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Progress and Prospects in Human-Agent-Robot Teamwork

Jeffrey M. Bradshaw, Paul Feltovich, Matt Johnson
{jbradshaw, pfeltovich, mjohnson}@ihmc.us
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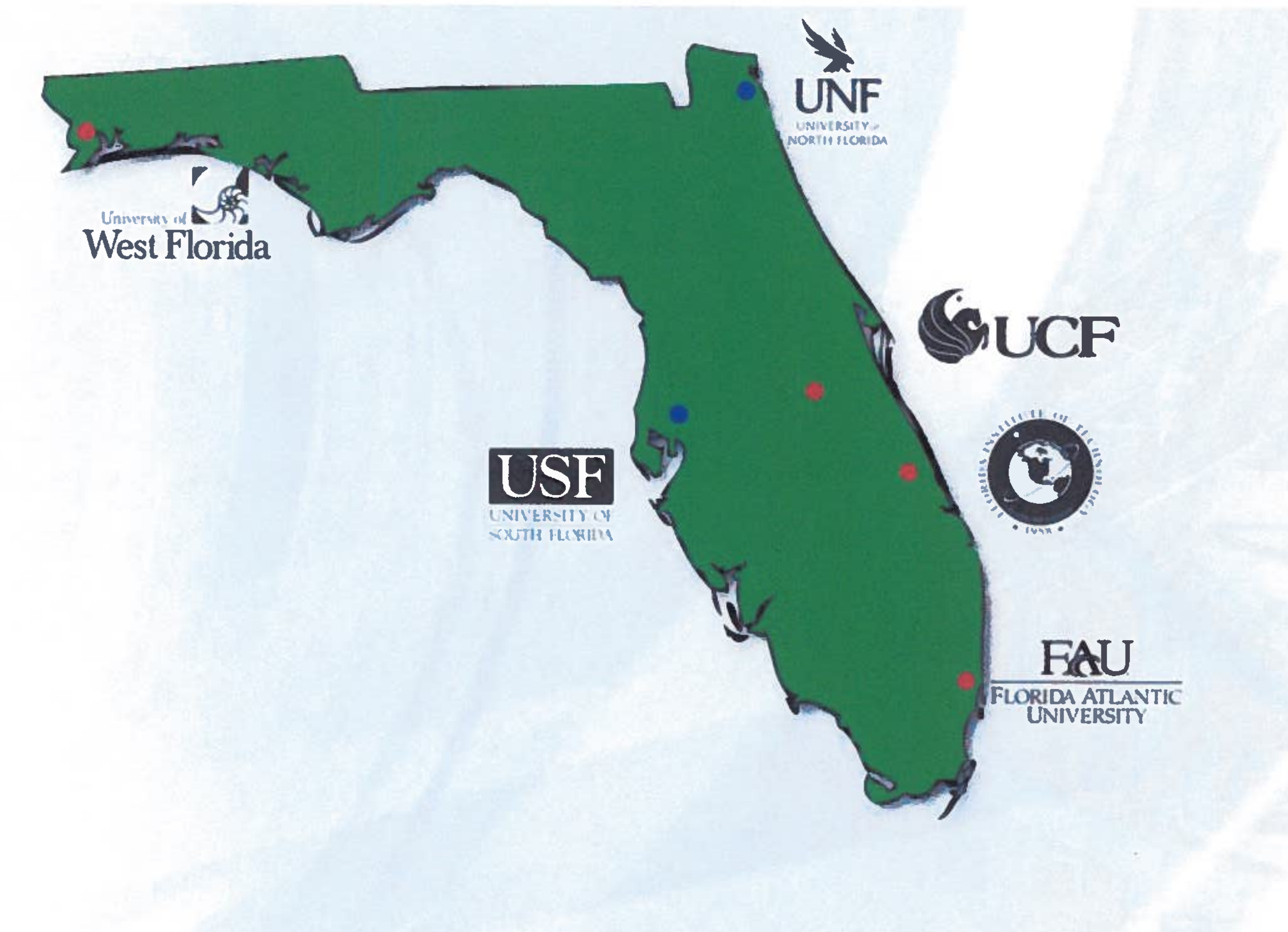
Florida University Affiliations



Some Current IHMC Focus Areas

- Next-Generation Interfaces
- Cognitive Work Analysis, Work Systems Design
- Intelligent Data Mining
- Semantically-Rich Policies for Distributed Systems and Human-Agent-Robot Teamwork
- Education, CmapTools
- Semantic Web Technologies, Cmap Ontology Editor
- MANET, Bio-Inspired Security, Learning
- Agile Computing Middleware
- Multi-Modal Dialogue
- Biologically-Inspired Robotics

SPR Field Test


LIVE
C-SPAN
30 YEARS
NASA

Cognitive, Robotic, and Social Prostheses

- Human-machine devices that augment human abilities
- Blur the line between humans and machines
- *Fit* the human and machine components together in ways that synergistically
  - exploit their respective strengths
  - mitigate their respective limitations

Ford, K. M., Glymour, C., & Hayes, P. (1997). Cognitive prostheses. *AI Magazine*, 18(3), 104.

Passive Exoskeleton

On May 02, 2008 we fitted wounded USAF veteran Brandon Gauvreau with the passive exoskeleton.

Brandon's partially paralyzed foot would always land on its side, making walking painful, awkward and difficult.

This pain lead to very short, inneffective rehabilitation sessions.

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Passive Exoskeleton

The weight bearing design of the Passive Exoskeleton extends the period of time that the subject can stay mobile.

Supporting Brandon's weakened leg muscles, the Exoskeleton let him train long enough to derive benefit.

A single 30 minute session with the Passive Exoskeleton allowed Brandon to "retrain" his foot to land correctly.

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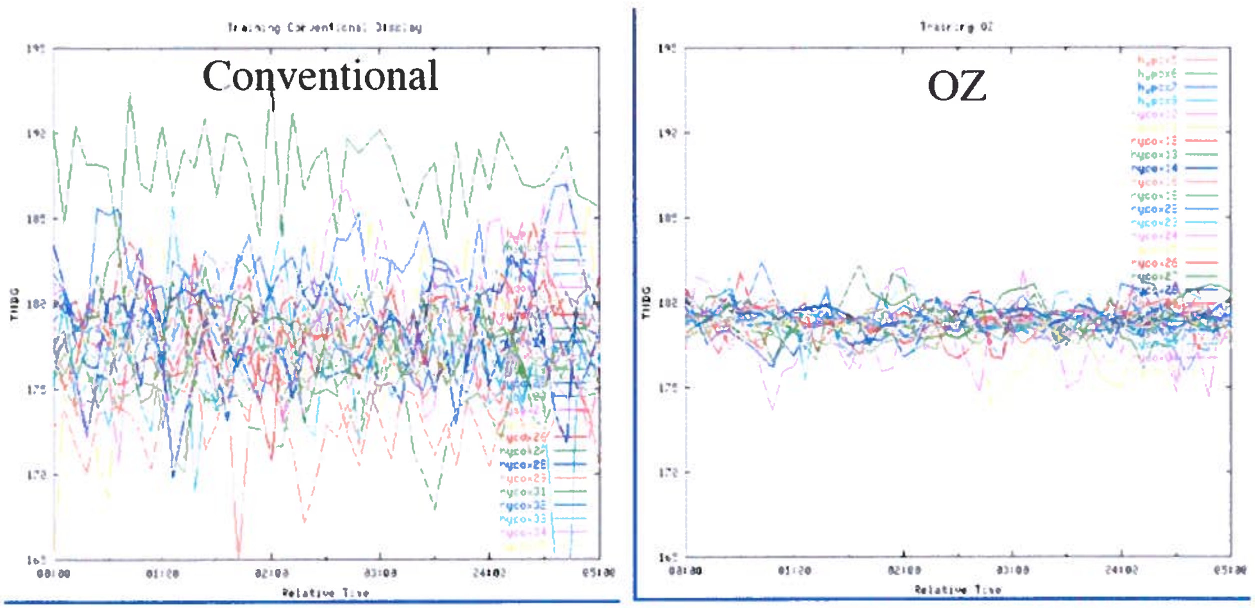
OZ Human-Centered Flight Display

Still, D.L. and L.A. Temme. "OZ: A human-centered cockpit display." Presented at the Proceedings of the Interservice/Industry Training, Simulation, and Education Conference, Orlando, FL, November 26-29, 2001.

Key Points

- Reduction of cognitive load enables operators to do more
  - Moving data to semantic primitives (direct perception)
  - Consistent design for diverse assets
  - Integration of multiple data streams
  - Based on biological perceptual principles
- Hierarchical design facilitates
  - Control and Data drill-down
  - Awareness of asset state
- Demonstrated performance

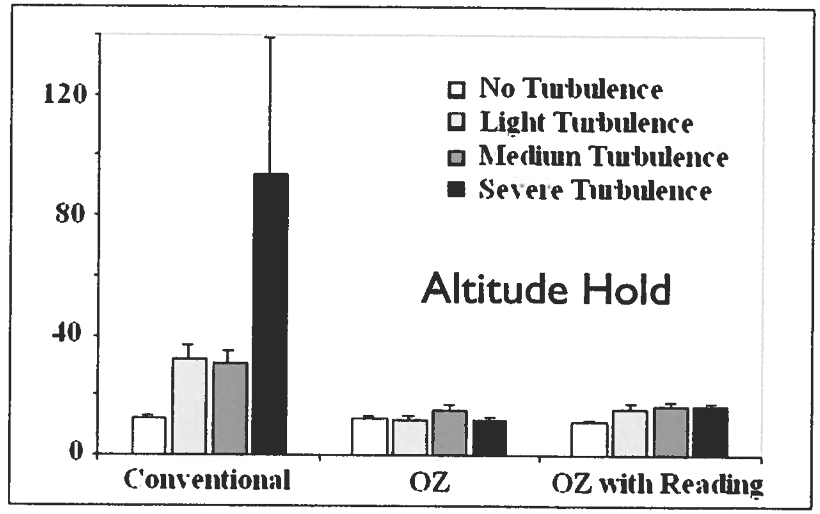
Increased Performance

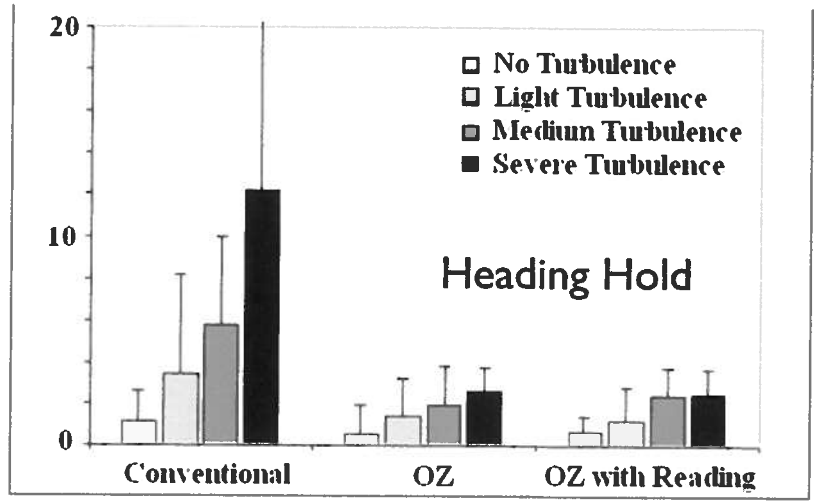


- 37 Active Duty Instructor Pilots, 1-5K hours
- 3 Hours training, Tested on slow flight maneuvering task
- 35 of 37 performed significantly better with OZ, two equal

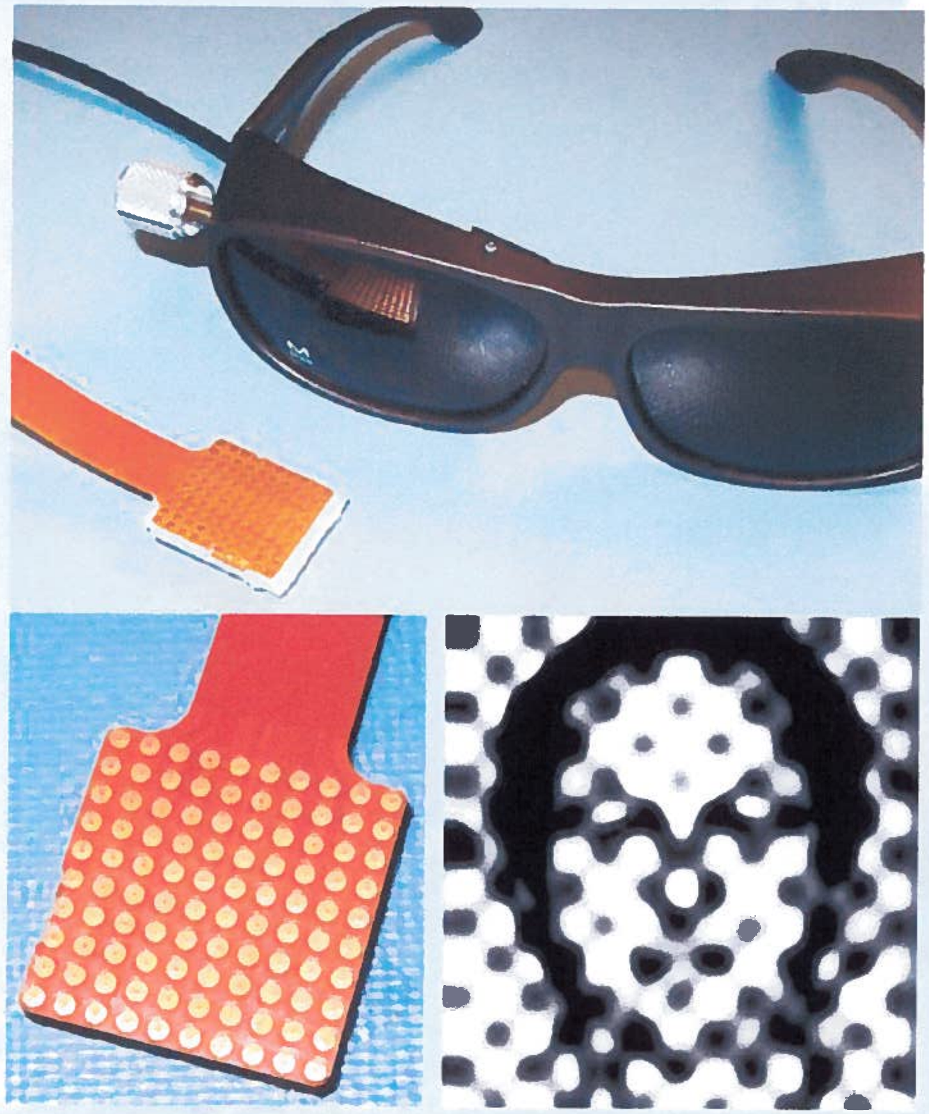
Reduced Cognitive Load

- Experiment to hold altitude, heading
- Additional task of reading on-screen text
  - OZ has no significant difference with additional task

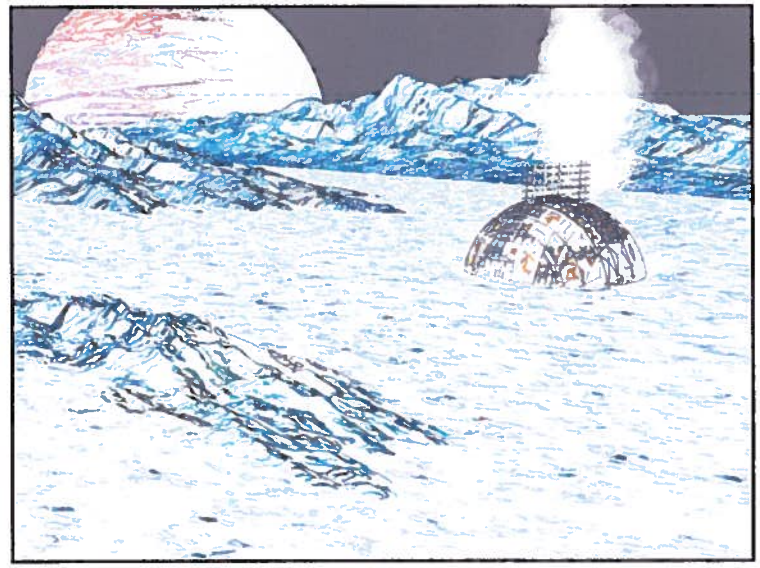




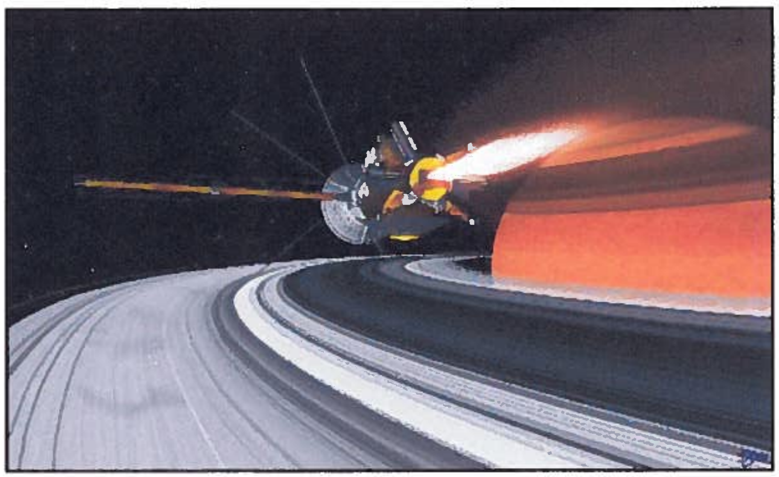
Sensory Substitution



Autonomous Space Systems at NASA

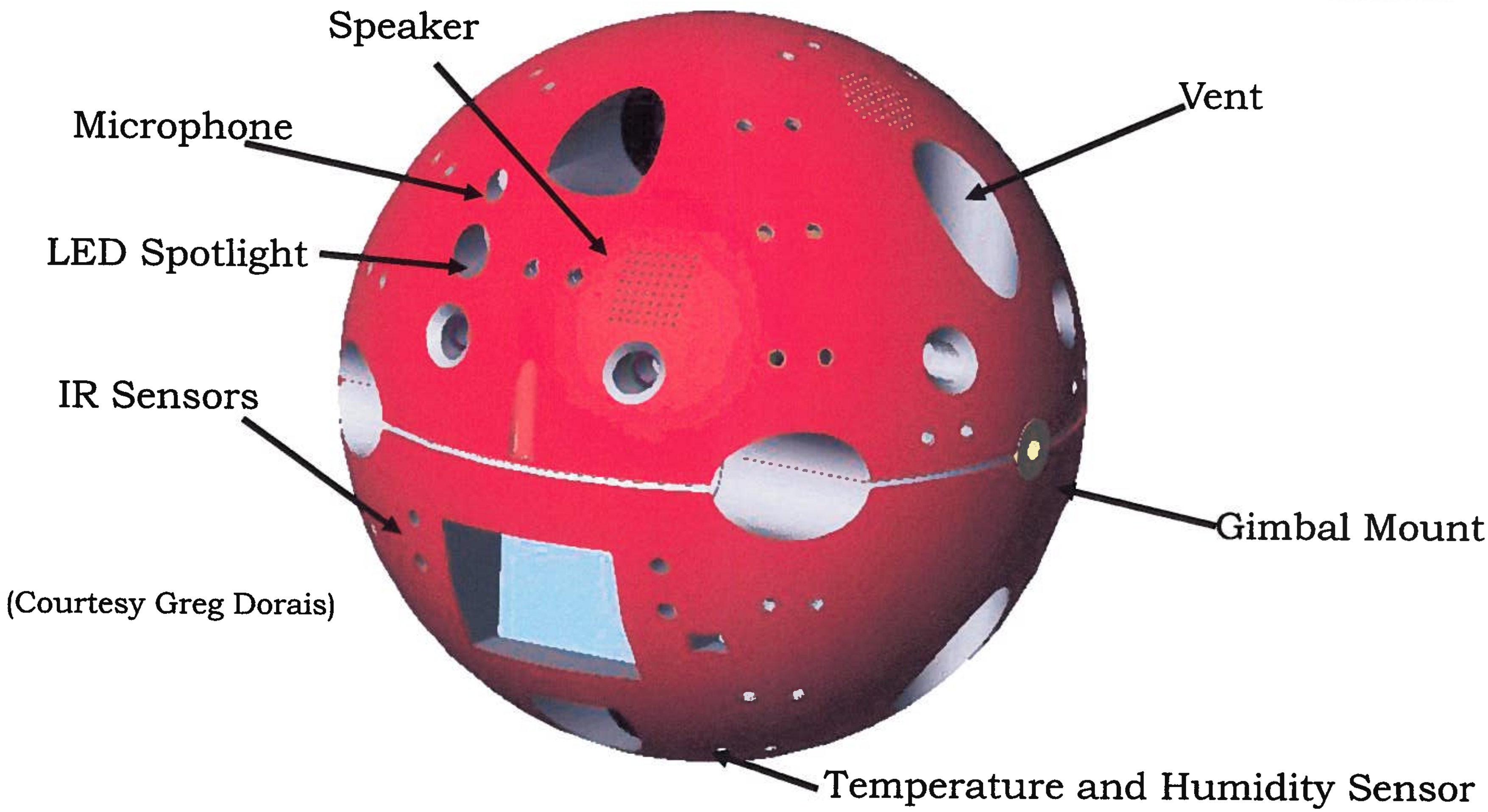


Autonomous Europa Submarine



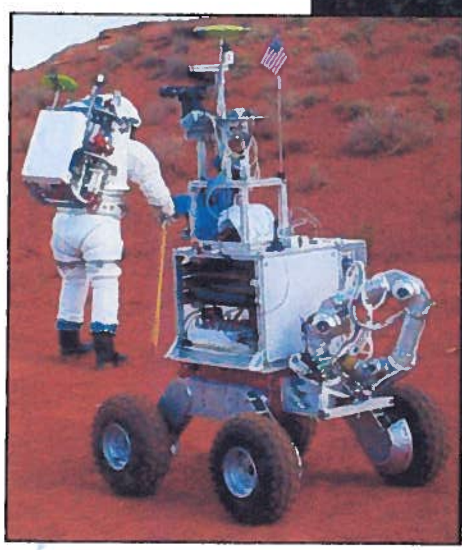
Deep Space Missions

NASA Personal Satellite Assistant



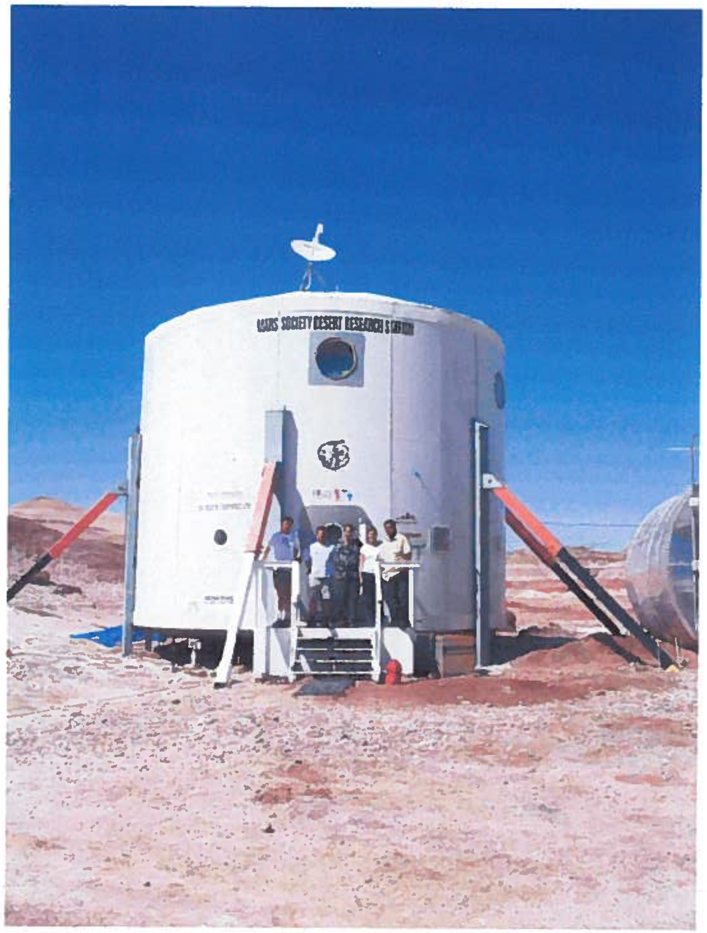
Bradshaw, J.M., M. Sierhuis, Y. Gawdiak, R. Jeffers, N. Suri, and M. Greaves. "Teamwork and adjustable autonomy for the Personal Satellite Assistant." Presented at the Workshop on Autonomy, Delegation and Control: Interacting with Autonomous Agents. Seventeenth International Joint Conference on Artivicial Inelligence (IJCAI-2001), Seattle, WA, 6 August, 2001.

NASA MDRS Full-Scale Field Tests



Sierhuis, M., J. M. Bradshaw, et al. (2003). Human-agent teamwork and adjustable autonomy in practice. *Proceedings of the Seventh International Symposium on Artificial Intelligence, Robotics and Automation in Space (i-SAIRAS), Nara, Japan.*

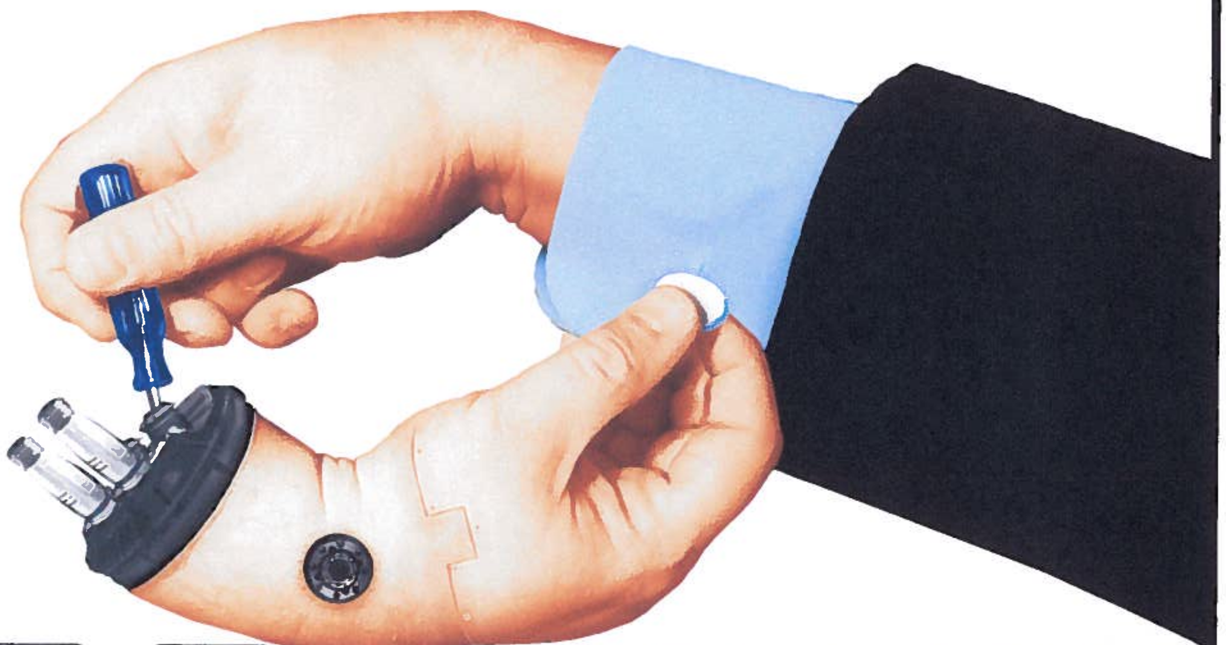
Mars Desert Research Station, 2005



Human-Agent-Robot Teamwork

- Importance of teamwork
  - Widely-accepted metaphor for agent-agent interaction
  - Strong logic-based theoretical foundations
  - High reusability of generic teamwork models
  - Many approaches and applications
- New directions in teamwork
  - Shift from *agent-agent* to *human-agent* interaction
  - Previous theoretical work incomplete
    - Need to incorporate theory from social sciences
    - Need for empirical observation and modeling
    - Need to incorporate ethical and safety considerations

Bradshaw, J. M., Sierhuis, M., Acquisti, A., Feltovich, P., Hoffman, R., Jeffers, R., Prescott, D., Suri, N., Uszok, A., & Van Hoof, R. (2003). Adjustable autonomy and human-agent teamwork in practice: An interim report on space applications. In H. Hexmoor, R. Falcone, & C. Castelfranchi (Ed.), Agent Autonomy. Dordrecht, The Netherlands: Kluwer, pp. 243-280.



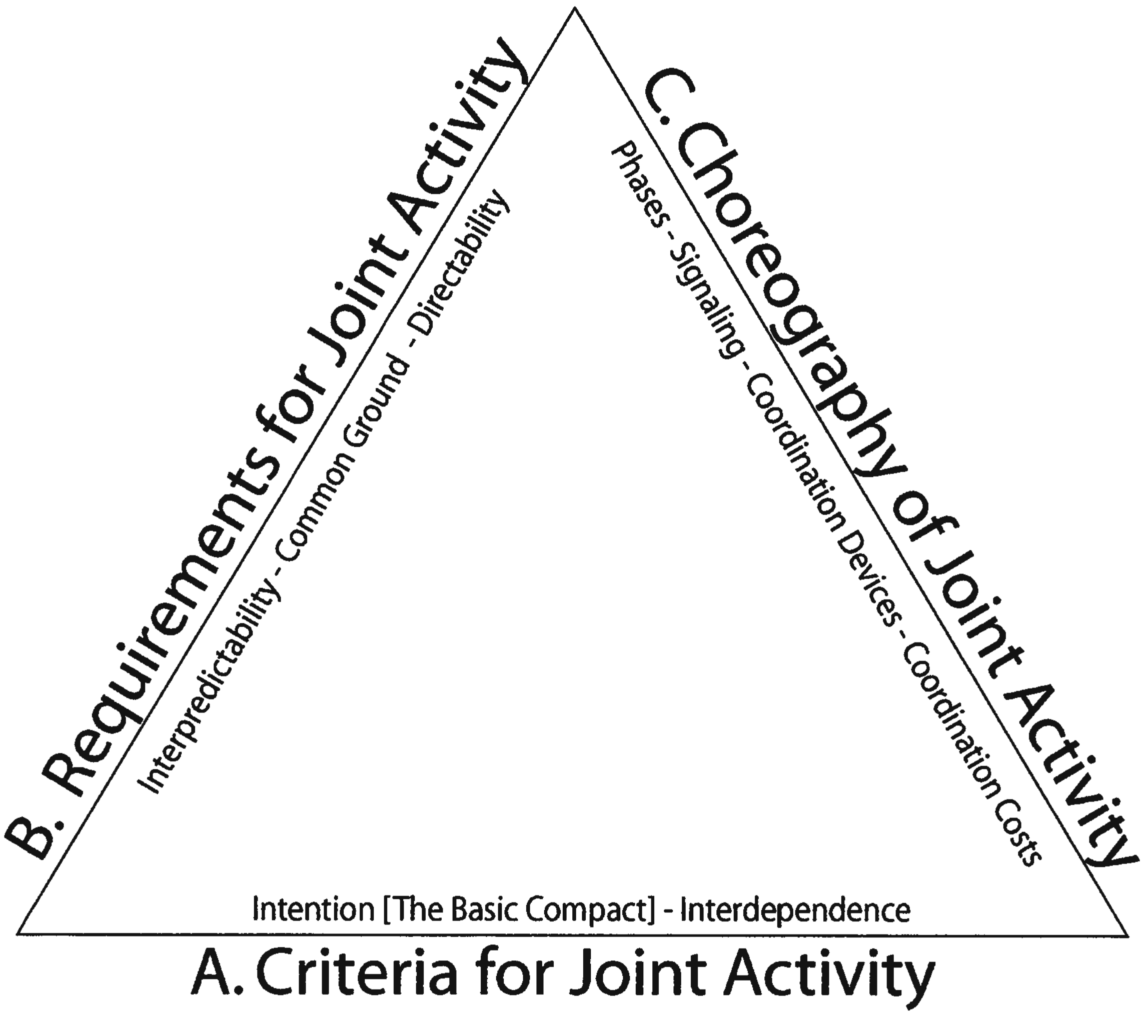
HART

Human-Agent-Robot Teamwork

Overview of HAI

- Variety of HAI approaches
  - Interface agents and assistants
  - Adjustable autonomy
  - Mixed-initiative systems
  - Agent teamwork
  - Collaboration theory
- Joint Activity Theory
  - Generalization of Clark's work in linguistics

Aspects of Joint Activity



Klein, G., Feltovich, P., Bradshaw, J. M., & Woods, D. D. (2005). Common ground and coordination in joint activity. *Organizational Simulation.* W. B. Rouse and K. R. Boff. New York City, NY, John Wiley.

Lessons Learned from Teamwork Research

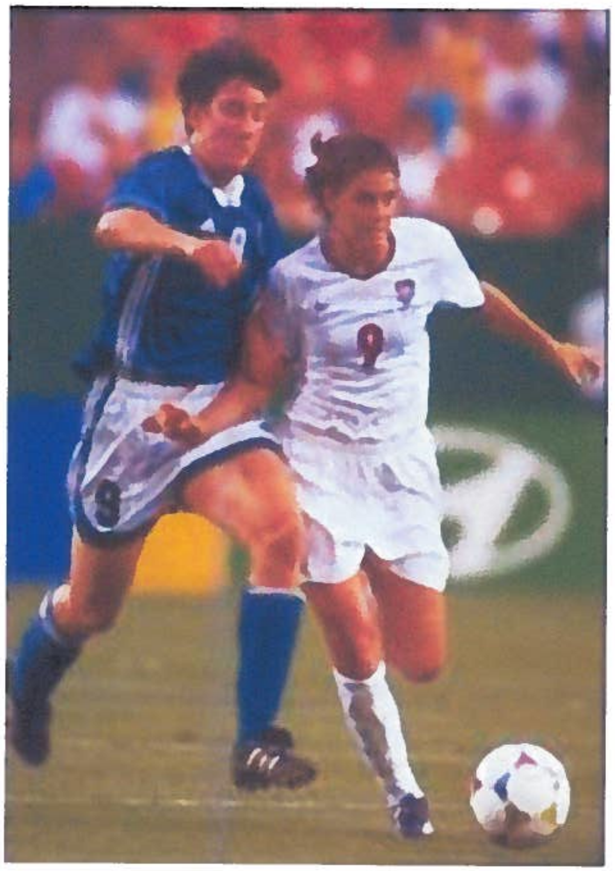
General lessons from agents community:

- Teamwork is reusable, separate from taskwork
- Explicit reasoning about teamwork, coordination

General lessons from robotics community:

- Continuous actions, with duration
- Cost of sensing and notifying others
- Increasing autonomy paradoxically leads to demands for *more sophisticated interaction* with humans

Teamwork and Taskwork are Separable



Soccer Taskwork:

- Kicking to a target
- Dribbling, tackling
- Tracking the ball, goal …

Soccer Teamwork:

- Allocating players to roles
- Synchronizing tactics
- Sharing relevant information
- …….

Roles

- Roles typically come with expectations about behavior
- They provide authorization or authority in some cases
- They also have associated obligations and expectations about knowledge and skills
- A given agent typically plays multiple roles

Representing Obligations and Authorizations as Policies

- Agent policies are more like constraints on actions then decision rules
- However, if sufficiently constrained they can look much like decision rules

Components of Policies

- **Authorization** - Permit or deny actions

  Robot X is not authorized to clean bedroom 1
  actor / modality / action

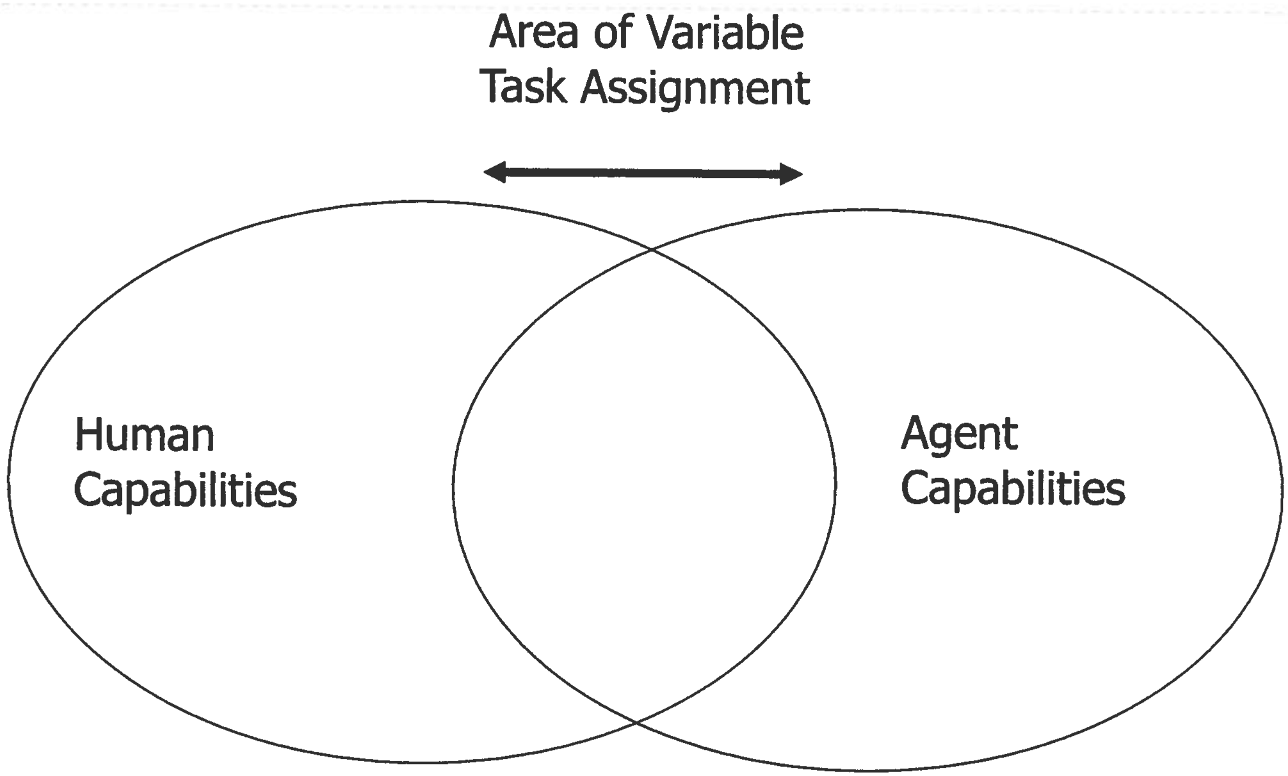
  When bedroom 1 is occupied
  context

- **Obligation** - Require or waive requirement to perform an action based on an associated condition (trigger)

  Robot X is obligated to Beep
  actor / modality / action

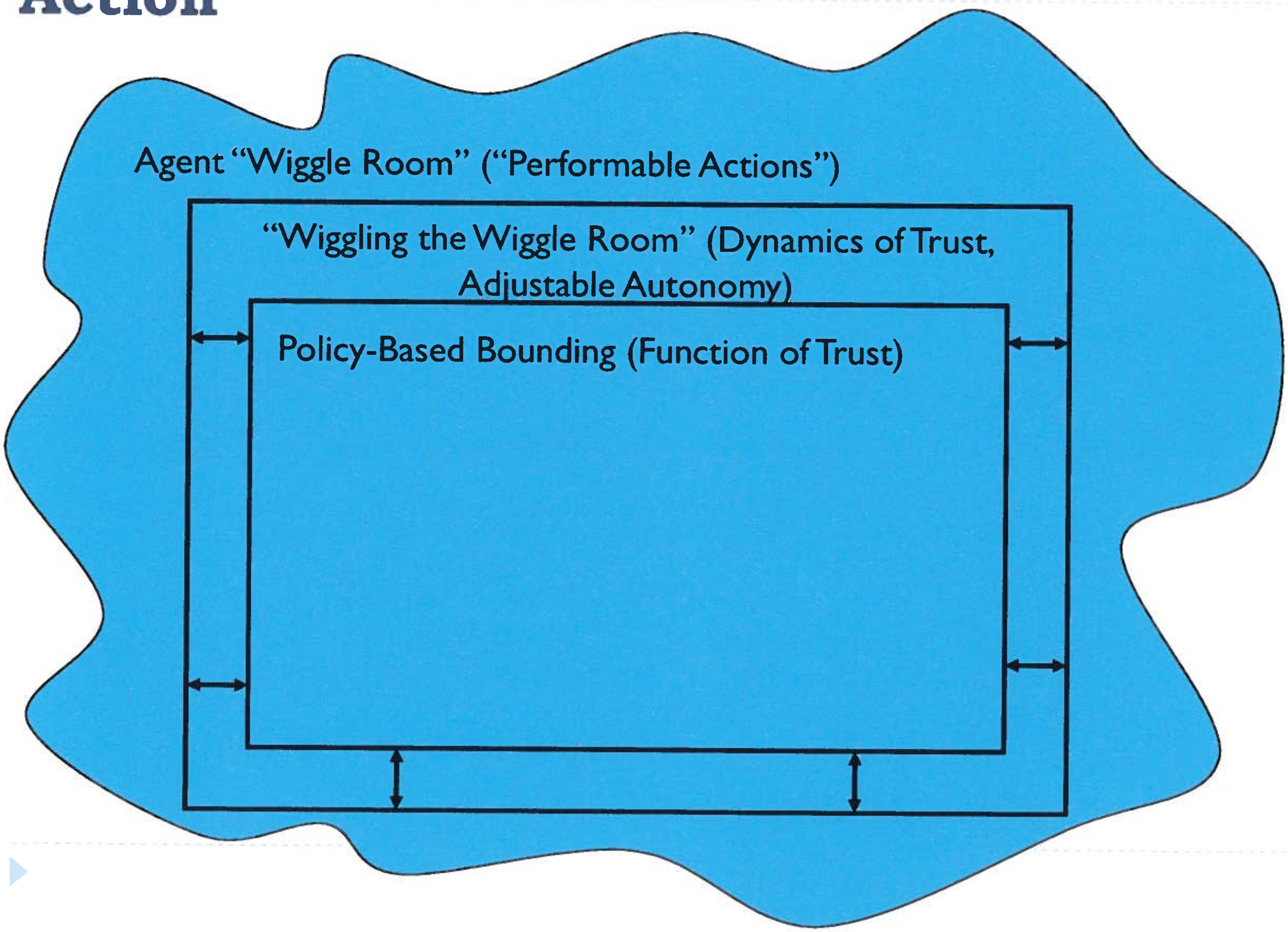
  When Robot X enters a room
  trigger

Simple View of Adjustable Autonomy

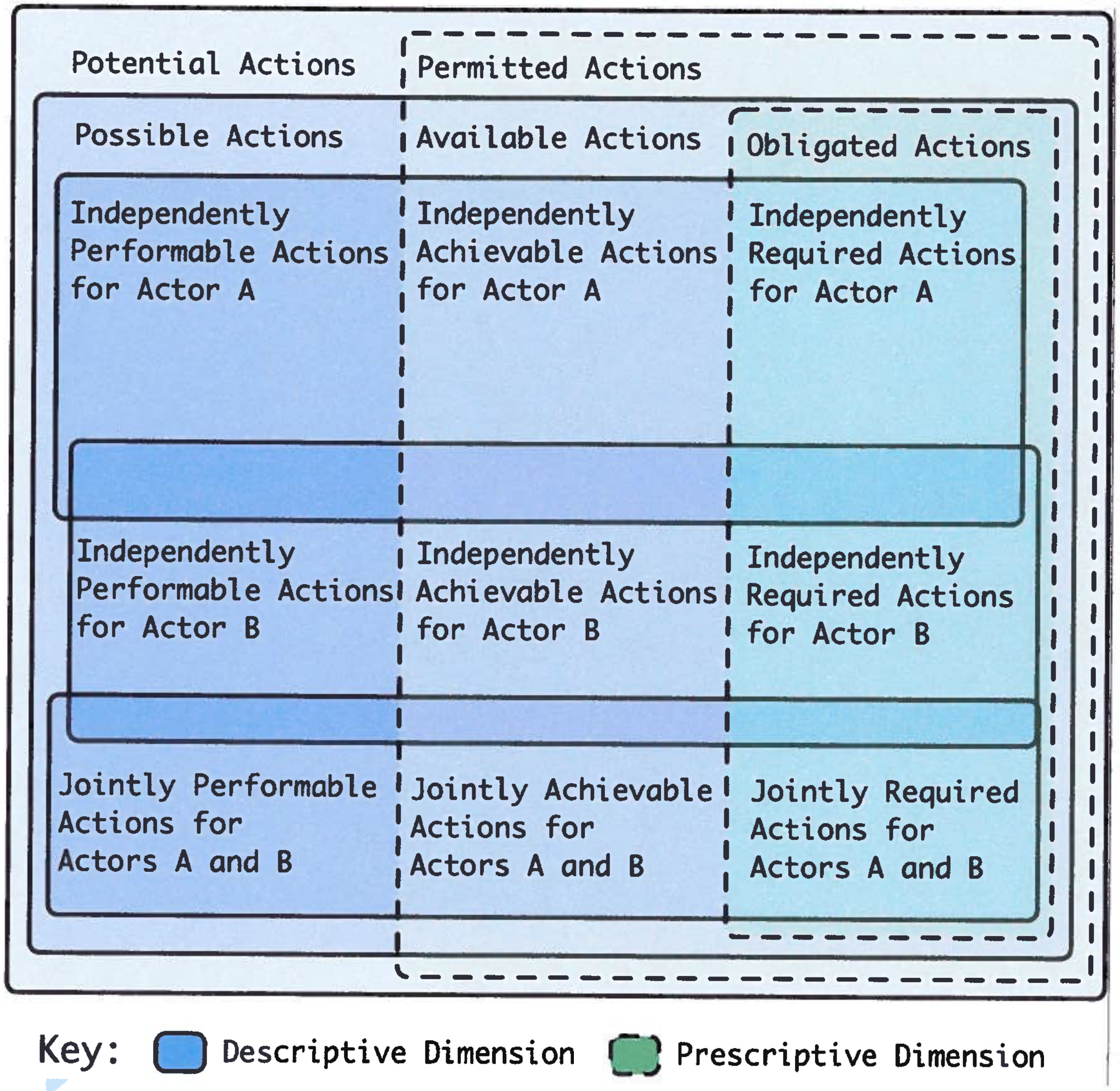


- Paul Fitts *et al.* MABA-MABA lists: Determine which things humans do best and which things agents do best, then allocate work accordingly
- Adjustable autonomy and adaptive allocation: Adjust these assignments according to context

The Dynamics of Trust in Coordinating Joint Action



Dimensions of Autonomy



Bradshaw, J.M., P. Feltovich, H. Jung, S. Kulkarni, W. Taysom, and A. Uszok. "Dimensions of adjustable autonomy and mixed-initiative interaction." In *Agents and Computational Autonomy: Potential, Risks, and Solutions. Lecture Notes in Computer Science, Vol. 2969*, edited by M. Nickles, M. Rovatsos, and G. Weiss, 17-39. Berlin, Germany: Springer-Verlag, 2004.

Coactive Design

- The basic premise of Coactive Design is that the underlying interdependence of joint activity is the critical design feature. Autonomous capability, while important, is secondary.
  - This is due to both the relative importance of managing interdependencies and the fact that it is hard to find true autonomy in a team setting.
  - We are no longer dealing with individual *autonomous actions* but with group *participatory actions* (Clark).
  - As Clark states, "a person's processes may be very different in individual and joint actions even when they appear identical." Clark's example is playing a musical solo versus playing a duet. Although the music is the same, the *processes involved are very different.*

Interdependence

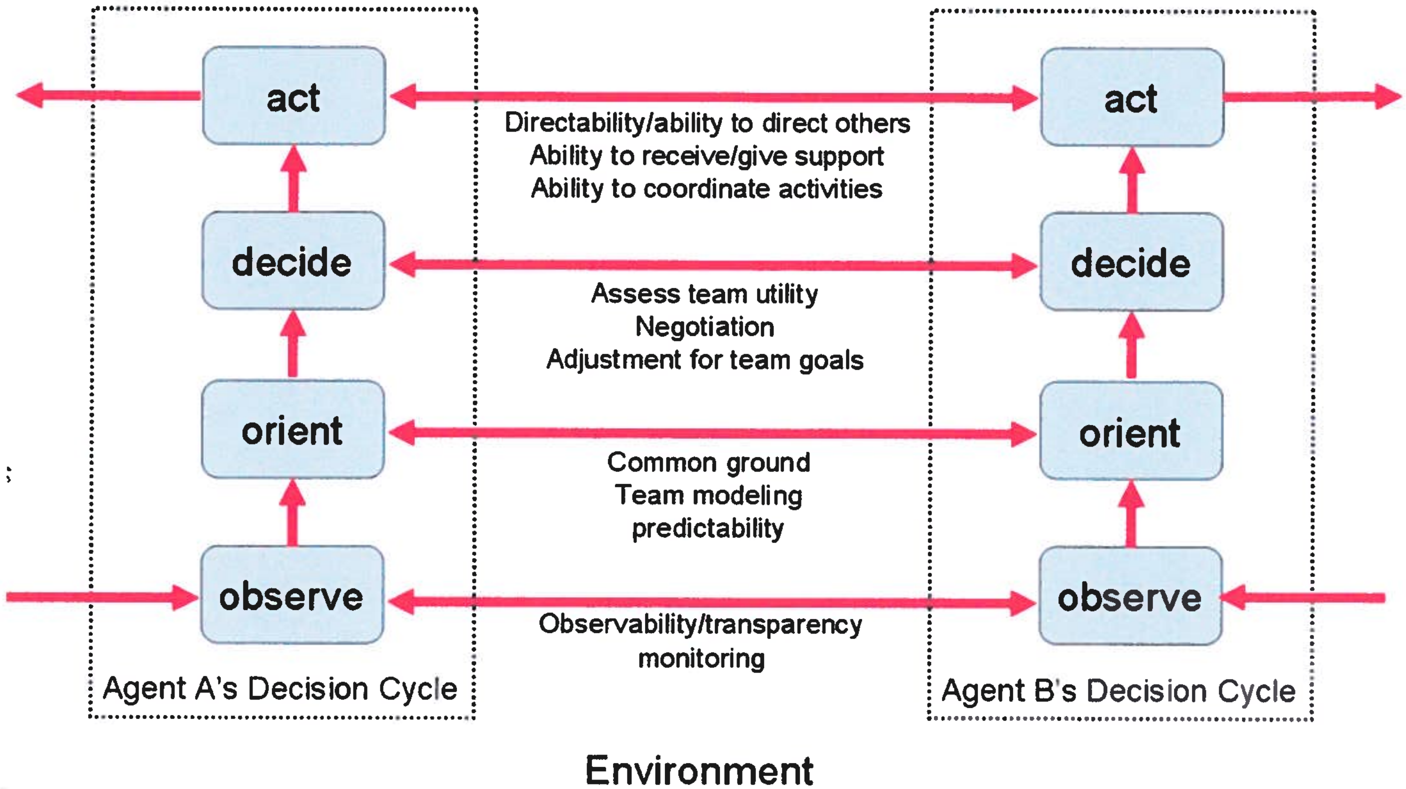
- Soft Dependency
  - "hard" means that activity *A* cannot proceed without *x*
  - "soft" means that activity *A* can potentially involve *x*, but it is not required.
  - "soft" dependency can also refer to information that is not required, but if provided it could potentially alter the behavior of the recipient.
    - progress appraisals ("I'm running late"), warnings ("Watch your step") and unexpected events ("It has started to rain").
  - These types of dependency can lead to much richer and more interesting types of interaction than have typically been implemented and are important aspects of Coactive Design.
- Monitoring Dependency
  - If there is dependence, either resource or temporal, there is also an implied "monitoring dependency," if joint activity is to be successful. The dependent agent is obligated to monitor the situation appropriately. There are two possible options:
    - *observe the environment (including time or other agents)*
    - *wait for a signal or message*
  - Each option has it challenges but for now it is only important to understand that monitoring is a basic requirement of Coactive Design.

Teamwork

- Teamwork implies a common goal so all activity is inherently dependent.
  - For example, given a joint goal A and two independent tasks *B* and *C* that meet *A* it is clear that A depends on B and C
- Although the tasks may be independent, their relation as subtasks of A creates a "soft" dependency.
  - B and C depend on each other by being part of the same joint goal
  - Some examples include: coming across information while executing B that is relevant to C, noticing that C is having trouble, temporarily suspending B to assist C, and abandoning B when observing C is unattainable.
- Good teams distinguish themselves by handling the "soft" dependencies better

Team OODA Model

- Highlights the interdependence of the individual decision cycles and connects various teamwork characteristics to portions of the decision cycle.
- There is one very important difference with the teamwork centered OODA model as opposed to the individual OODA model; the reciprocal nature of having two entities.



Summary: Coactive Design Principles

- *In Coactive Design all activity is interdependent*
- *Identifying areas of dependence (both hard and soft) is crucial to Coactive Design*
- *Soft dependencies are important in Coactive Design*
- *Coactive Design has an implied monitoring dependency*
- *Coactive Design includes the coordination of the content and the process of joint activity*
- *Teamwork is inherently reciprocal in nature*
- *The Team Decision Model can aide in understanding aspects of teamwork and identifying the reciprocal relationships important to Coactive Design*

Generic Qualities of a Good Agent (Human or Software)

- A good agent is *observable*. It makes its pertinent state and intentions obvious.
- A good agent is attuned to the requirement of *progress appraisal*. It enables others to stay informed about the status of its tasks and identifies any potential trouble spots ahead.
- A good agent is *informative* and *polite*. It knows enough about others and their situations so that it can tailor its messages to be helpful, opportune, and appropriately presented.
- A good agent *knows its limits*. It knows when to take the initiative on its own, and when it needs to wait for outside direction. It respects policy-based constraints on its behavior, but will consider exceptions and workarounds when appropriate.
- A good agent is *predictable* and *dependable*. It can be counted on to do its part.
- A good agent is *directable*. It can be retasked in a timely way by a recognized authority whenever circumstances require.
- A good agent is *selective*. It helps others focus attention on what is most important in the current context.
- A good agent is *coordinated*. It helps communicate, manage, and deconflict dependencies among activities, knowledge, and resources that are prerequisites to effective task performance and the maintenance of "common ground."

Human-Centered Perspectives on Active Modeling and Visualization of Complex High-Tempo Situations

Jeffrey M. Bradshaw, Larry Bunch, Marco Carvalho, Tom Eskridge, Paul Feltovich
{jbradshaw, lbunch, mcarvalho, teskridge, pfeltovich}@ihmc.us

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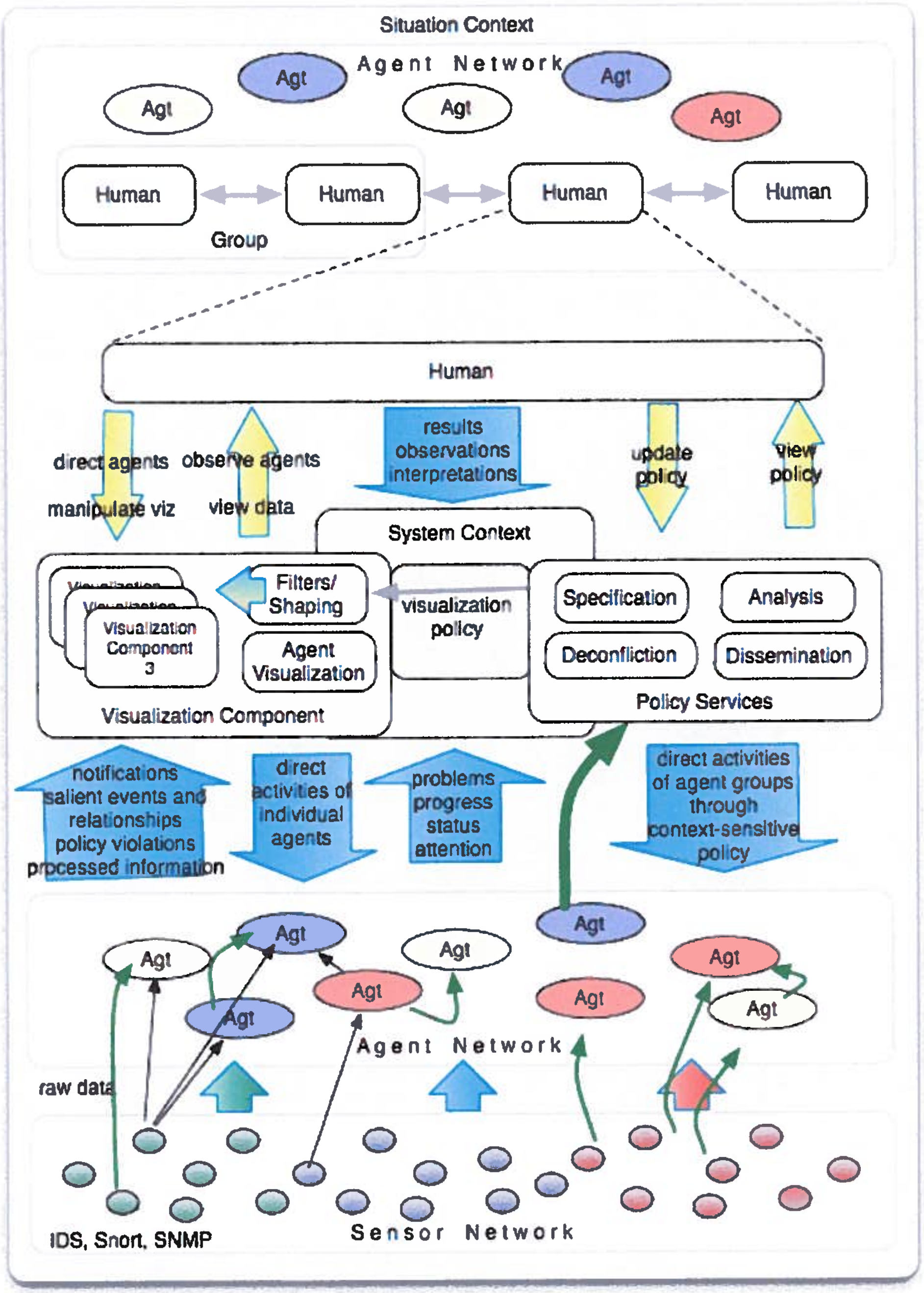
Cyber-Defense Conceptual Architecture



ONR NAIMT Collaboration

- Surfzone Crawler
- Lane Clearing Scenario

Coordinated Operation of Humans, Agents, and Unmanned Vehicles for Littoral Warfare

State University System of Florida

U.S. Army Research Laboratory
Human Research and Engineering Directorate
ARL-HRED

U.S. Army Research Office

Office of Naval Research

NAVSEA
NAVAL SURFACE WARFARE CENTER
Panama City

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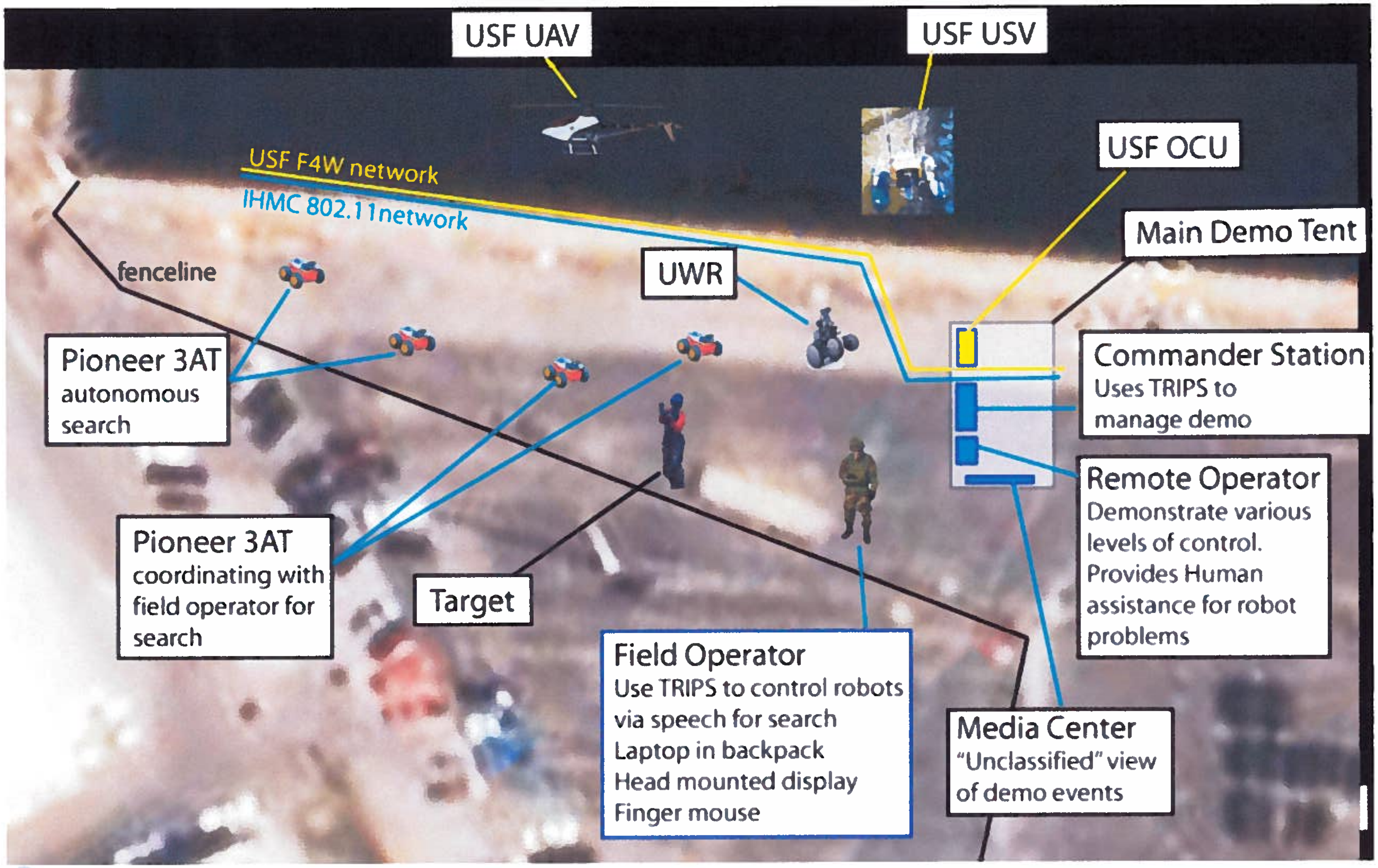
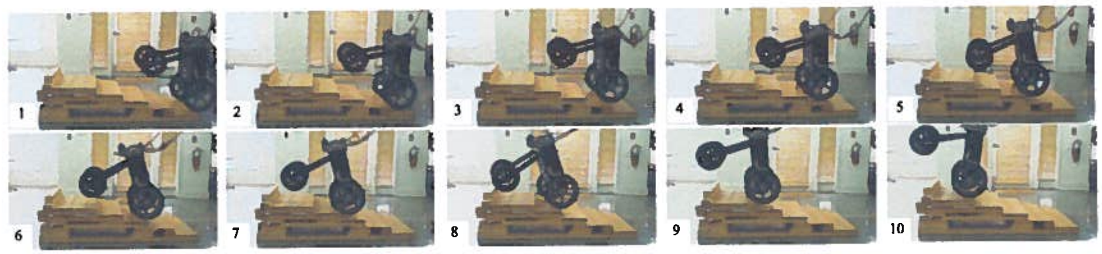
Coordinated Operations Scenario



Pratt: tBot

V0.2 - Reduced degree of freedom prototype.

- Demonstrates balance control.
- Demonstrates stair climbing capability
- Integrated with KAoS HART Services



V1.0 –Fully functional 10 actuator robot

- Assembly completed Aug '07.
- Capable of stable 10 mph in 4 wheel mode.
- Turn in place in two wheel mode.
- Climb stairs and over obstacles.
- Active suspension for operation in two wheel mode on uneven terrain.
- Top mount payload for high vantage point.

tBot

More Information

- http://www.ihmc.us/users/jbradshaw
- jbradshaw@ihmc.us