Coactive Design

Florida Institute for Human and Machine Cognition

Presented by Matthew Johnson (mjohnson@ihmc.org)

Disclaimer

I will use the terms robot, AI, unmanned system and agent fairly interchangeably, as the need for teaming does not change and our approach works the same in any case.

No AI is an Island

As we pursue more advanced intelligent capabilities, it is advisable to remember that just as “no man is an island” the same can be said about AI, or robots or any technology.

Johnson, M., & Vera, A. H. (2019). No AI is an Island: The Case for Teaming Intelligence. AI Magazine, Spring, 16–28.

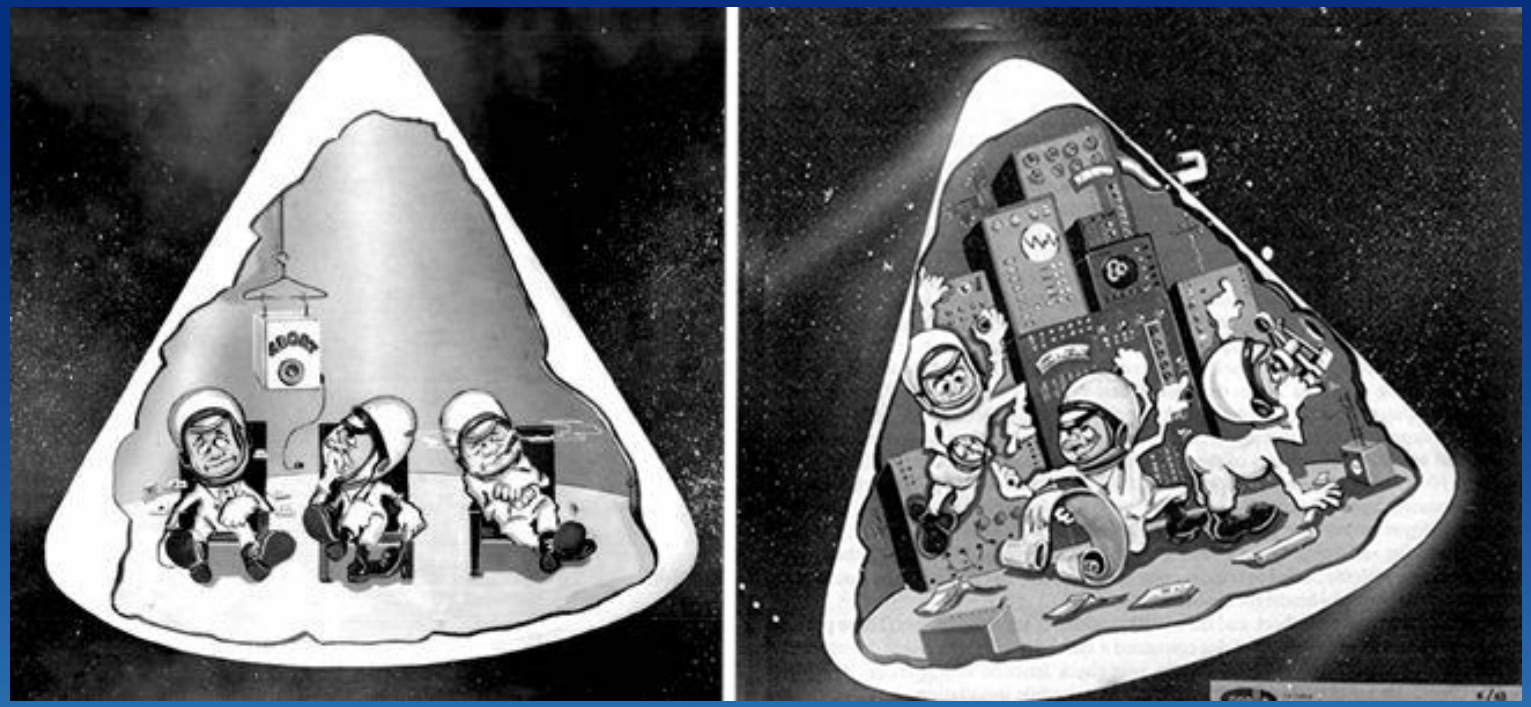
Myths of "Autonomous Systems”

A key misconception is in the role of AI or technology.

Very often, AI is seen as ***replacing*** the human.

Bradshaw, J.M, Robert R. Hoffman, Matthew Johnson, and David D. Woods. The Seven Deadly Myths of "Autonomous Systems.” *IEEE Intelligent Systems*, May/June 2013 (vol. 28 iss. 3), pp. 54-61.

The Myth of Replacement



Black Boxes vs. Grey Matter
the real story with is how humans and automated technology worked together to achieve these great accomplishments
— neither was likely to succeed alone.

(paraphrased from David Mindell's Digital Apollo)

The Myth of Replacement

- The Substitution Myth:

  “The idea that new technology can be introduced as a simple substitution of machines for people — preserving the basic system while improving it on some output measure (lower workload, better economy, fewer errors, higher accuracy, etc.)”

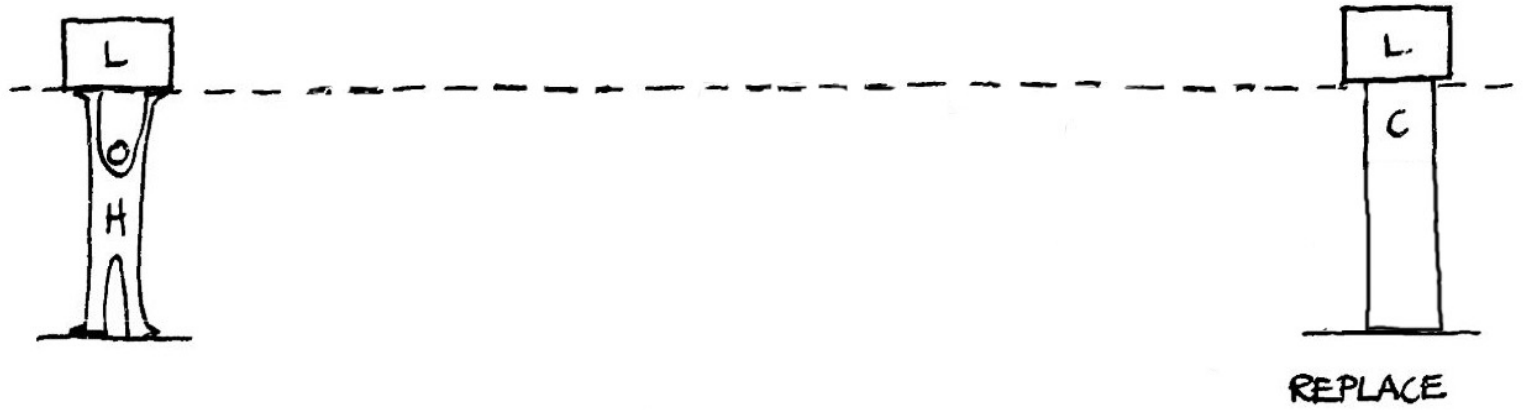
  (Christoffersen and Woods 2002)

Autonomy != Replacement

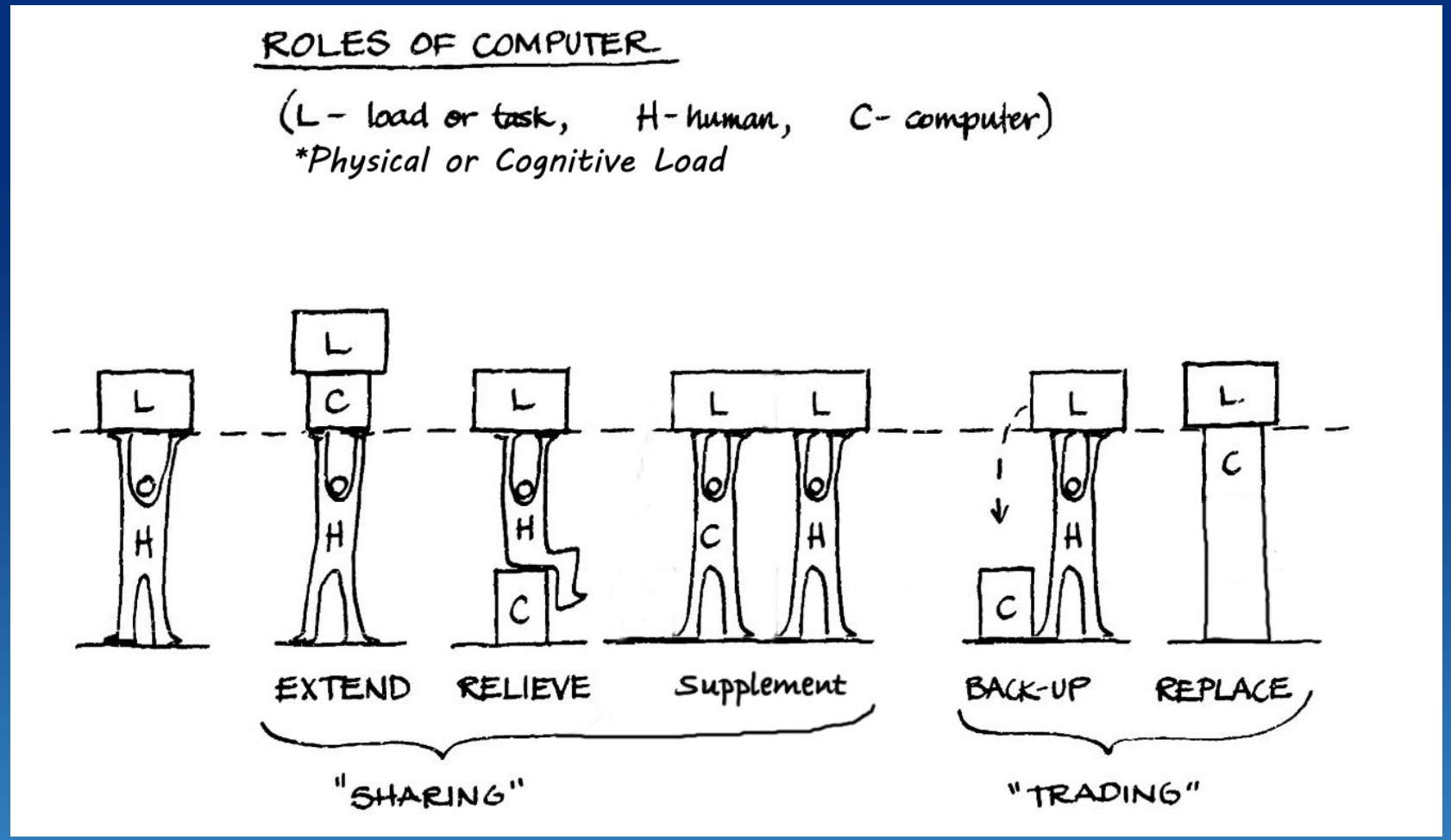
- Replacement is rarely what is actually happening with the addition of technology.
- Technology changes the nature of the work.
- Humans are often the enabling components of many technologies.
- Replacement is not the only, or even the best, way to view technology.

ROLES OF COMPUTER

(L – load or task, H – human, C – computer)
*Physical or Cognitive Load



[1] Modified from Sheridan, T. B., & Verplank, W. (1978). Human and Computer Control of Undersea Teleoperators. Cambridge, MA: Man-Machine Systems Laboratory, Department of Mechanical Engineering, MIT.



[1] Modified from Sheridan, T. B., & Verplank, W. (1978). Human and Computer Control of Undersea Teleoperators. Cambridge, MA: Man-Machine Systems Laboratory, Department of Mechanical Engineering, MIT.

Why Human-AI Teaming is Important

Technology does not work in isolation from people (No AI is an Island).

For technology to achieve its full potential and deliver on its promised benefits, these systems will need to seamlessly work with and alongside people.

Proper Human-AI Teaming is often the difference between a cool technology demonstration and something actually being useful.

The Problem with Current Practice

- It focuses solely on "autonomy" or "artificial intelligence" capabilities to support taskwork.
- The main design question asked is "what to automate?" or worse "what can we automate?".
- It is based on function allocation which simplifies work to task decomposition.

> *"When it comes to the job itself, however, the problem is not to dissect it into parts or motions, but to put together an integrated whole. This is the new task."*

– Peter Drucker *The Practice of Management* (1954)

What is the goal of building intelligent systems?

What is the goal of building intelligent systems?

Dependent *-Autonomy-* **Independent**

What is the goal of building intelligent systems?

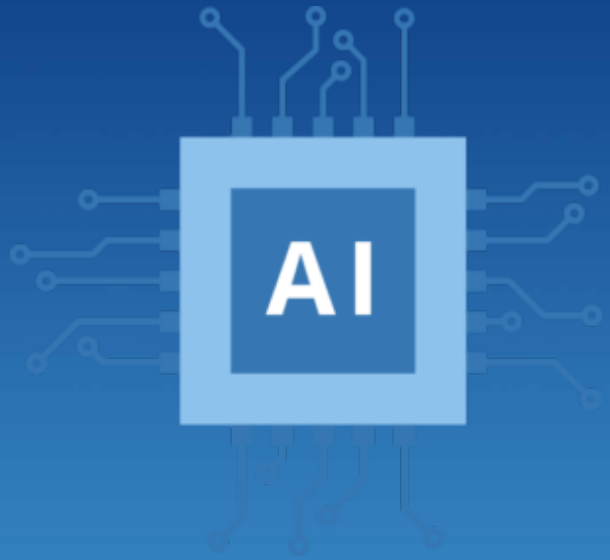
Dependent *-Autonomy-* **Independent** *-Teamwork-* **Interdependent**

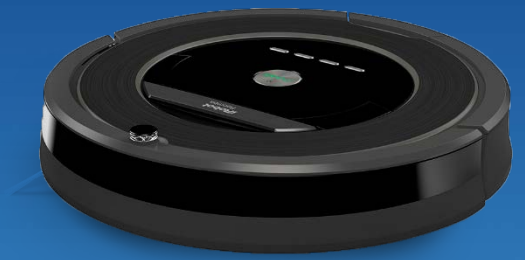
What is the goal of building intelligent systems?

Dependent *-Autonomy-* **Independent** *-Teamwork-* **Interdependent**

What is the goal of building intelligent systems?

Dependent *-Autonomy-* **Independent** *-Teamwork-* **Interdependent**





So what does it mean to be interdependent?

The Theory of Interdependence

The Theory of Interdependence

"Interdependence" describes the set of complementary relationships that two or more parties rely on to manage required or opportunistic dependencies in joint activity

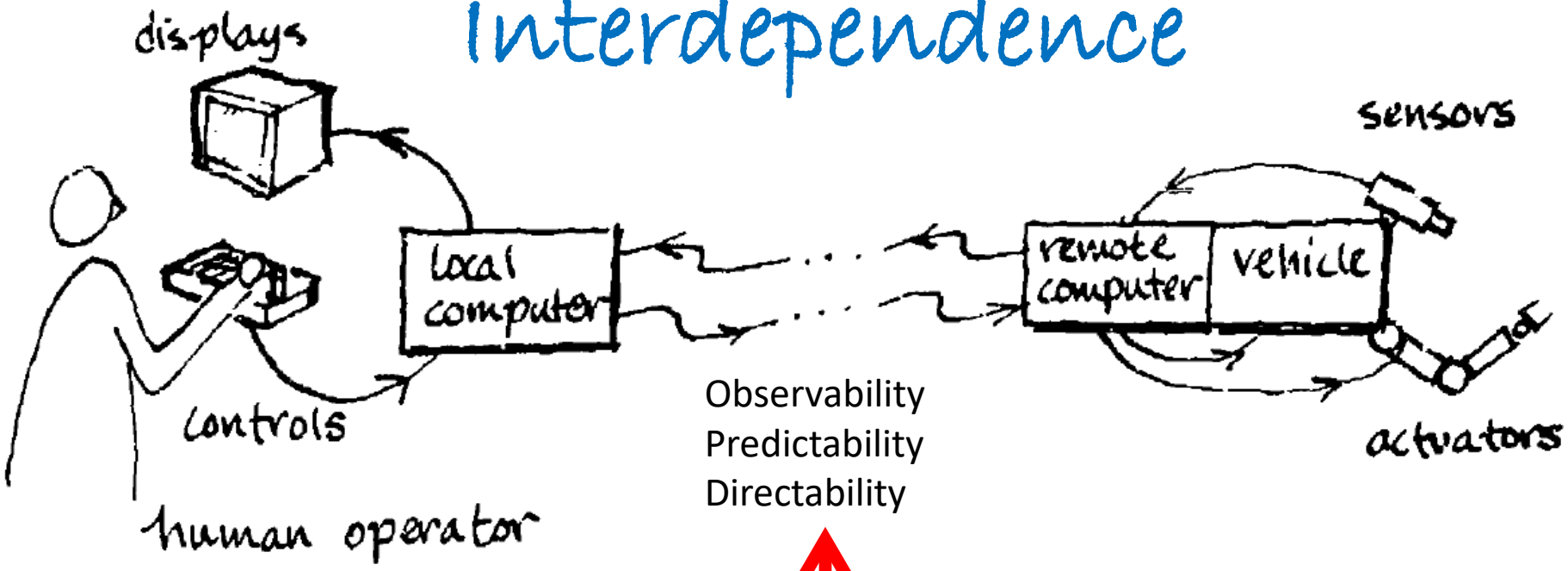
The Theory of Interdependence

"Interdependence" describes the set of complementary relationships that two or more parties rely on to manage required or opportunistic dependencies in joint activity

What kind of relationships are used to manage dependencies in joint activity?

~~"SUPERVISORY CONTROL"~~

Interdependence



Observability
Predictability
Directability

Interface Design and Human Factors

Autonomy and Control Theory

(Sheridan & Verplank, 1978)

These are where the requirements for supporting interdependence come from.

Why is Human-AI Teaming Important

Although counter-intuitive,

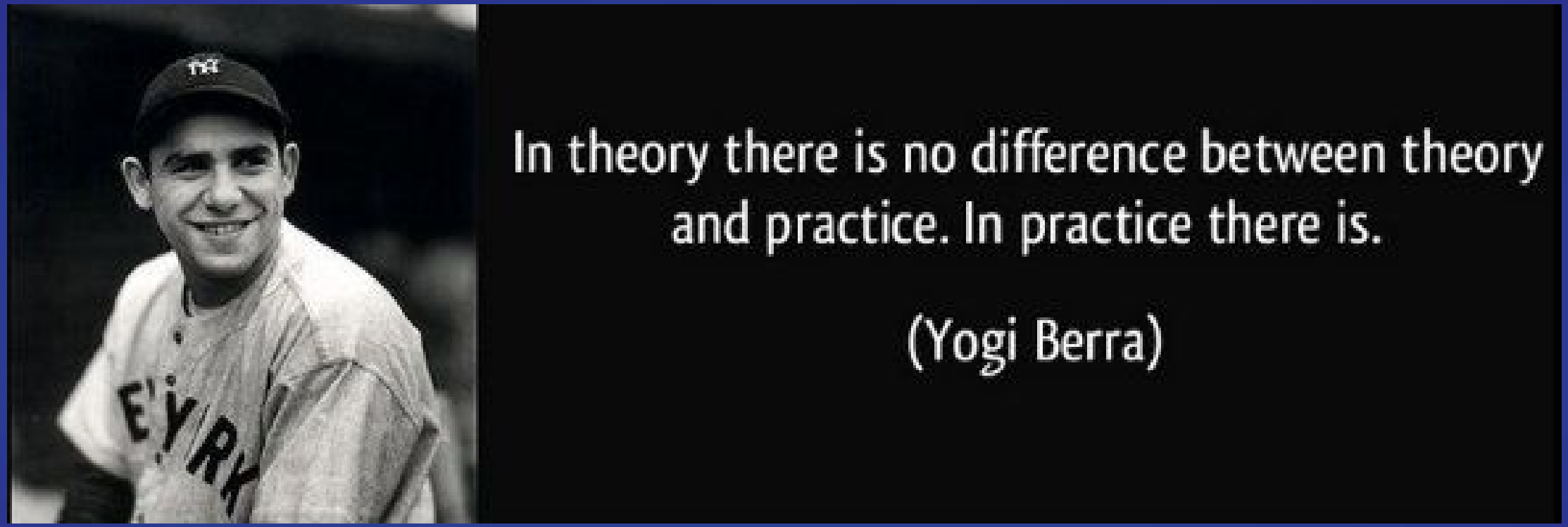
the greater the individual competence (autonomy/intelligence),

the greater the need for more sophisticated collaborative skills.

What is Teaming?

- "improve the **teaming** of unmanned systems with the manned force" - Unmanned Systems Integrated Roadmap FY2011-2036
- "The goal of the National Robotics Initiative is to accelerate the development and use of robots in the United States that work beside, or **cooperatively** with, people." and "…**symbiotic relationship**..." – NRI 2013
- "human-system **collaboration**" – Defense Science Board 2012
- "**combine the inherent strengths** of manned platforms with the strengths of UAS" – UAS Roadmap 2010-2035
- "Humans and machines will need to become far more **closely coupled**, through improved human-machine interfaces and by direct augmentation of human performance." – Technology Horizons 2010
- "**shared-control** concept … the operator works "**in-the-loop**" with the robot" – Roadmap for US Robotics 2009

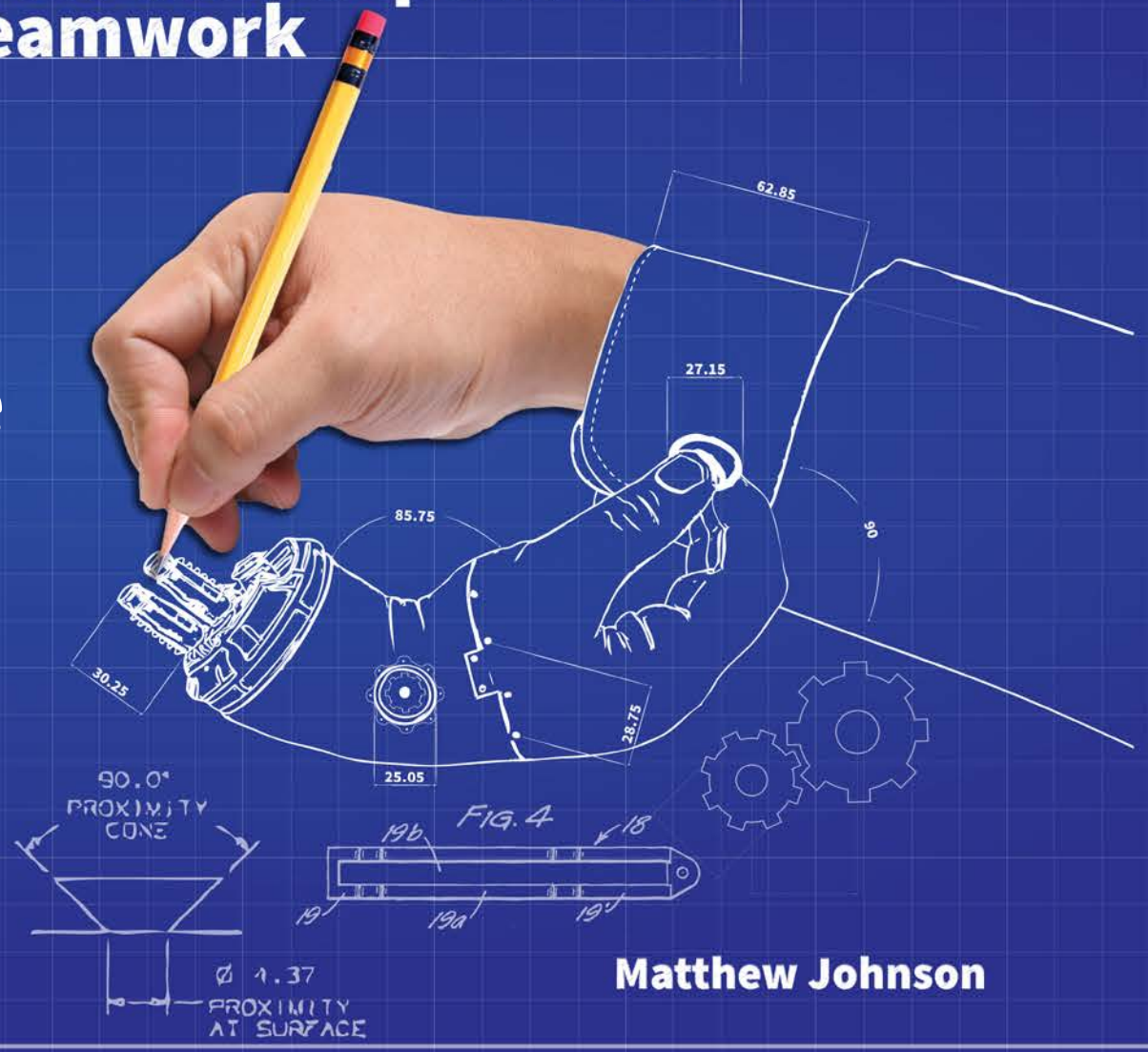
So, what does this mean to an engineer?


In theory there is no difference between theory and practice. In practice there is.
(Yogi Berra)

Coactive Design

Designing Support for Interdependence in Human-Robot Teamwork

Bridging design into practice

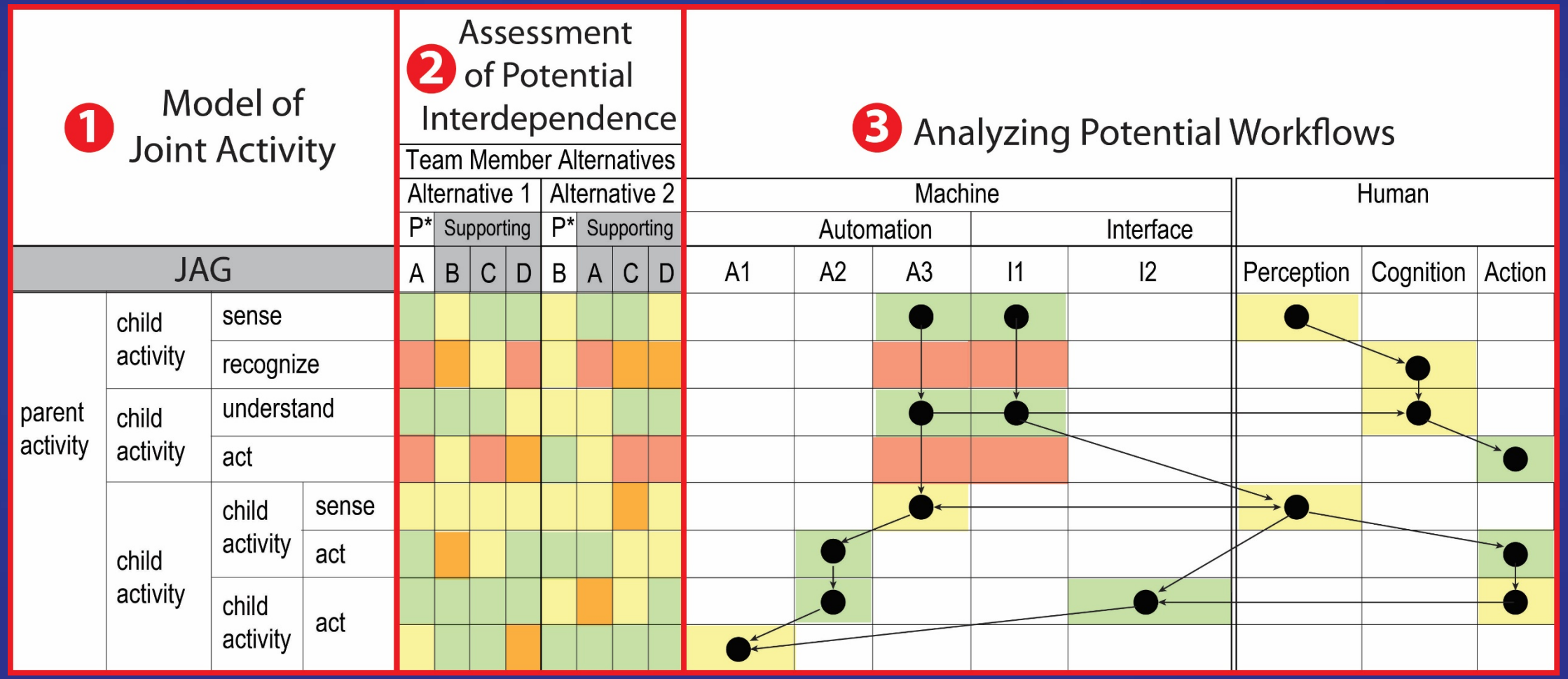


Matthew Johnson

How to bridge design into practice?

- Design tools that can ground out in implementation
  - Interdependence Analysis
- Behavior modelling tools capable of supporting theory
  - Joint Activity Graphs

Interdependence Analysis



Benefits of Interdependence Analysis

models both the human and the machine

Can model multiple teammates

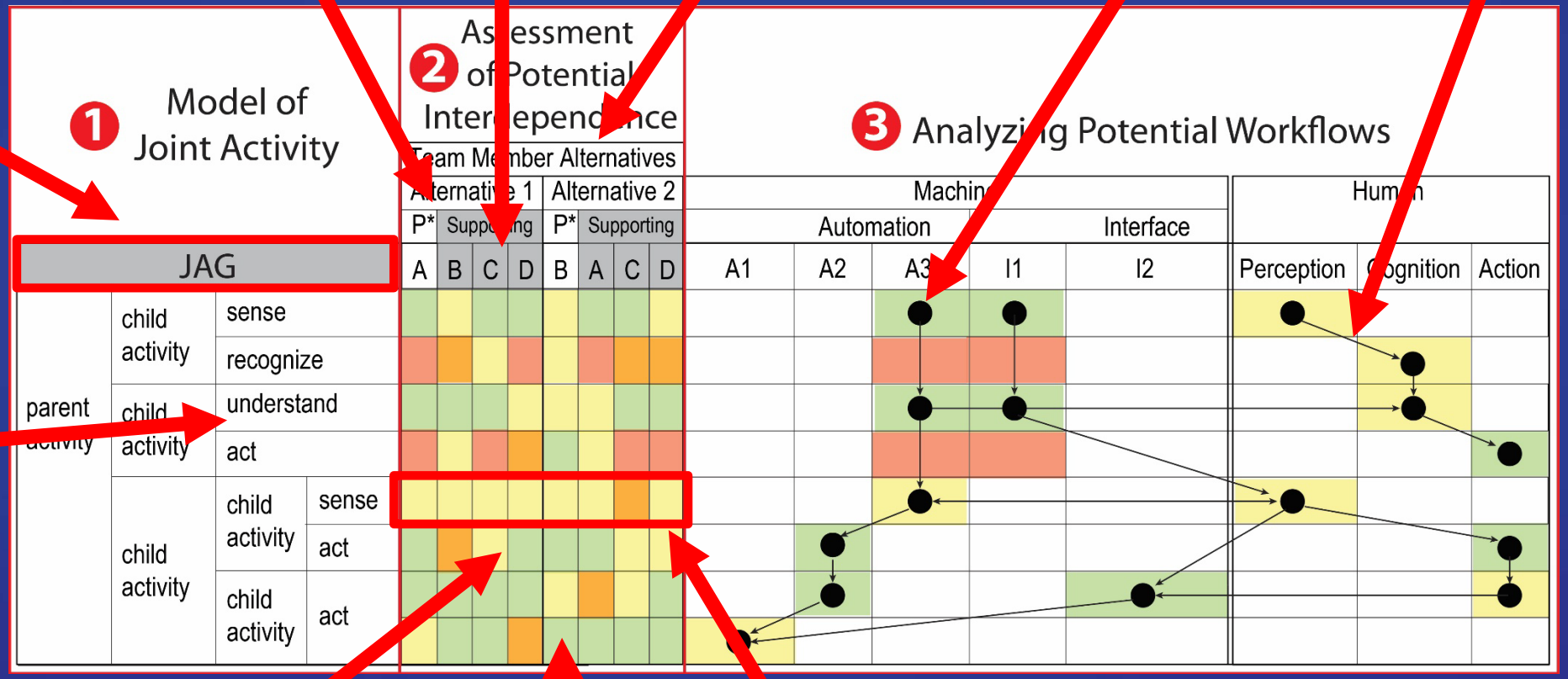
models interdependencies between teammates

Maps to implementation

Models workflows

models work context

models physical and cognitive work



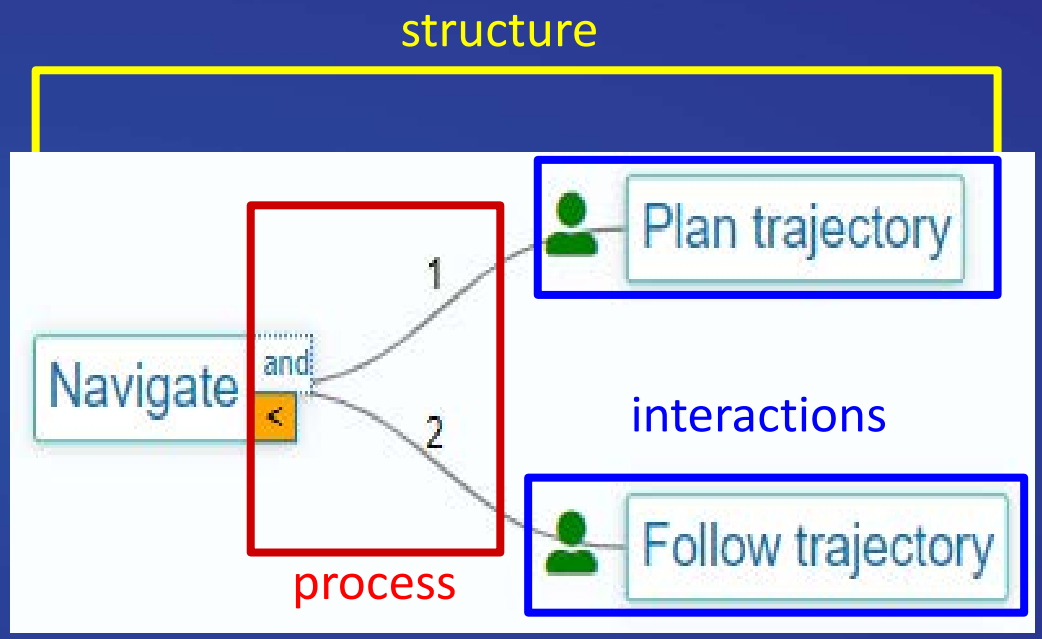
models soft interdependencies

Helps design for resilience by understanding risk

Helps design for flexibility by identifying alternative ways to accomplish the same task

Joint Activity Graphs

- **Purpose:**
  - to design, understand, and run complex behavior
  - to capture the key elements of joint activity:
    - structure
    - process
    - potential interactions



Comparison of JAGs to other approaches

	Joint Activity Graph	Planner	Behavior Tree	Finite State Machine
Teaming	Joint activity	Single agent	Single agent	Single agent
Reusability	Composable	Composable	Composable	Specific
Execution	Event based	N/A	Tick driven	Cond. transitions
Task Structure	Hierarchical	Flat (cut set)	Hierarchical	Graph
Data Structure	Graph	Knowledge store	Spaghetti	undefined
Behavior Composition	*Dynamic**	Dynamic	None	None
Data flow	Formal specification	Ontological	Back channel	undefined
Context	Dynamic - Broad	Static	Dyn. - Task specific	Dyn - State specific
Agent knowledge	Knowledge store	N/A	Blackboard	N/A
Task Prioritization	Dynamic	N/A	None	N/A
Interruptions	First class	Ext. replanning	None	undefined

Joint Activity Graphs

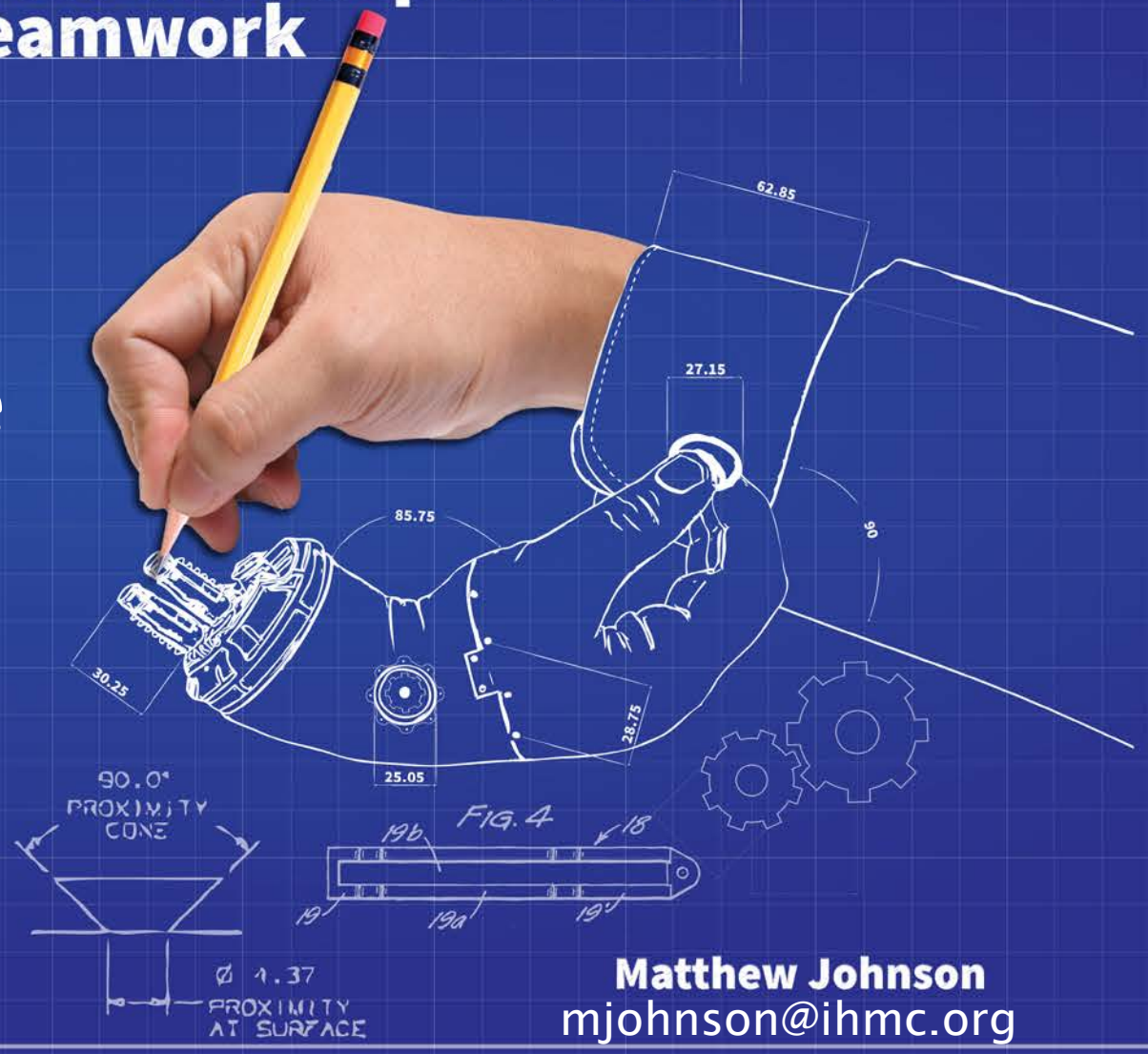
- Same exact JAGs are running on each agent for all scales
- JAGs compute locally based on available information and are inherently distributed

Coactive Design

Designing Support for Interdependence in Human-Robot Teamwork

Bridging design into practice

Thank you!



Matthew Johnson
mjohnson@ihmc.org