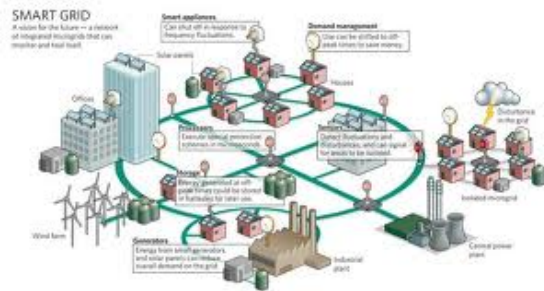




Accessible Remote Testbeds

A workshop held on November 12-13, 2015
National Science Foundation

Kishan Baheti
Program Director
Directorate for Engineering



Role of Testbeds in Engineering Research

- Increasing investments by universities and funding agencies
- Examples
 - Nanotechnology
 - Robots and autonomous vehicles
 - Materials engineering laboratories
 - Smart and connected communities

Challenges and Opportunities

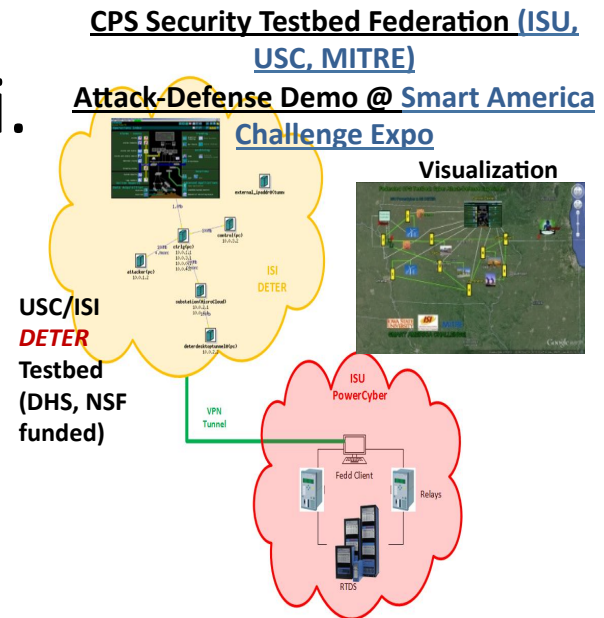
- Limited tradition of sharing of research infrastructure in engineering
- Limited access to the state-of-the art facilities
- Uncoordinated duplication of infrastructures and limited leveraging
- Talented faculty and students at institutions without facilities
- What if we could eliminate these limitations and inefficiencies?

Vision

- Remote access to state-of-the-art experimental facilities in engineering
- New collaborations across institutions, faculty and students
- New communities, ideas, and breakthroughs
- Broaden participation in engineering by people from all backgrounds

Motivating Example

- Prof. Manimaran Govindarasu, Iowa State Uni.
- Physical facility remotely networked with DETER
- Research on cyber-physical security of power grid
- Hosts educational cyber-physical security games for students





The Innovation Framework

- Need

- Understanding the trade-offs between networked engineering systems, cybersecurity, collaborative communication, and real-time performance
- Improving and broadening research and education

- Approach

- Developing open/remote access engineering test beds for research, education, learning, and competition
- Sharing valuable engineering resources
- Harnessing the power of the network by people working together to reach beyond the traditional, isolationist research model

Key Questions

- What are the fundamental research questions inherent in moving testbeds to remote access formats?
- What is the proper scope of work and resources needed ?
- How is a community of users to be established and sustained ?
- What is the vision of success and milestones to achieve the goal ?



The Main Message

**We are interested in creating a
community of CPS researchers
and users interested in
remotely accessible engineering
testbeds**

Workshop on Accessible, Remote Testbeds

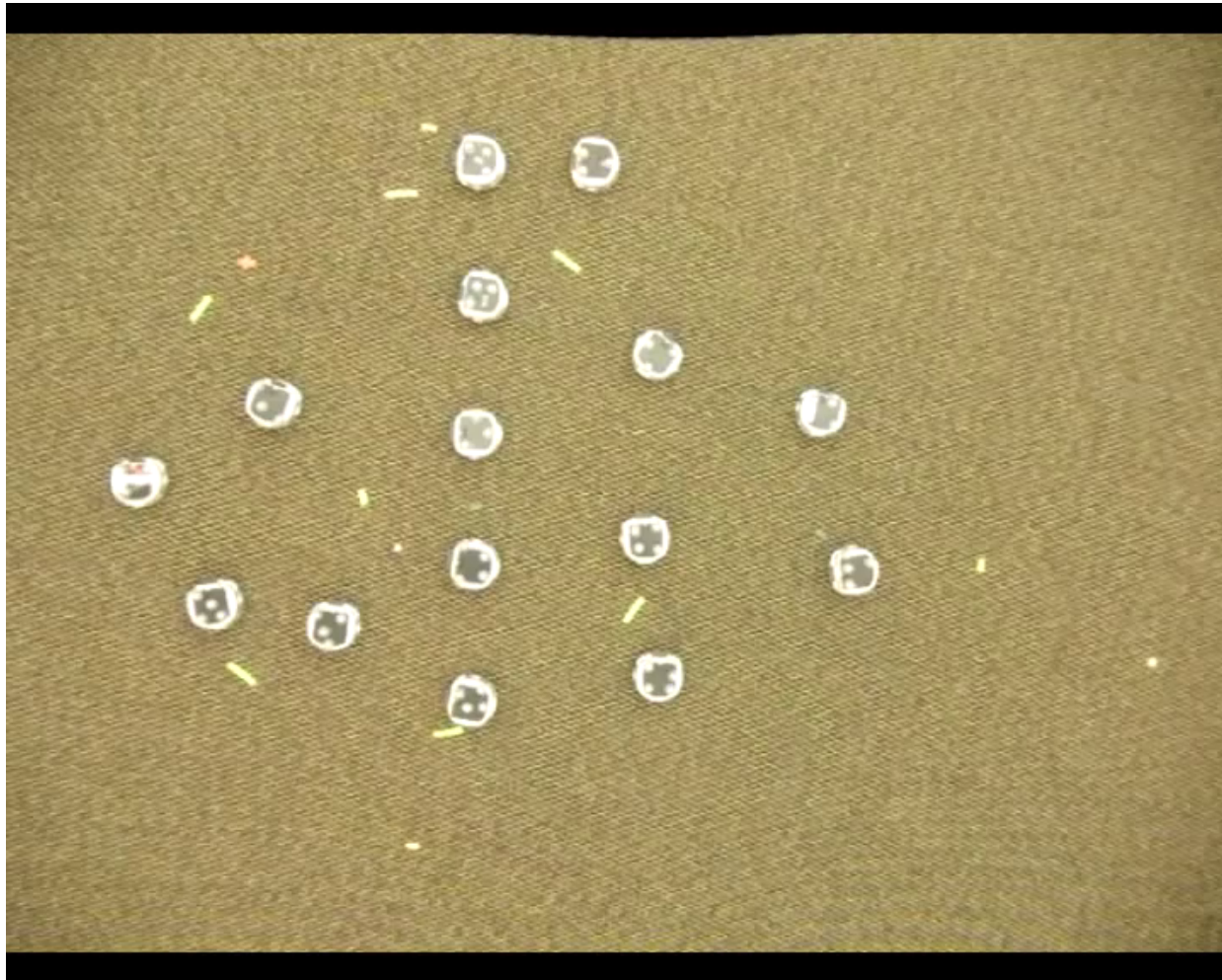
November 12-13, 2015, Arlington, VA

M. Egerstedt, M. Govindarasu, R. Baheti, Y. Podpaly



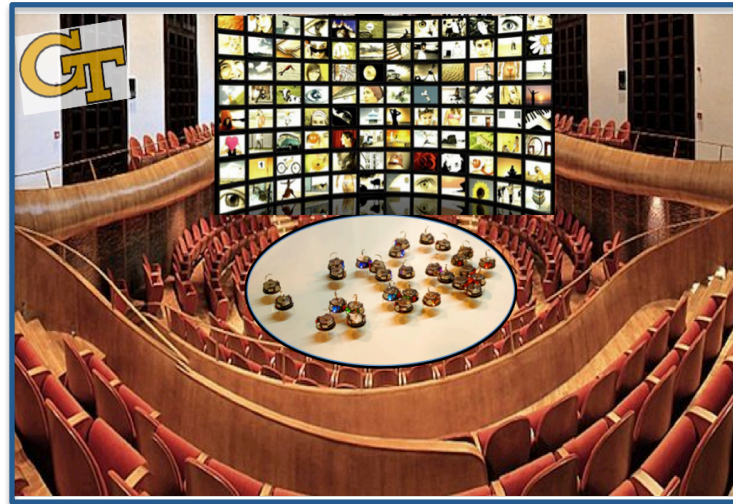
What does it mean to be an effective, remote-access research testbed in the CPS domain?

But First...





Example: The ROBOTARIUM



www.robotarium.org

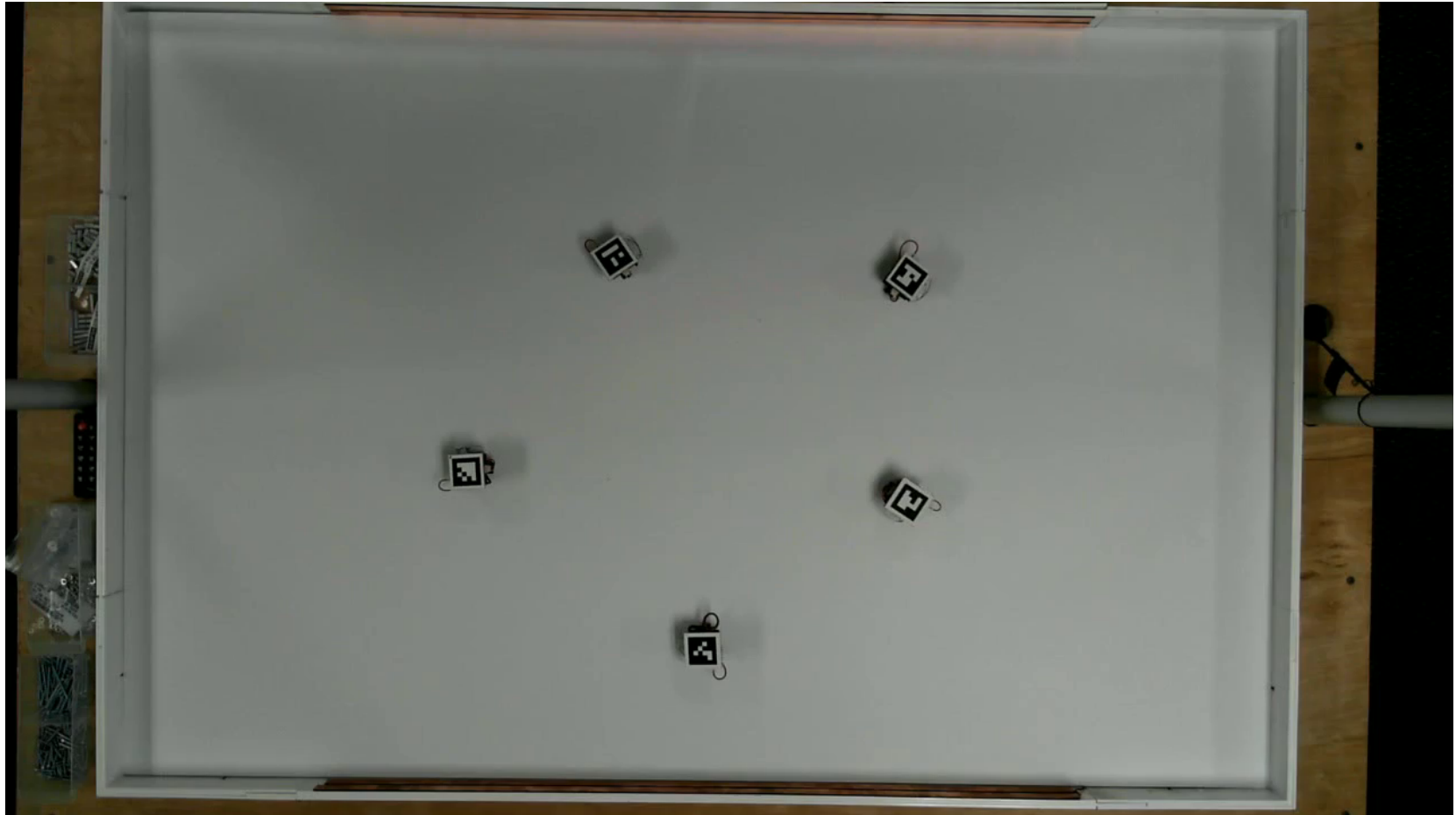


MRI: Development of the Robotarium: A Shared, Remote-Access Multi-Robot Laboratory (ECCS-1531195)



CPS: TTP Option: Synergy: Secure, Open-Access Multi-Robot Systems (CNS-1544332)

First “Remote-Access” Experiment



Code from Jorge Cortes, UCSD

Workshop on ART?



Accessible Remote Testbeds



Remote-Access Testbeds

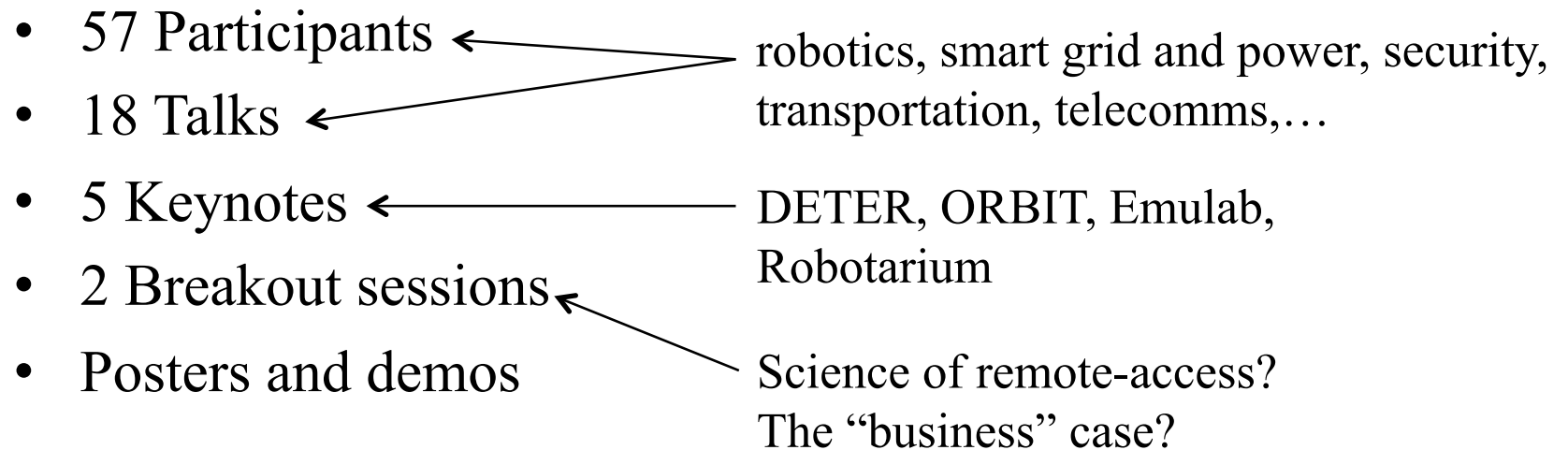
Workshop: ART Inventory

- What's out there already?
- What worked?
- What didn't work?



Workshop Logistics

Program:

- 57 Participants
 - 18 Talks
 - 5 Keynotes
 - 2 Breakout sessions
 - Posters and demos
- robotics, smart grid and power, security,
transportation, telecomms,...
- DETER, ORBIT, Emulab,
Robotarium
- Science of remote-access?
The “business” case?
- 

The Science of Remote Access for CPS



Outcomes:

- Safe and secure
- Flexible
- Access at different levels of abstraction
- Hardware vs simulation

The “Business” Case

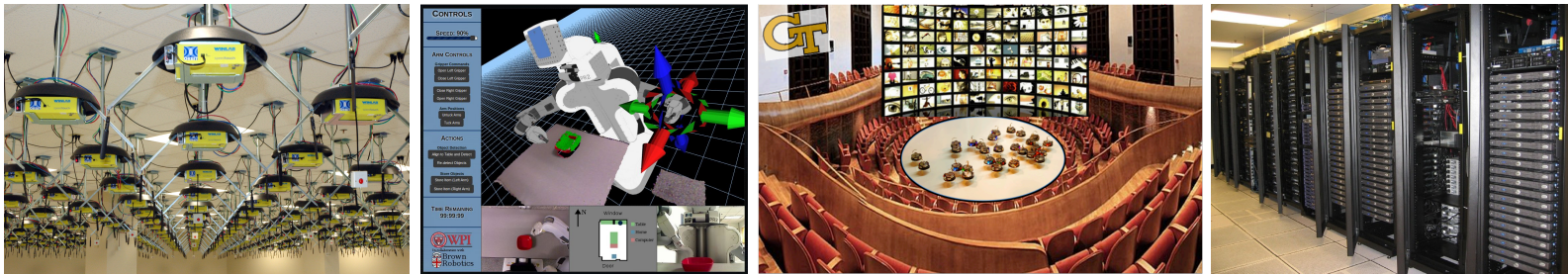


Outcomes:

- User community recruitment and management
- Access management
- Sustained operations
- Collaborative research

Workshop Outcomes

- Workshop report summarizing findings



- CPS is special!
- Going forward!?