered around our research thrust areas: Efficiency, Resiliency, Edge Intelligence

FCC's Future Study Program (FSP) and DEVCOM-FCC's Focused Excursions (FE) are the key experiments used to assess and refine how the Army of 2040 could operate, be equipped, and be organized; and the associated concepts' priority S&T needs





# FOCUSED EXCURSION TAKEAWAYS

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## Operational Hypotheses

*IoBT will help commanders distill prioritized information from vast amounts of data faster for decision making by providing efficient, real-time processing*

*IoBT capabilities that provide robustness, resiliency, and adaptive services in the face of adversarial disruption and deception in conjunction with camouflaged sensing and communication, are essential to maintain commander confidence in data and reduce risk*

*IoBT will increase situation awareness tempo by exploiting ubiquitous, - multimodal sensors, unconventional sensing, and edge computation in the operating environment*

*IoBT, with rigorous testing and training, will enable trust despite a contested and dynamic environment by providing performance guarantees, uncertainty quantification and the ability to explain*

## Key Takeaways

### Potential High Impact Research Priorities:

- **Efficiency at scale** in the presence of vast amounts of data
  - Semantic compression; processing at the edge
  - Prioritization and filtering of data push
  - Optimal network usage and network inference
- **Reconfigurable and adaptable algorithms to induce flexibility** (flexibility empowers creative alternatives)
  - Dynamic tuning to changing priorities/objectives
  - Resilience, safety, and risk mitigation (a distribution-tail challenge)
  - Fast optimization
- Information verification by exploitation of **multi-modal and multi-vantage sensing** for joint inference
  - Hybrid analytics – ML and rule-based; multiple time-scales
- **Uncertainty quantification** of network or analytics composition (in the presence of open/commercial sources)

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# FOCUSED EXCURSION TAKEAWAYS

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## Operational Hypotheses

- IoBT will help commanders distill prioritized information from vast amounts of data faster for decision making by providing efficient, real-time processing*
- IoBT capabilities that provide robustness, resiliency, and adaptive services in the face of adversarial disruption and deception in conjunction with camouflaged sensing and communication, are essential to maintain commander confidence in data and*
- IoBT will increase commander tempo by exploiting multi-modal sensors, uncertainty quantification, and edge computation in the dynamic environment*
- IoBT, with rigorous testing and training, will enable trust despite a contested and dynamic environment by providing performance guarantees, uncertainty quantification and the ability to explain*

## Key Takeaways

### Potential High Impact Research Priorities:

- **Efficiency at scale** in the presence of vast amounts of data
  - Semantic compression
  - Prioritization
  - **Open and adaptable algorithms** to induce **creativity** (flexibility empowers creative alternatives)
  - Dynamic tuning to changing priorities/objectives
  - Resilience, safety, and risk mitigation (a distribution-tail challenge)
  - Fast optimization
- Information verification by exploitation of **multi-modal and multi-vantage sensing** for joint inference
  - Hybrid analytics – ML and rule-based; multiple time-scales
- **Uncertainty quantification** of network or analytics composition (in the presence of open/commercial sources)

**IoBT will be critical for future success on the battlefield**



# IOBT CRA RMB REVIEW



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## Questions?

To view read-ahead material visit:

<https://iobt.illinois.edu/RMB22-Readahead>

Start	Topic	Presenter
1300	Welcome – Introductions	Kott
1310	Program Overview	Wigness/Abdelzaher
1350	Research Focus 1: Efficiency & Timeliness	Verma/Fragouli
1420	Research Focus 2: Resiliency	Kaplan/Tabuada
1450	<b>Break</b>	
1500	Research Focus 3: Intelligence at the Point of Need	Panneton/Shenoy
1530	Experimentation Overview	Wigness/Shenoy
1550	IoBT – Way Ahead	Swami/Abdelzaher/Wigness
1610	<b>Break</b>	
1620	RMB Caucus (Government Only)	All Government
1700	Adjourn	