

Robotics and IoT:

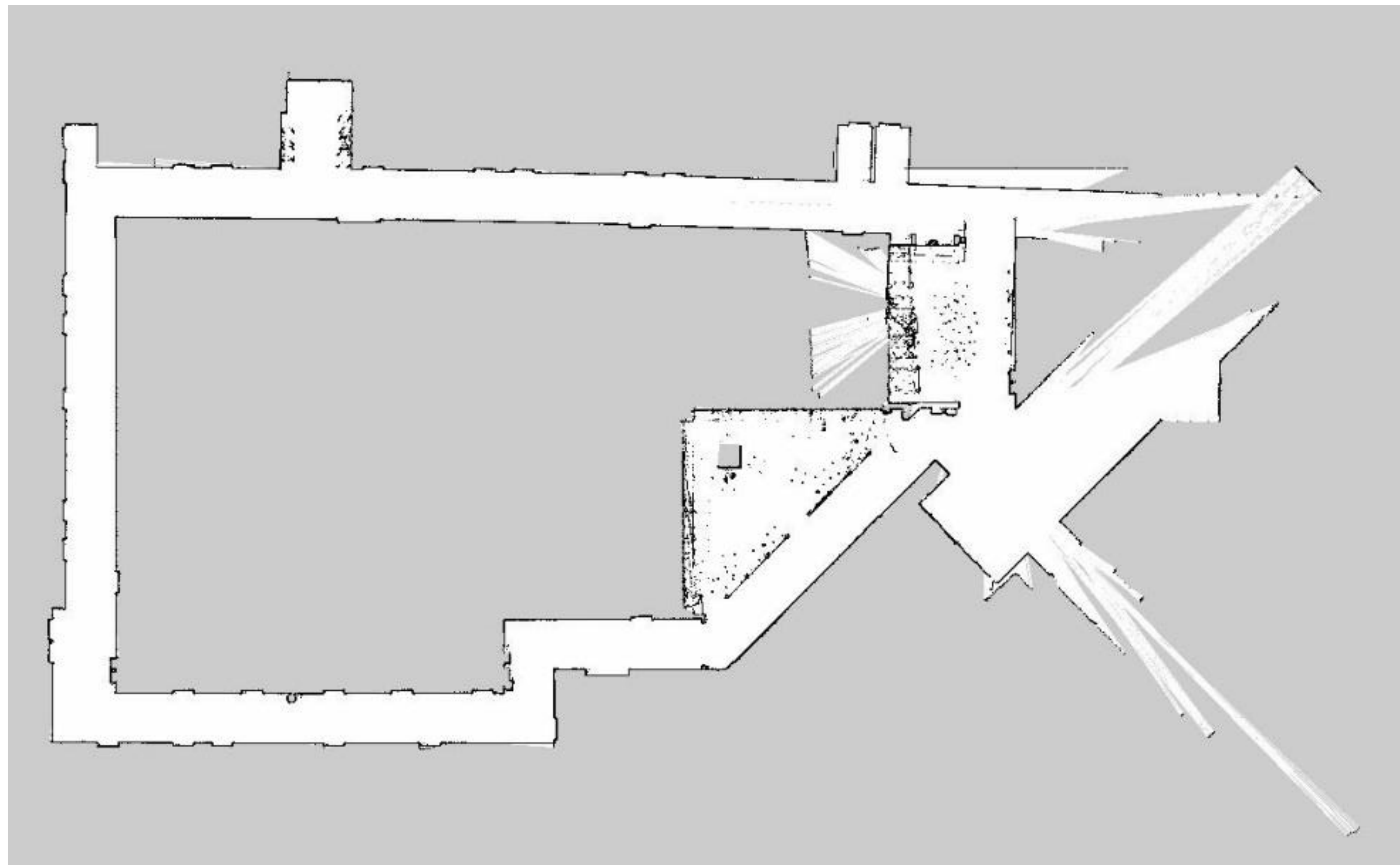
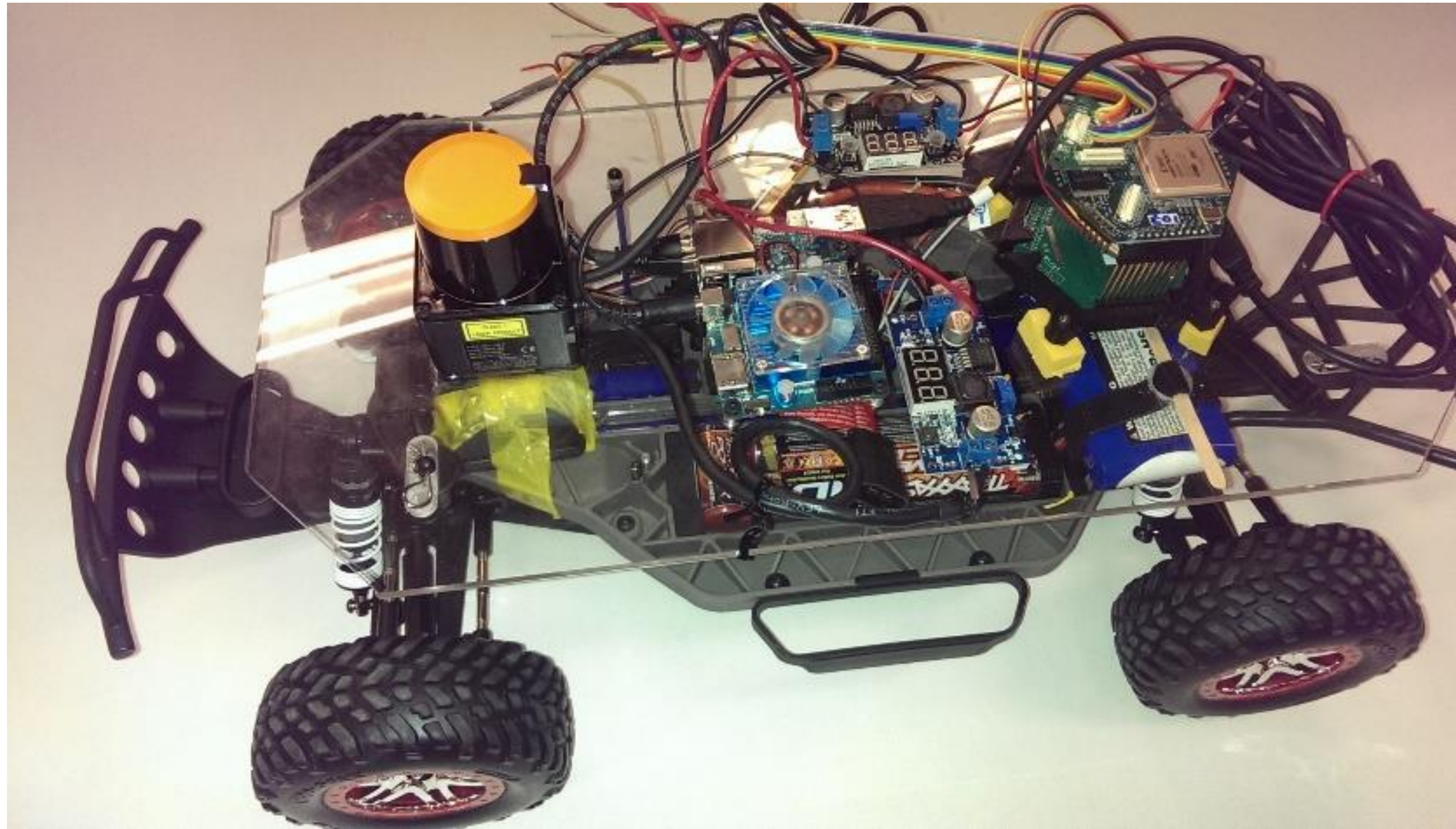
Interdisciplinary Applied Research in the RIoT Zone



Richard Voyles

Professor and Director, Purdue Robotics Accelerator

Purdue University



*K*noy *S*peedway



500 dodecimeter race

Welcome Race Fans to the KNOY Speedway!!

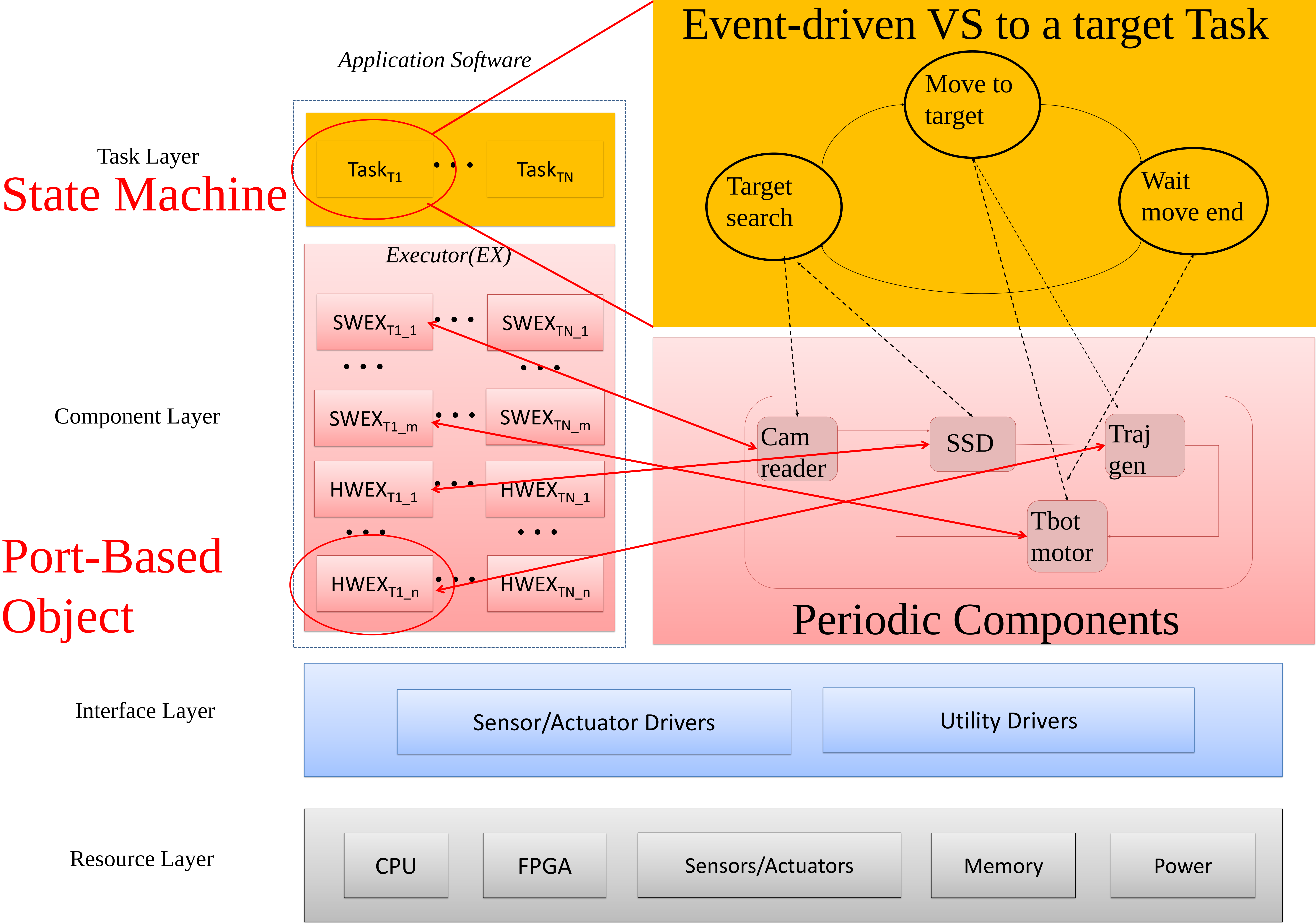
The first time trial of the inaugural race

Team "Rocky Valpo-a"

Kirby Neihouser, Matt Scott, Rocky Narkevicius

Electric-powered Tri-Car using Wall Following





ReFrESH
Architecture

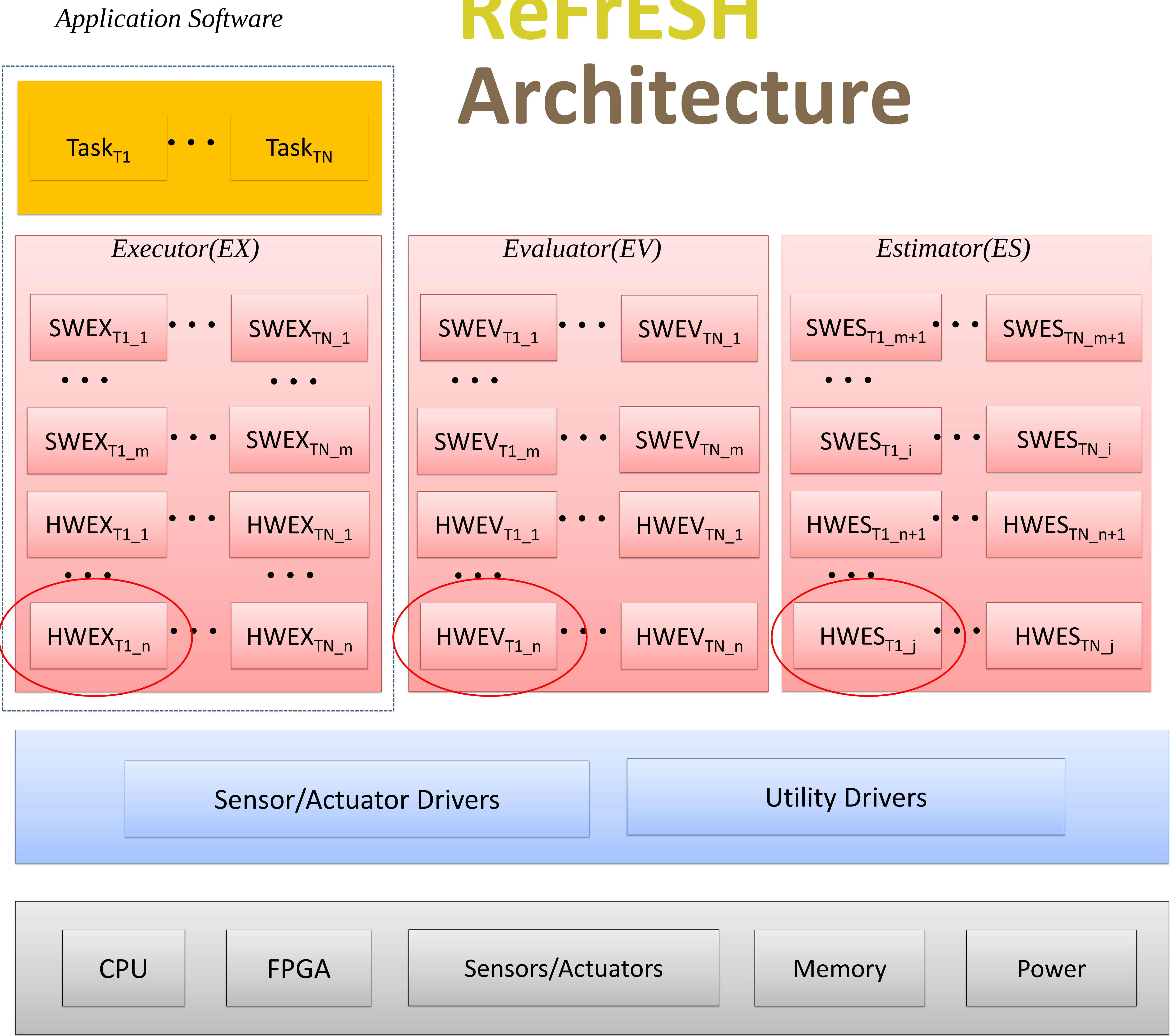
Extended
Port-Based
Object(E-PBO)

Task Layer

Component Layer

Interface Layer

Resource Layer



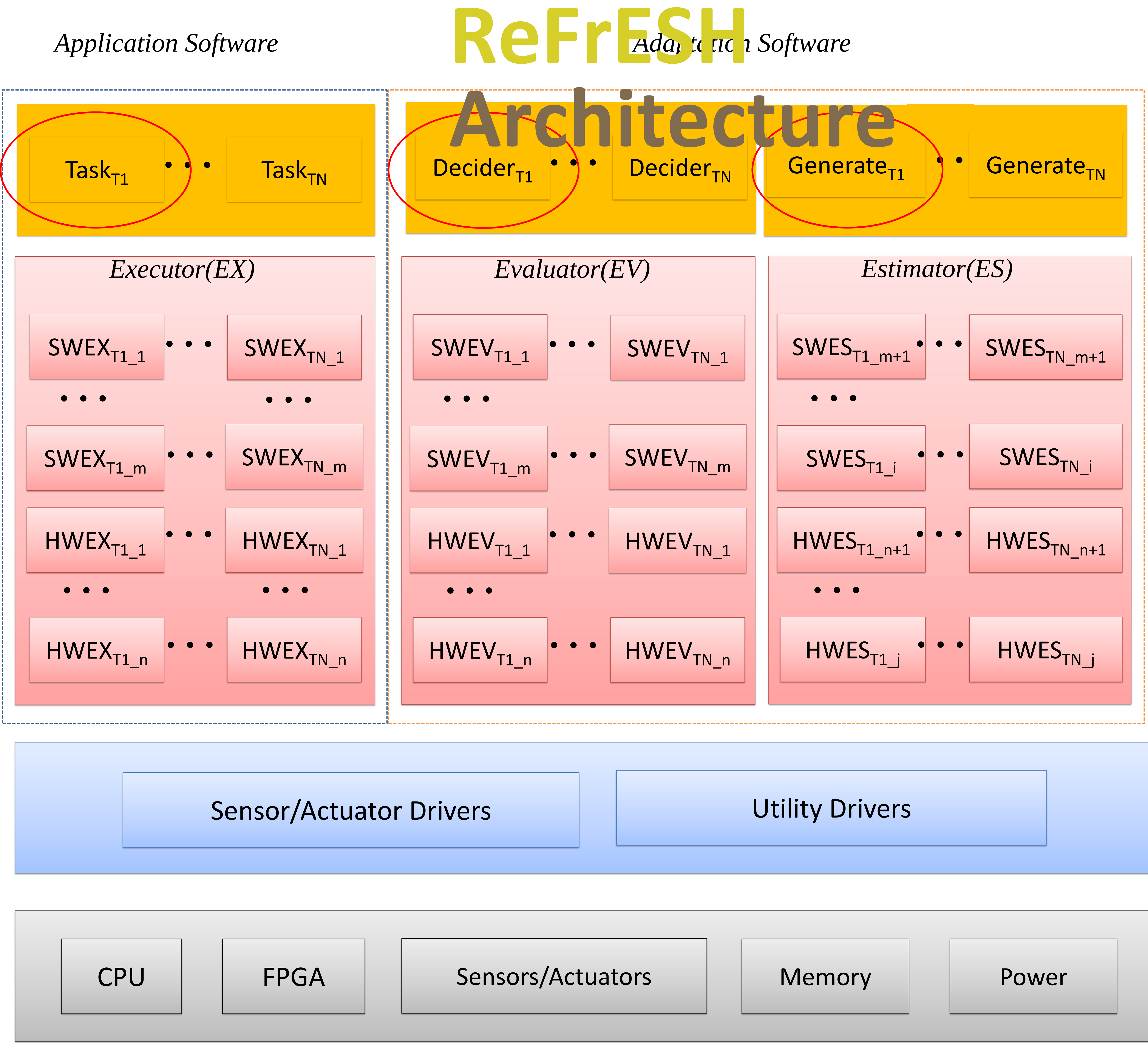
Augmented Task

Task Layer

Component Layer

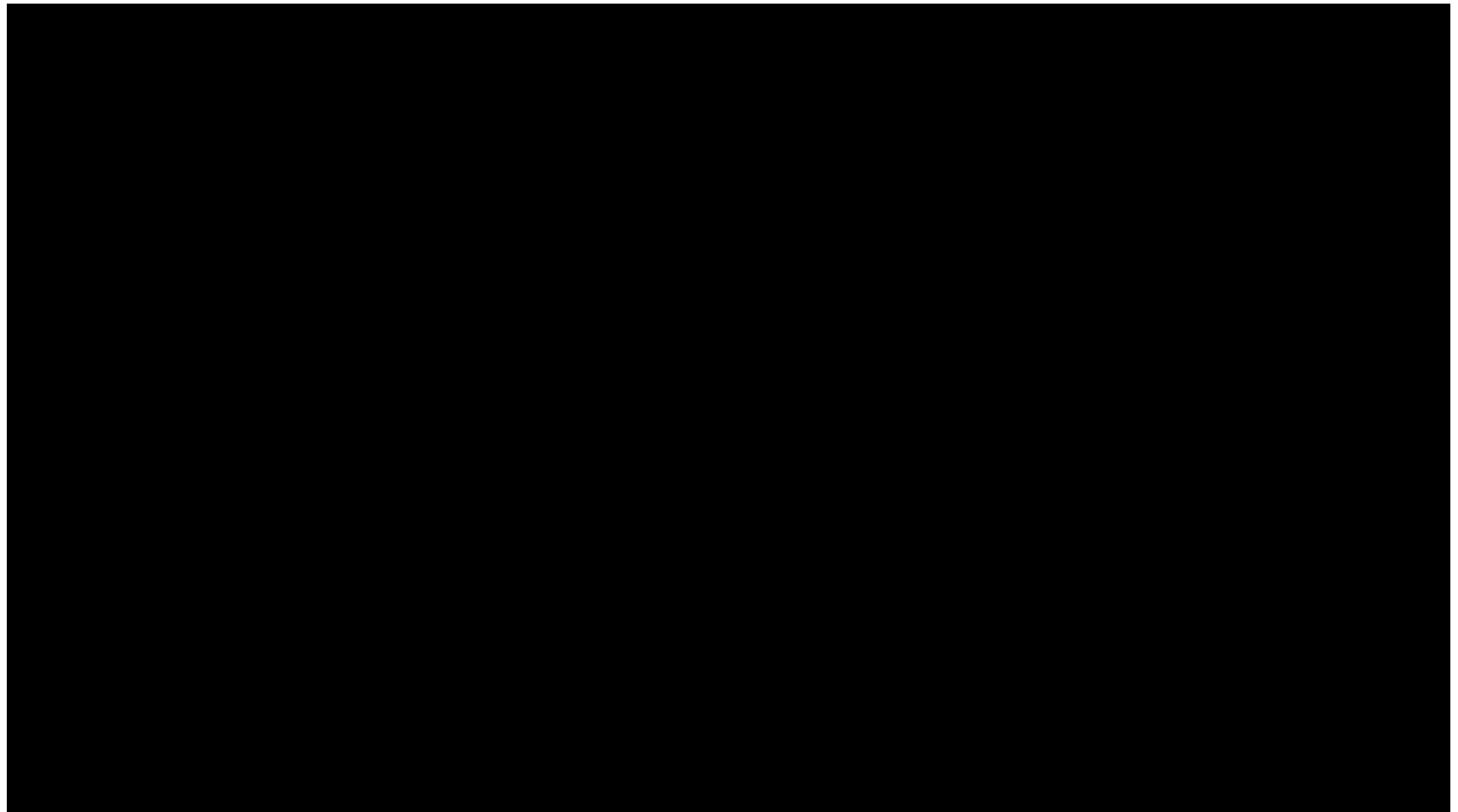
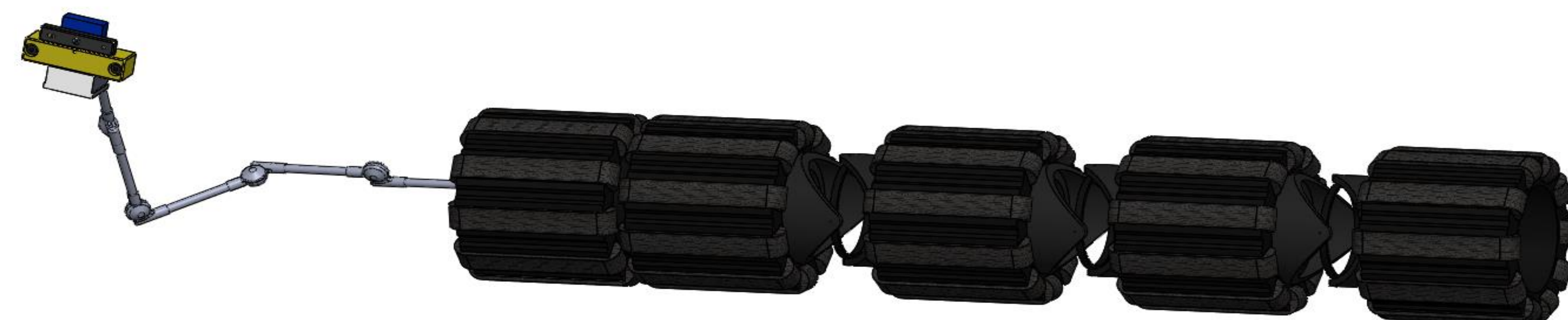
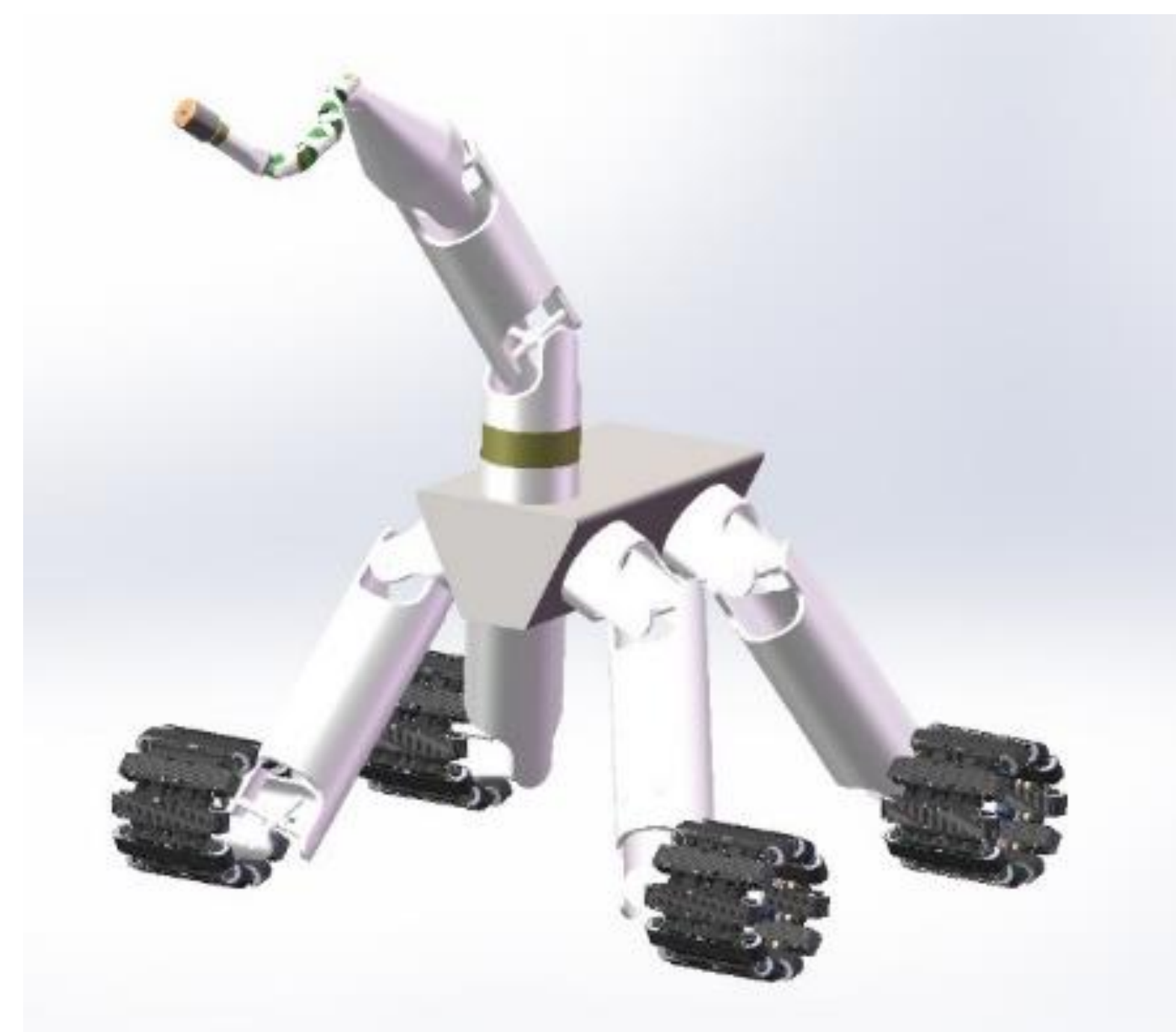
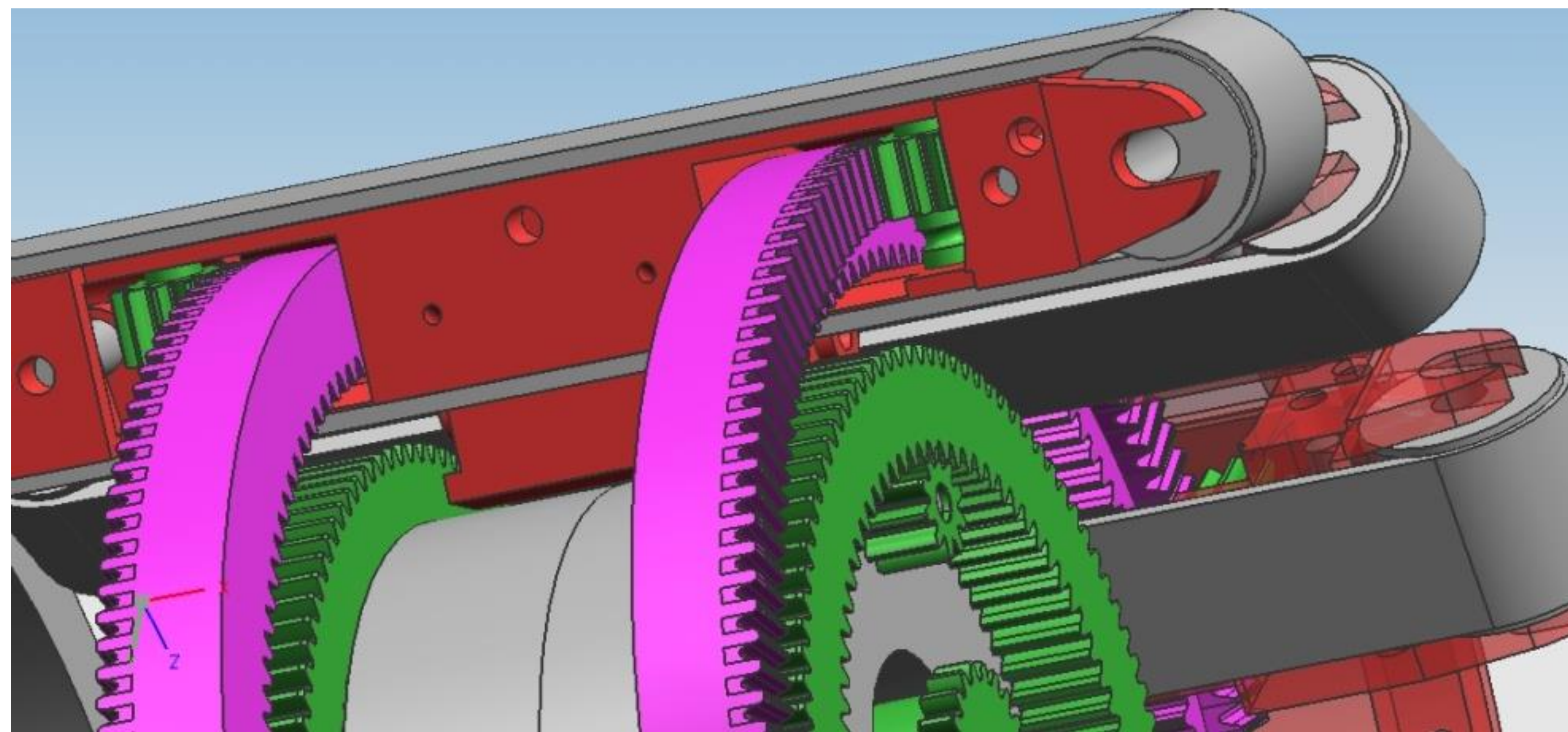
Interface Layer

Resource Layer

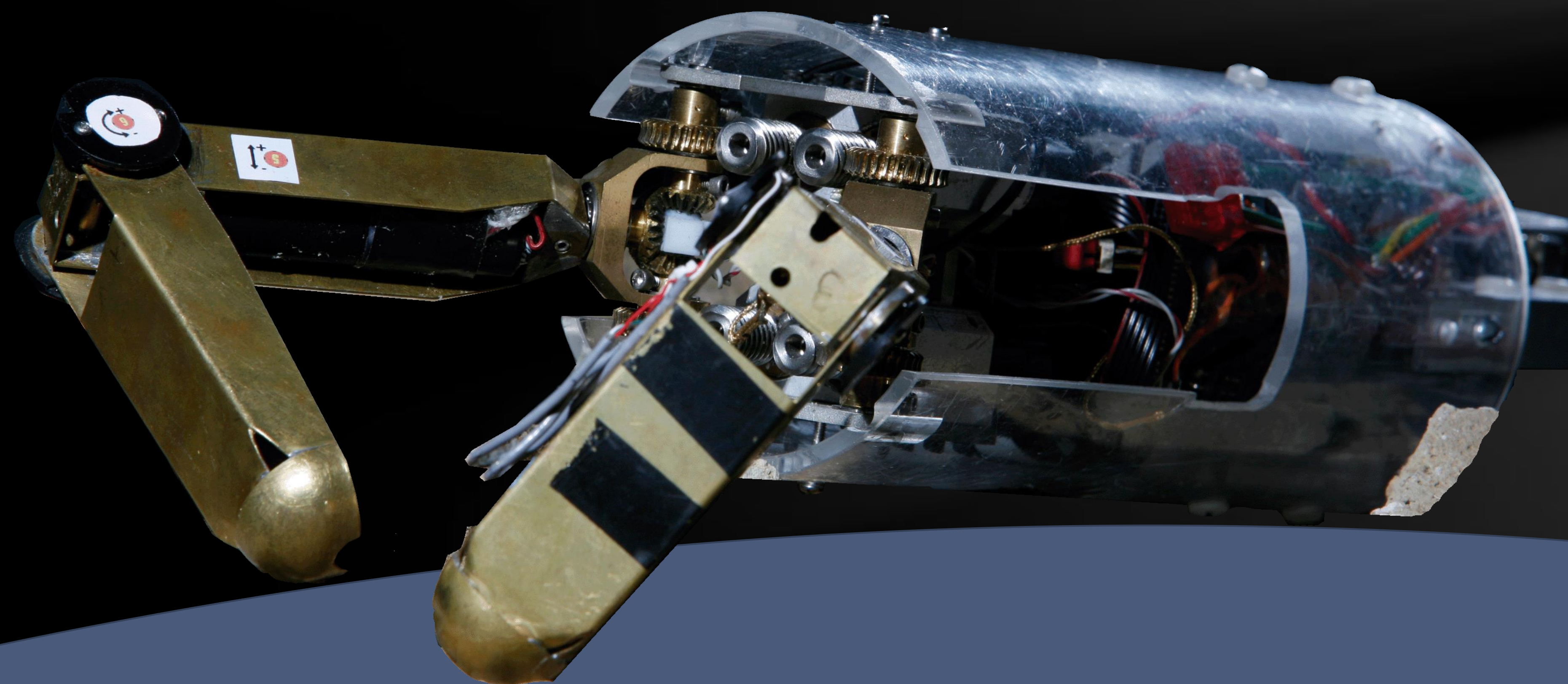


MOTHERSHIP Tread/Limb/Serpentine Hybrid

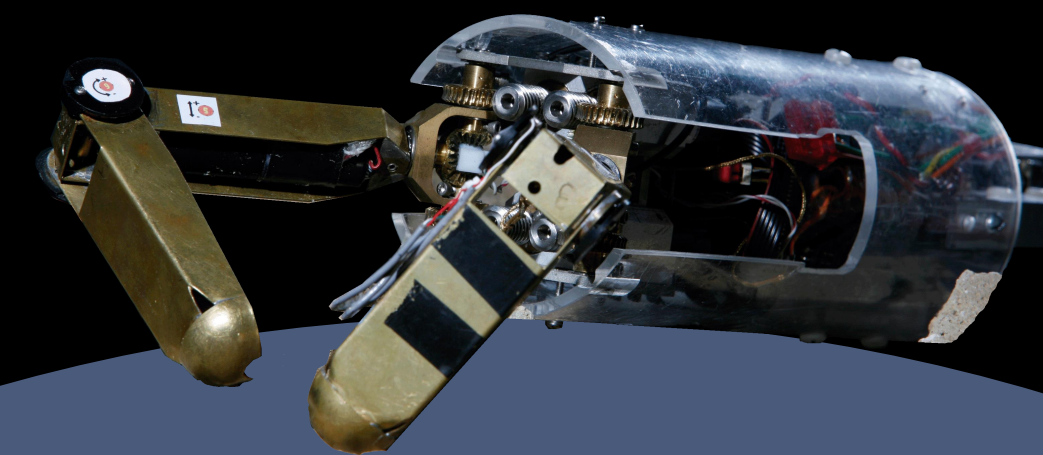
Modular Omnidirectional Tread Hybrid for Emergency Response with Serpentine and Holonomic Instantaneous Propulsion



Locomotion/Manipulation Duality

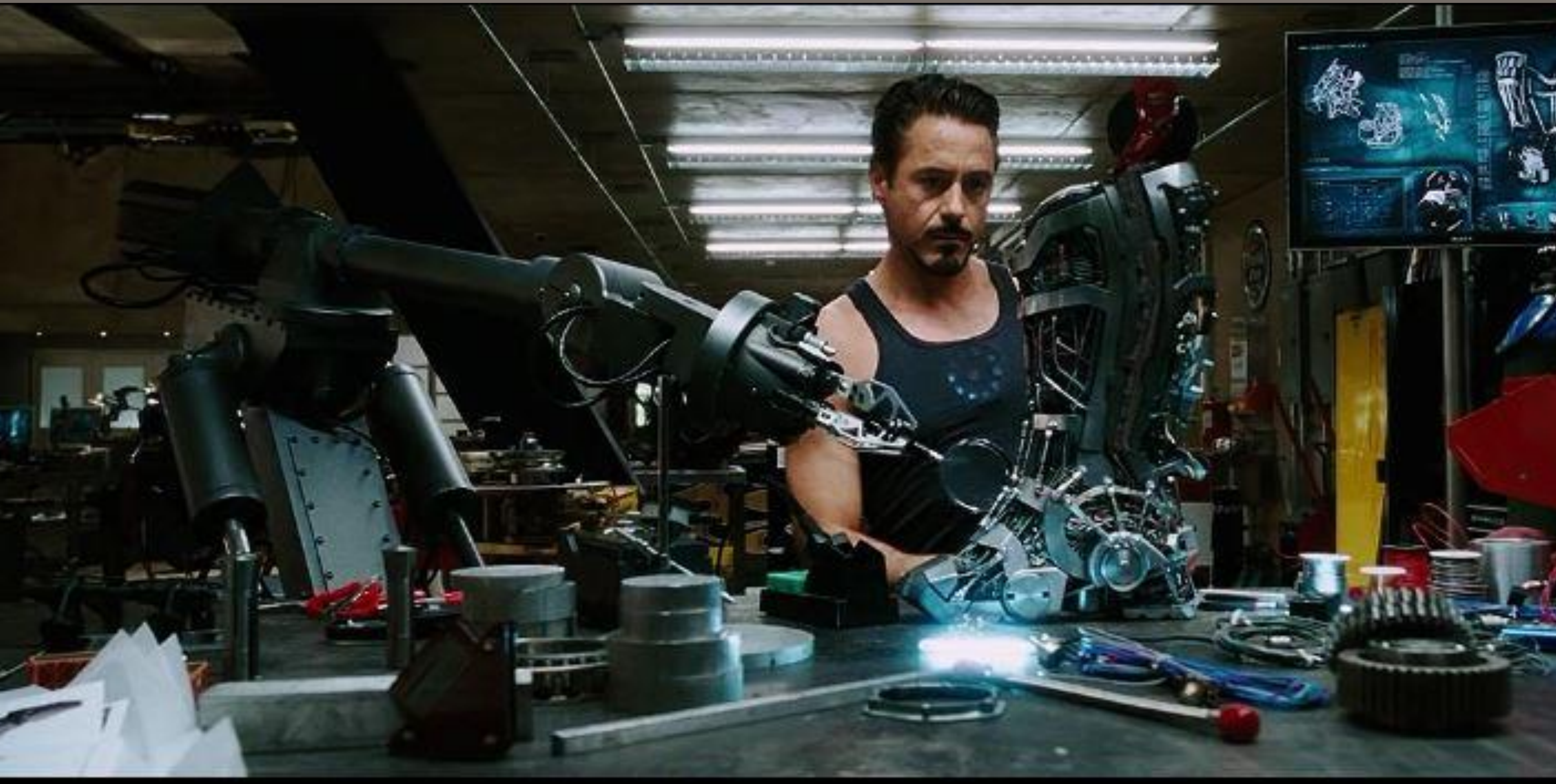


Locomotion/Manipulation Duality



Locomotion/Manipulation Duality

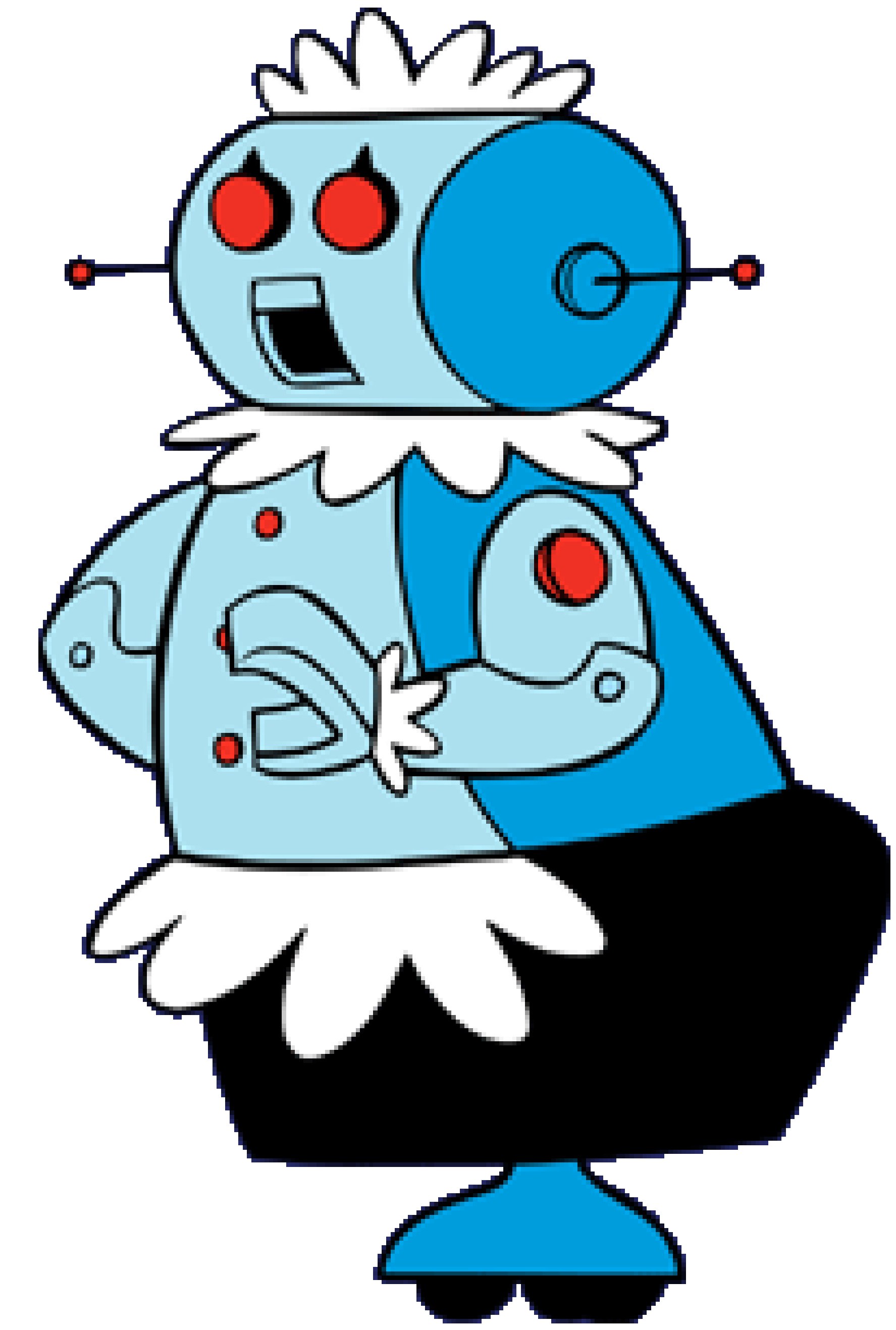
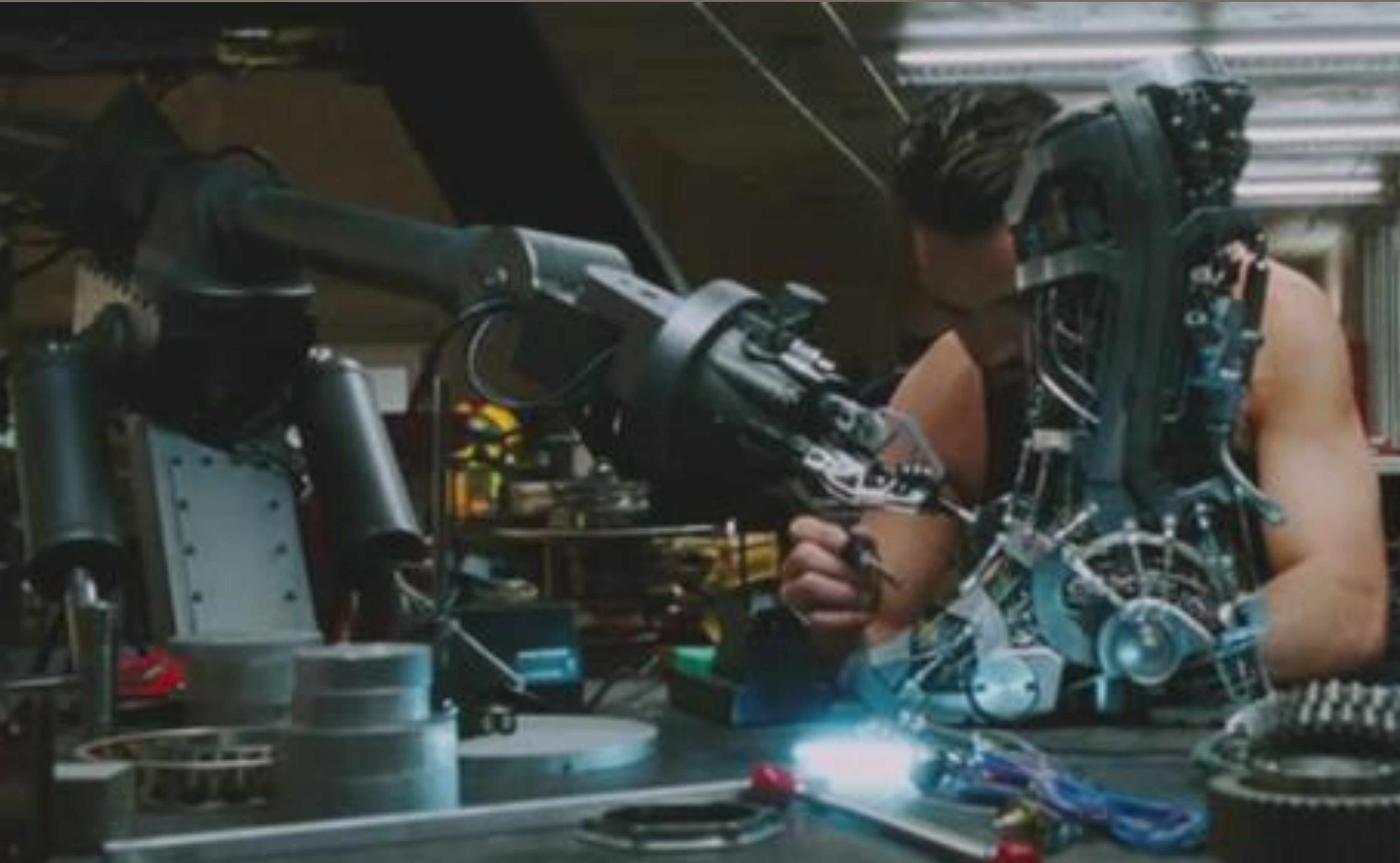




SCIENCE FICTION – WHAT HOLLYWOOD THINKS OF “INTUITIVE AUTONOMY”



INTUITIVE AUTONOMY FOR ROBUST AND TRUSTWORTHY COOPERATION



INTUITIVE ASSISTIVE TECHNOLOGIES SPAN THE GAMUT OF HUMAN AUGMENTATION

Design &
Programming



Intelligent
Maintenance



Physical &
Decision
Enhancement

Training &
Coaching



Digital
Manufacturing



Digital
Logistics



INTUITIVE AUTONOMY TRUSTED ASSISTANT TO INSPECT, TRAIN

PURDUE
UNIVERSITY®

Spoken Dialog System allows
hands-free interaction

Rear-projection avatar displays
complex emotion without
Mechatronics – portable
to mobile devices

Gesture-Based
Programming
with Intelligent
Coaching is
natural for task
experts

Activity Recognition for
assistance, inspection,
validation

Predict human intent:
Anticipate needs

Shared
understanding for
Augmented Reality

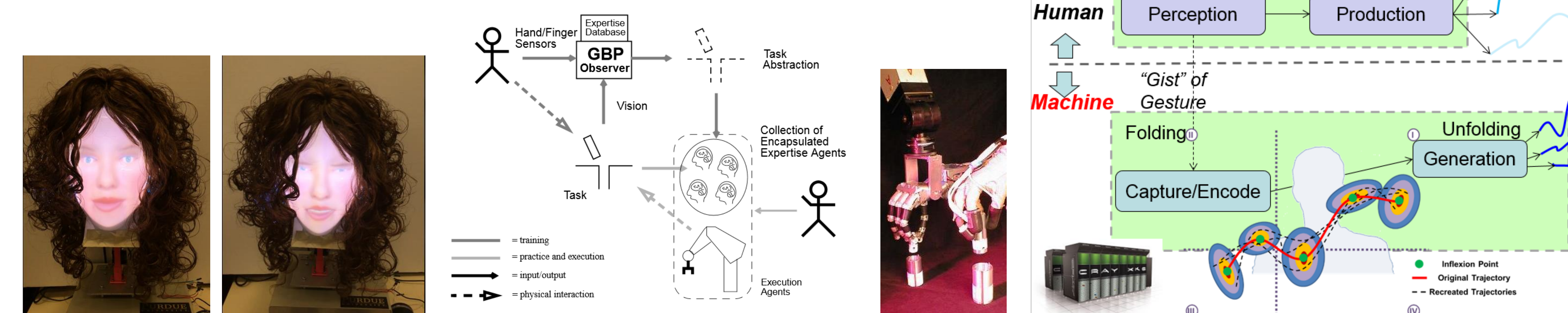


DIVERSE TEAM SPANNING TECHNOLOGY, ENGINEERING, COMPUTER SCIENCE, COMPUTER GRAPHICS, PSYCHOLOGY, LINGUISTICS, LIBERAL ARTS

Current and Ongoing Projects: Richard Voyles, Juan Wachs

Research themes: Social Robotics for Intuitive Communication and Intent

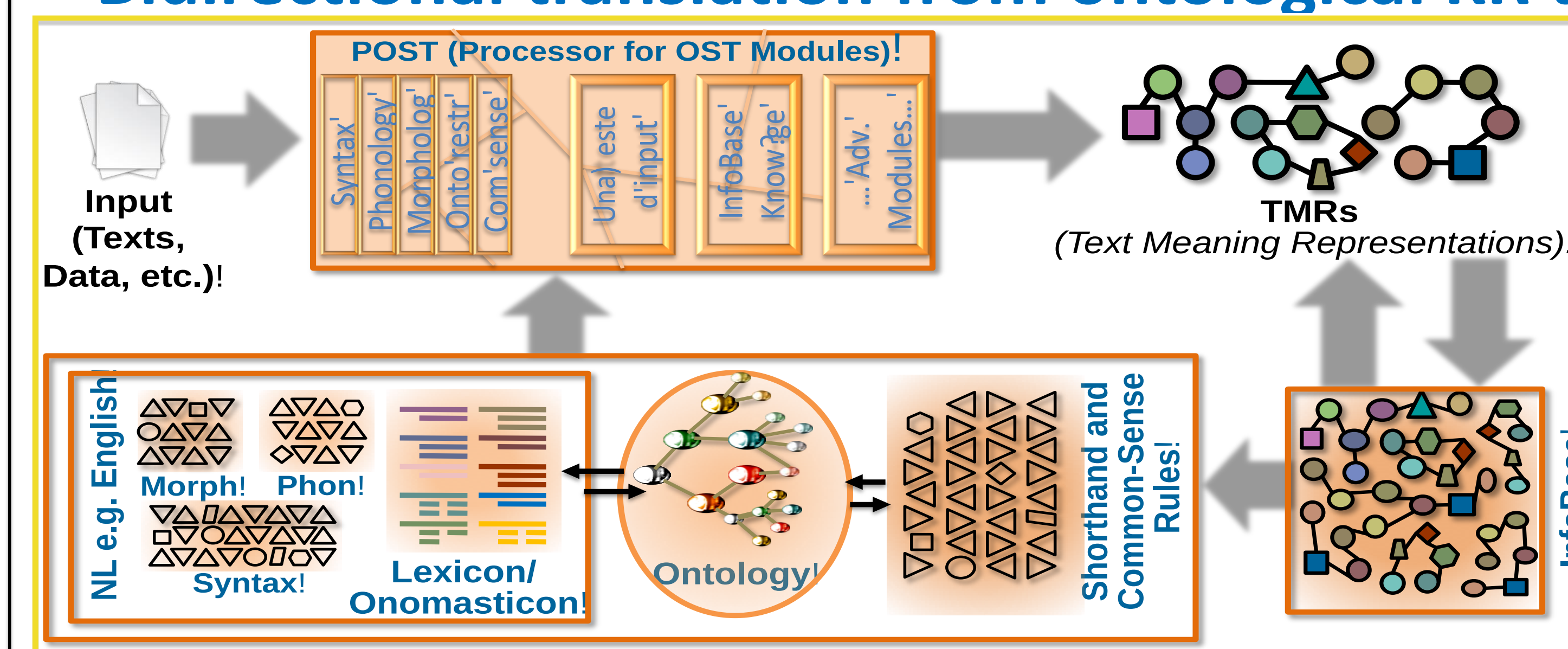
- Virtual and physical embodiments for intuitive and trusted interaction using gestures, natural language, and emotive recognition and display
- Activity recognition for shared understanding
- One-shot learning of gestures for coaching and refinement of Gesture-Based Programming



Current and Ongoing Projects: Julia Taylor, Victor Raskin

Research themes: Natural Language Understanding through Ontological Semantics

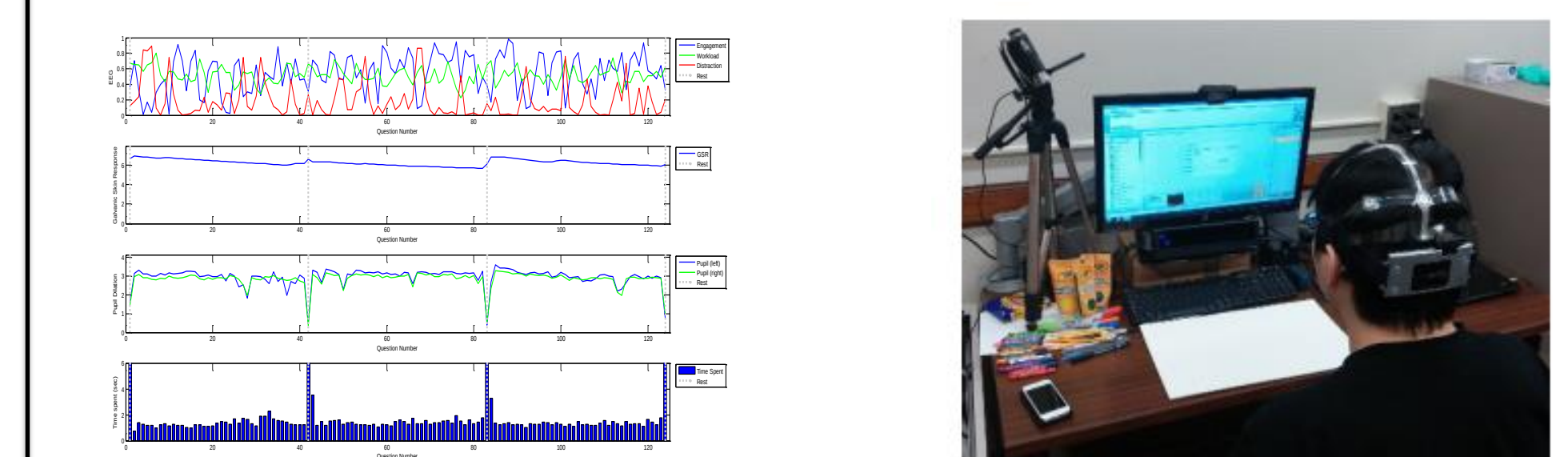
- Domain-relevant knowledge representation (KR) of the world
- Mapping between human and computer/robot knowledge bases
- Bidirectional translation from ontological KR to natural language



Current and Ongoing Projects: Tahira Reid

Research themes: Design Insights through Eye-Tracking and Sensors

- Dynamic trust modeling using psychophysiological data
- Dynamic Data-driven Approach for Modeling Human Error
- Reducing Inhibition to Sketch



Current and Ongoing Projects: Daniel Aliaga, Yingjie Chen

Research themes: Augmented Reality; Graphics & Visualization

- Provide in-situ augmented reality to the naked eye using digital projection over physical objects
- Many simultaneous viewers, arbitrarily shaped objects
- Uses perceptual psychology and advanced signal processing to enhance contrast and resolution
- Information visualization approaches to improve situational awareness between humans and multi-robot teams



Original Naked-Eye View

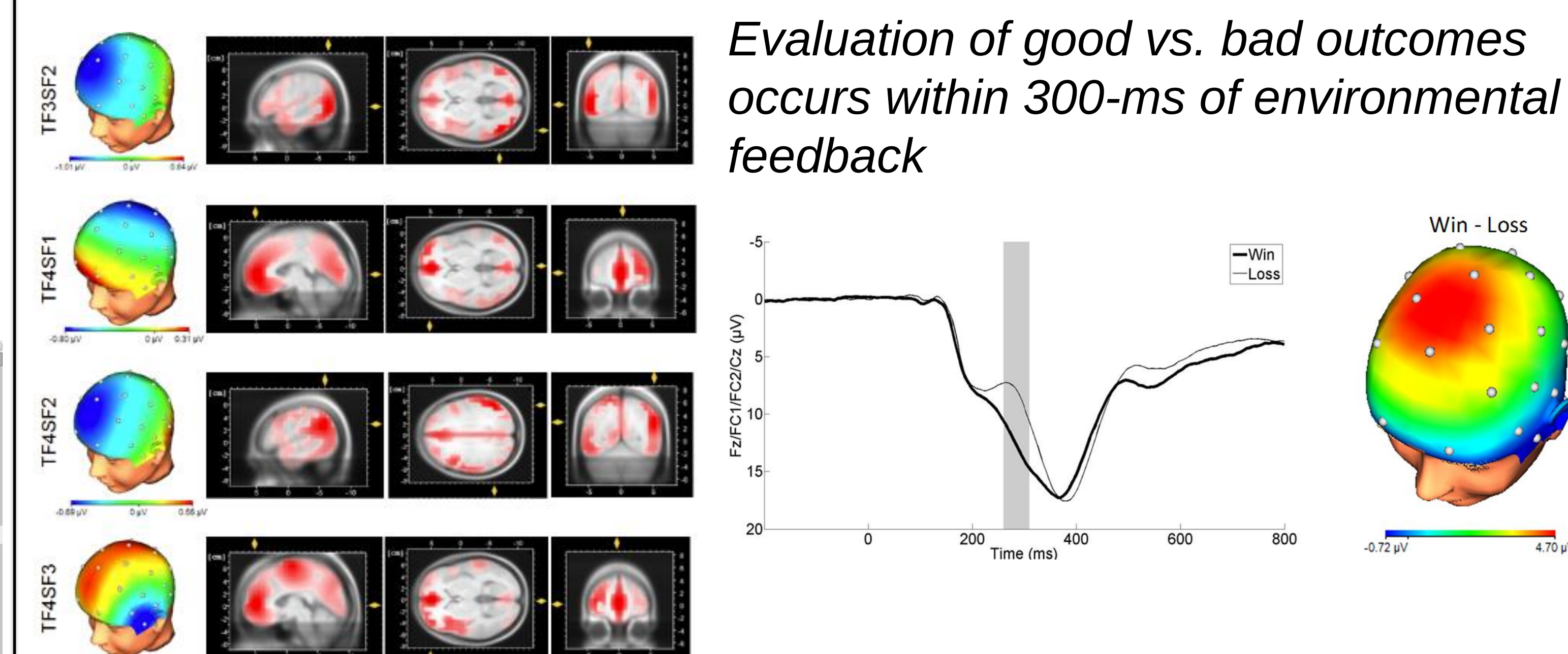
Enhanced Naked-Eye View

Human/Team Visualization

Current and Ongoing Projects: Dan Foti

Research themes: The Brain's Continuous Monitoring of Behavior

- Learning from natural consequences
- Anticipating speaker turn-taking

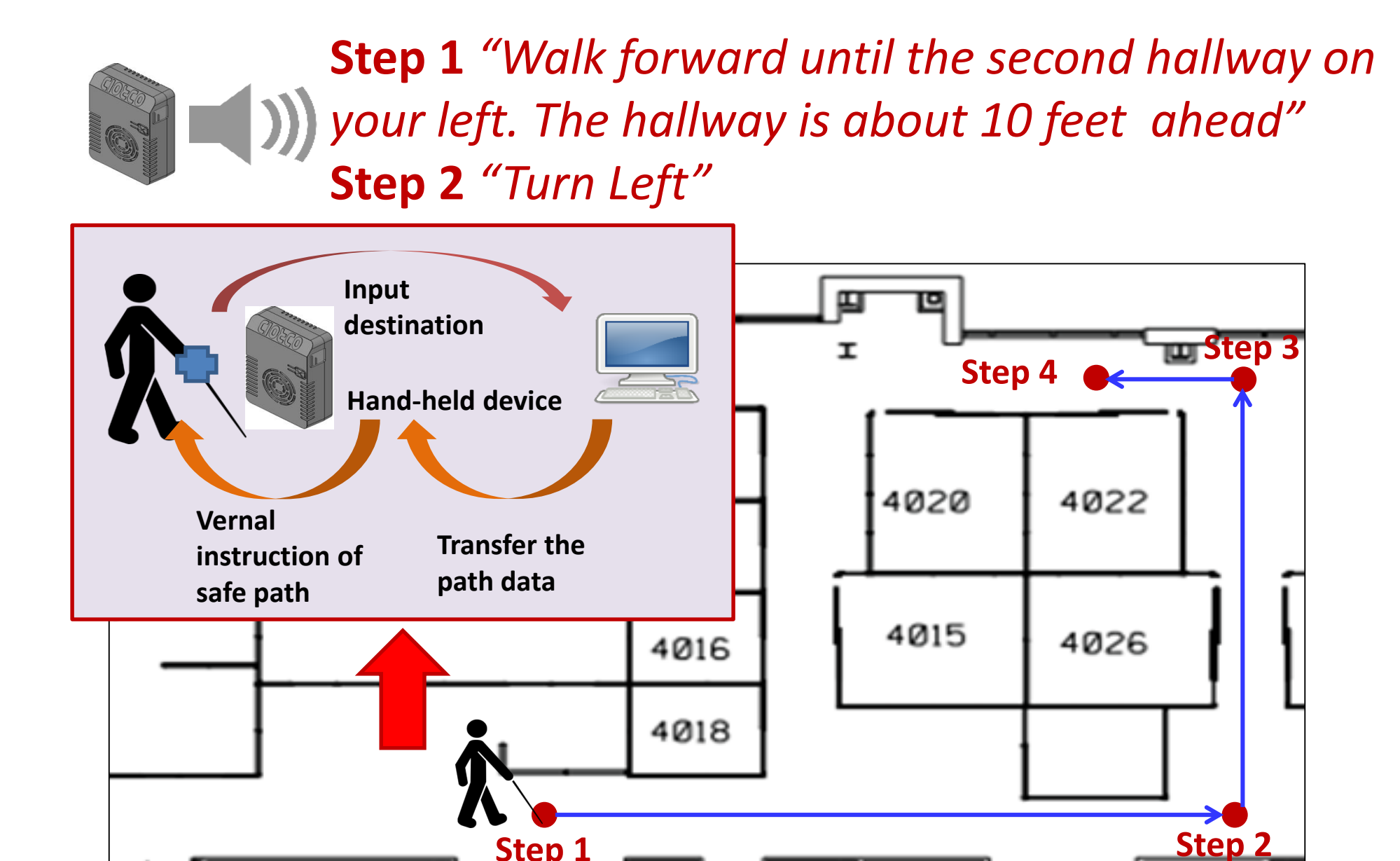


Processing of joint language—interactions between two or more individuals—relies on highly precise timing of natural rhythms and activity in multiple brain regions.

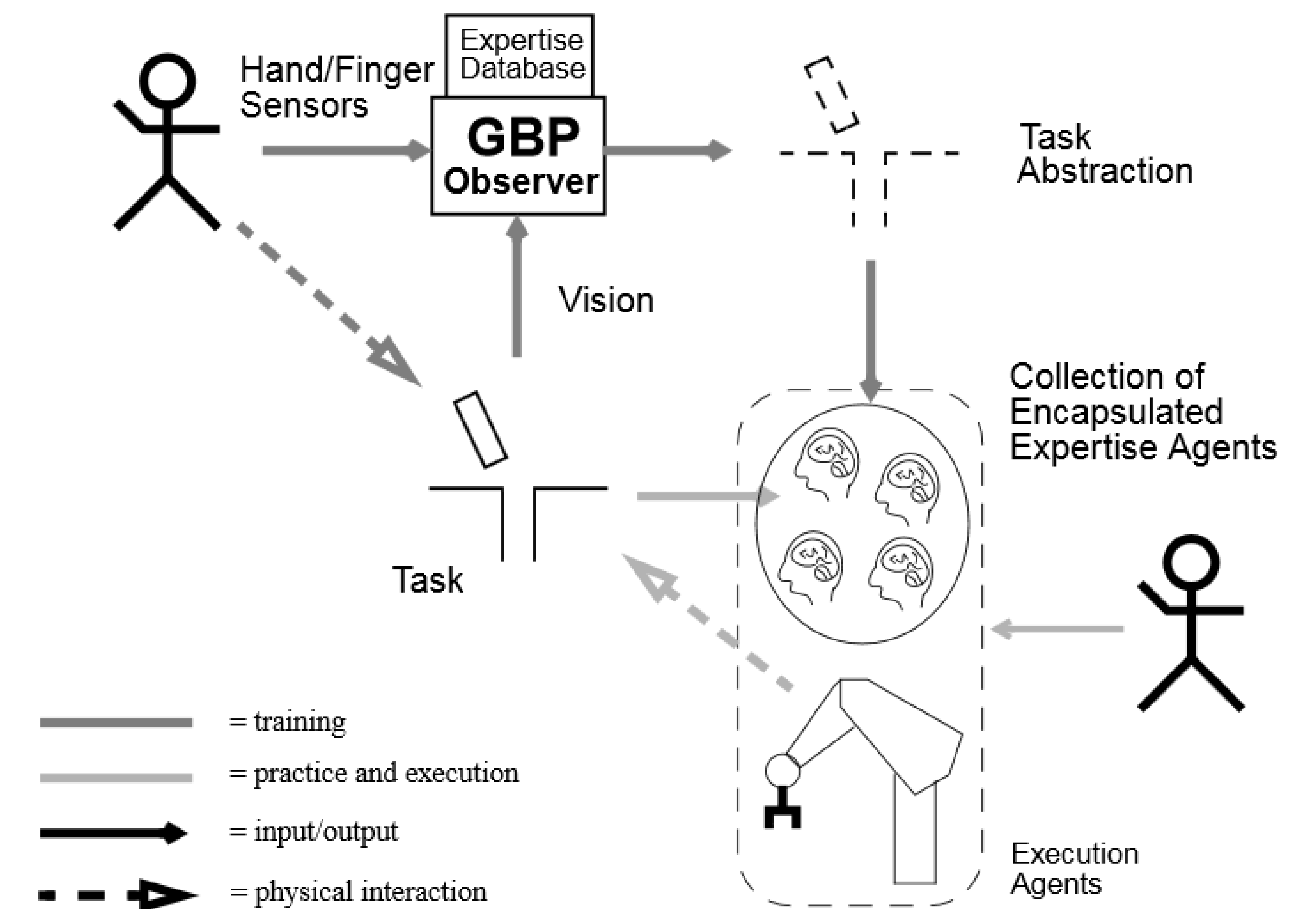
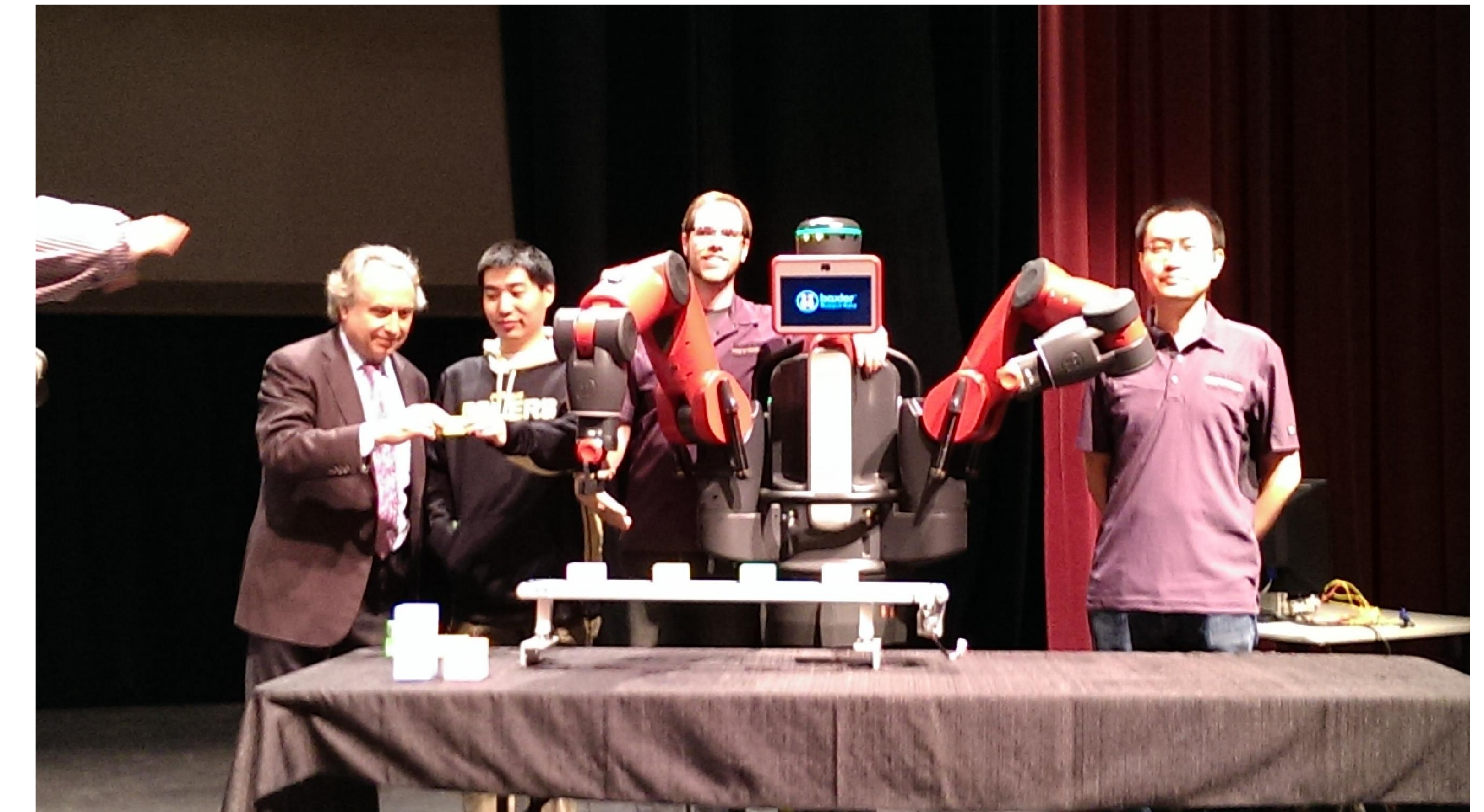
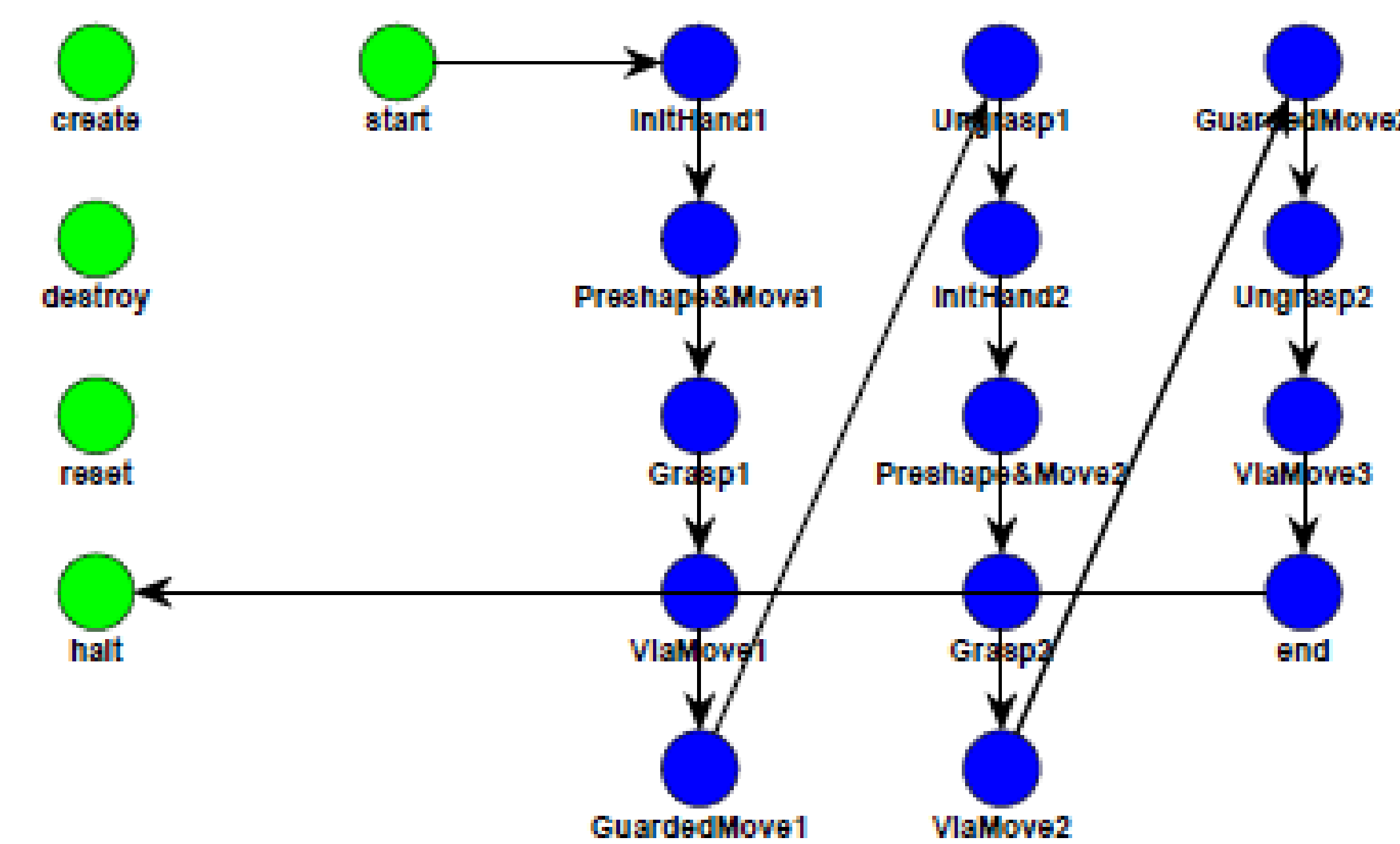
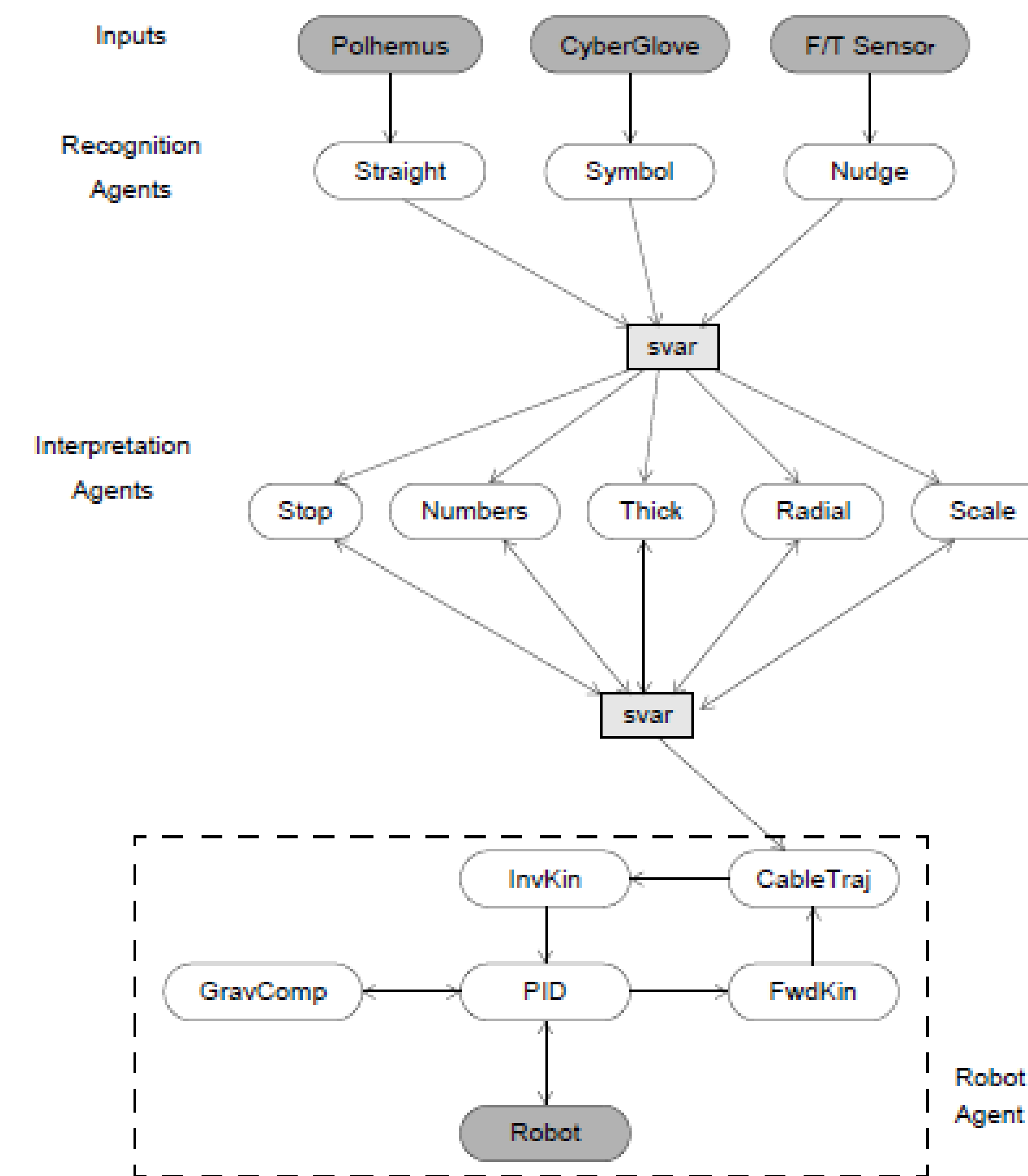
Current and Ongoing Projects: BC Min

Research themes: Assistive Technology and Robotics for the Blind

- Interactive navigation aid system for the blind in unknown environments
- Incorporating assistive navigation-related information from trusted sources
- Creating effective cooperation mechanisms



COMPUTER ENGINEERING -- GESTURE-BASED PROGRAMMING

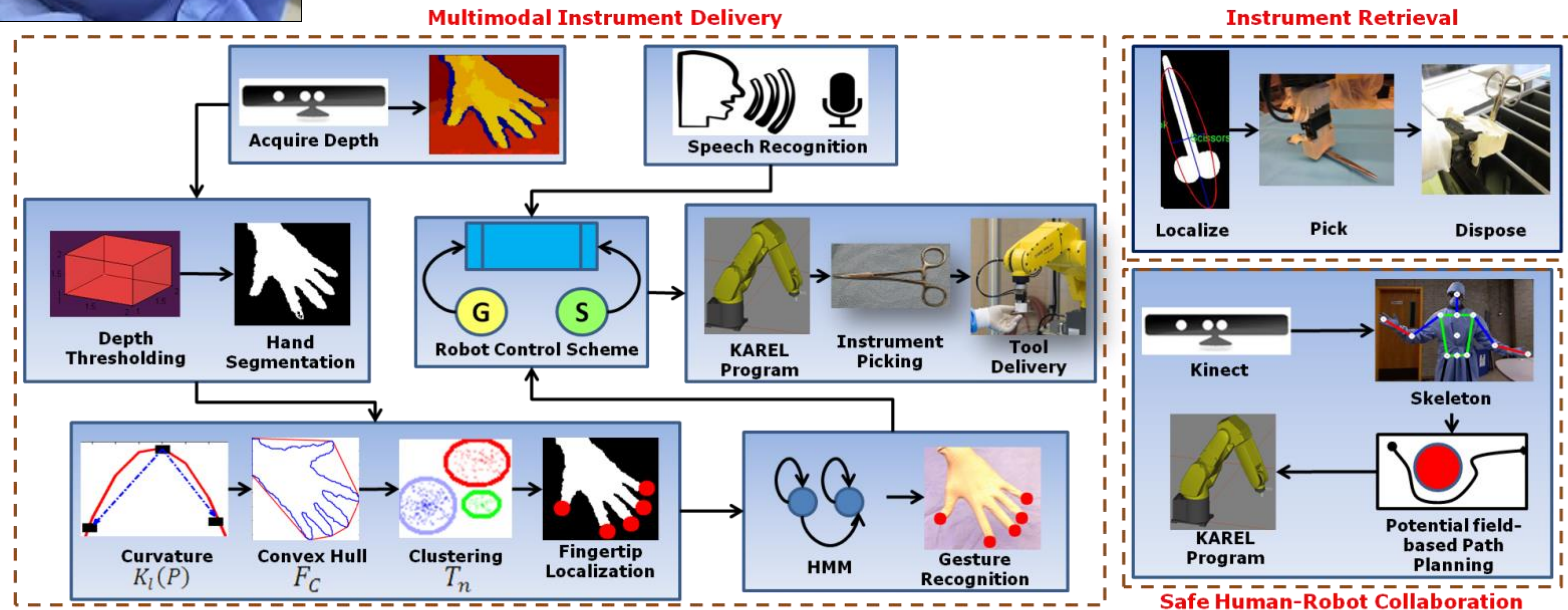




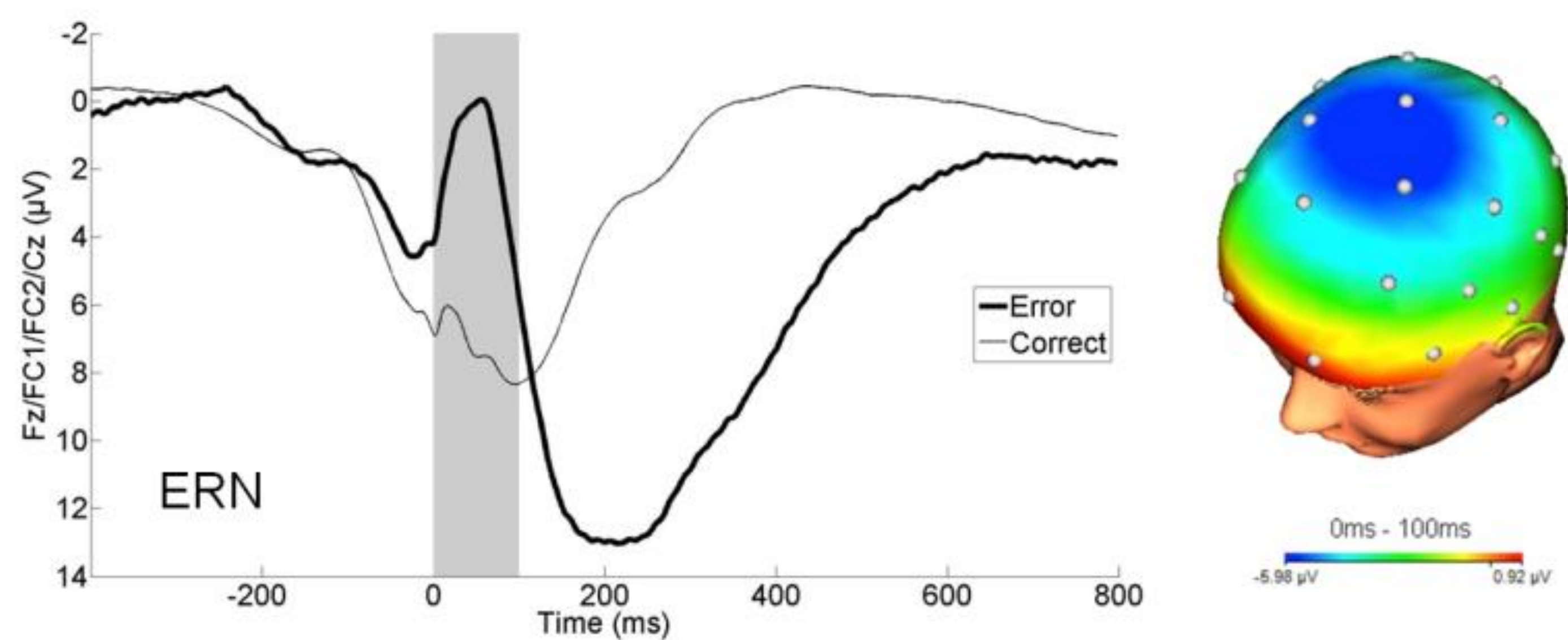
Robotic assistant that delivers surgical instruments according to multimodal requests

"Gestonurse: A Multimodal Robotic Scrub Nurse" Jacob, M; YT Li, Wachs, JP (2012). In *Proc. of the 7th ACM/IEEE International Conference on Human Robot Interaction (HRI 2012)*. March 5-8, 2012, Boston, Massachusetts.

Jacob, M.; Li, Y-T; Akingba, G., Wachs, J. 'Gestonurse' a robotic surgical nurse for handling surgical instruments in the operating room. *Journal of Robotic Surgery*. ISSN: 1863-2483. pp. 1-11, 2011.

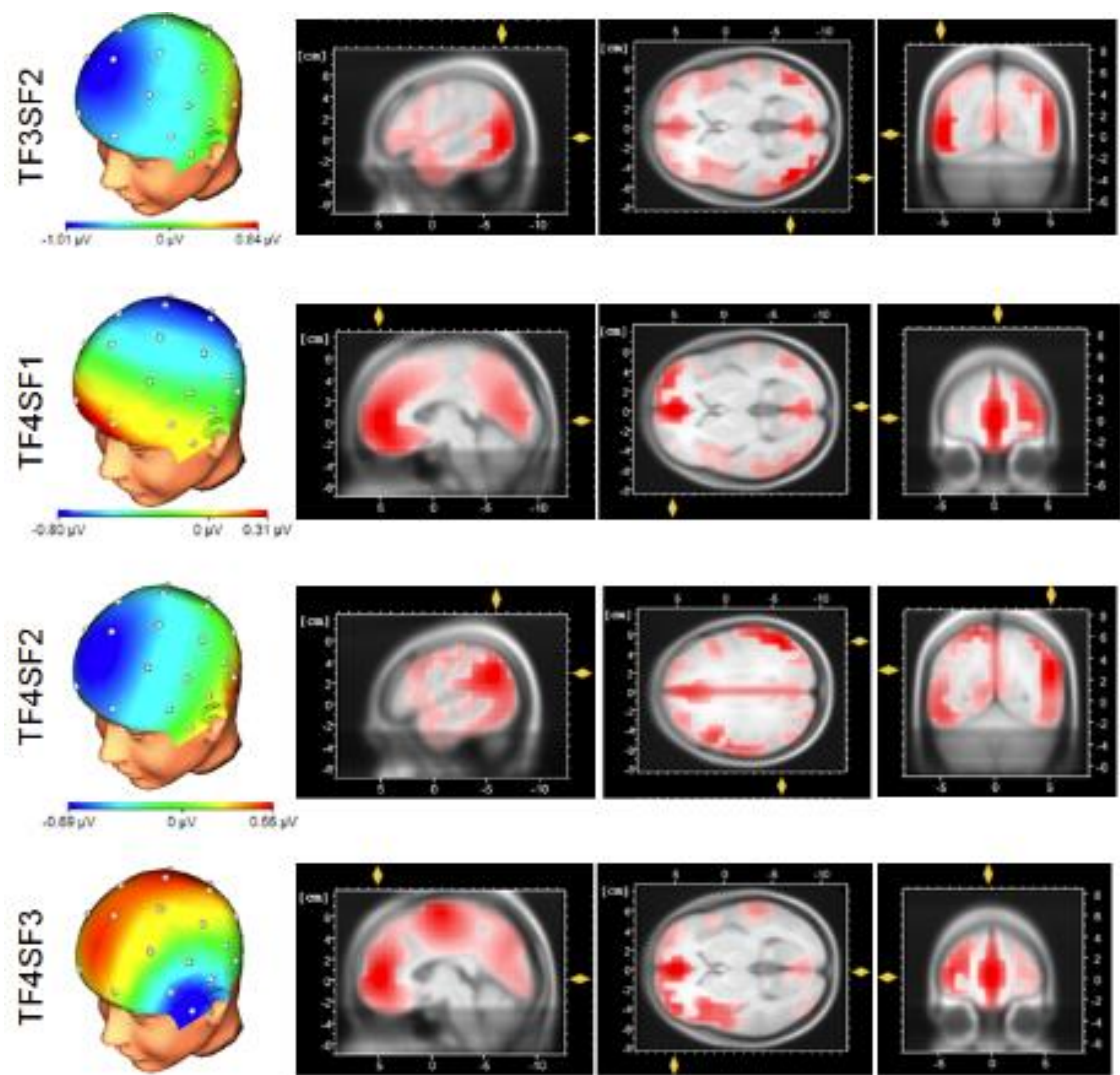
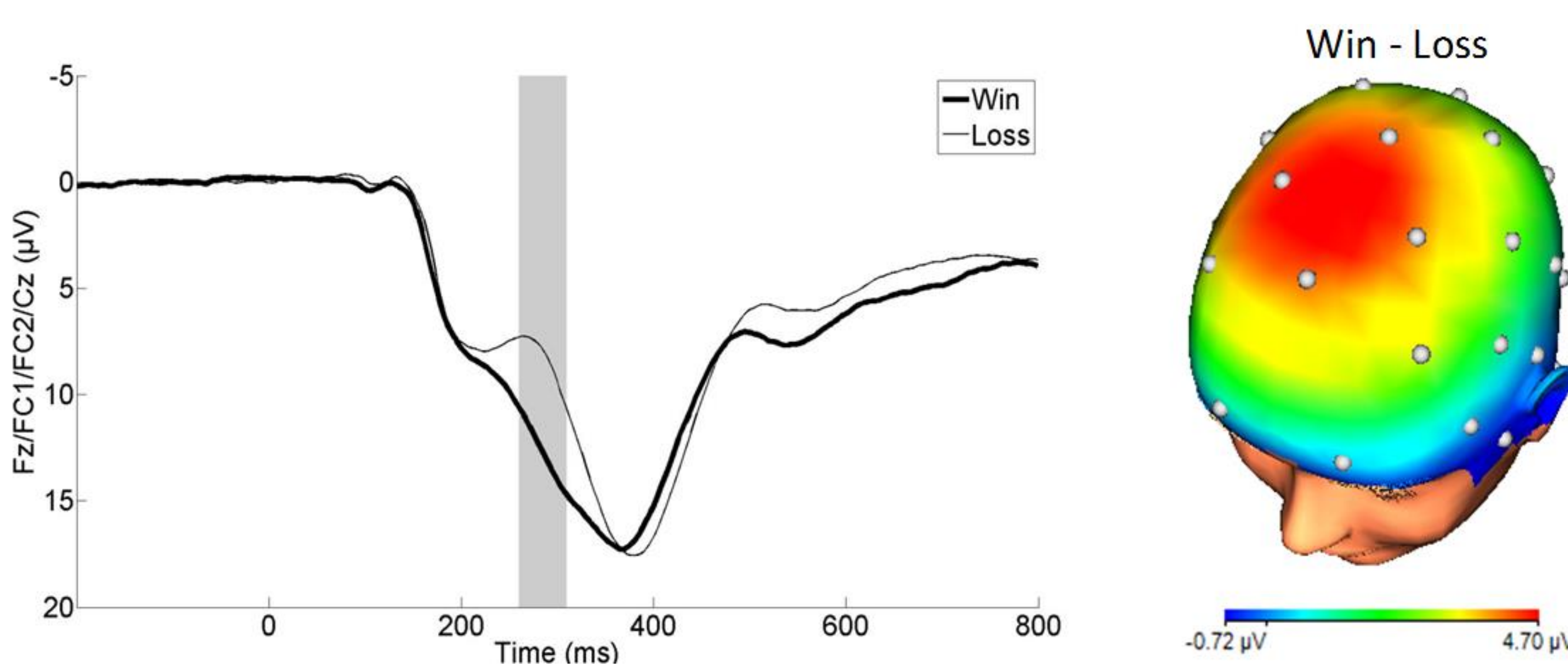


Examining automatic processes of feedback learning and error detection using neural measures



Errors: Pre-conscious, automatic detection occurs within 100-
ms of making an error, and is a critical process for dynamically
adapting behavior for survival.

Feedback: Evaluation of good versus bad outcomes
occurs within 300-ms of environmental feedback,
shaping subsequent decision-making and rule learning.



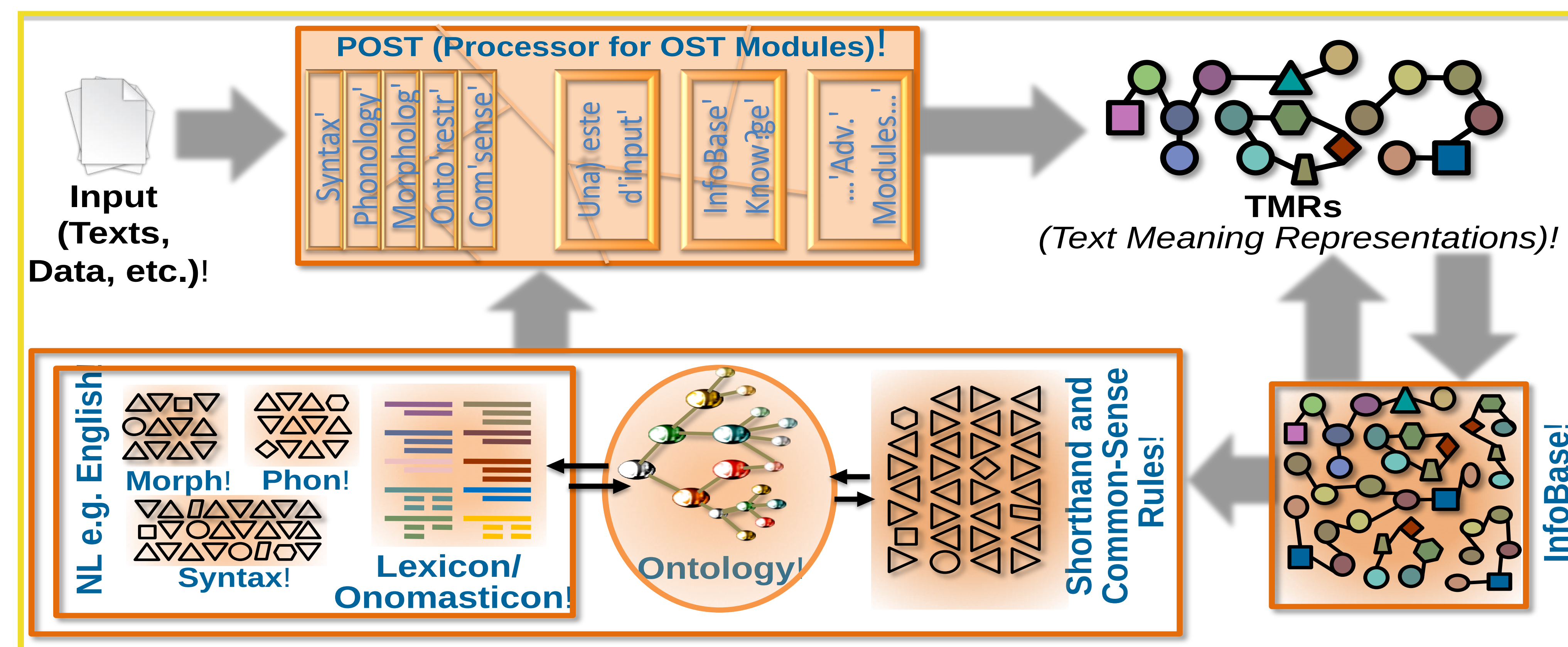
Processing of joint language—interactions between two
or more individuals—relies on highly precise timing of
natural conversational rhythms, and involves coordinated
activity across sensory, language, motor, and prefrontal
brain regions.



Dan Foti,
Assistant
Professor,
Psychology

Natural Language (NL) Understanding

- Informal communication between people and intelligent agents
 - Explicitly stated sentences/commands
 - Understanding of the unsaid/implied information
 - Handling of vagueness and uncertainty in language

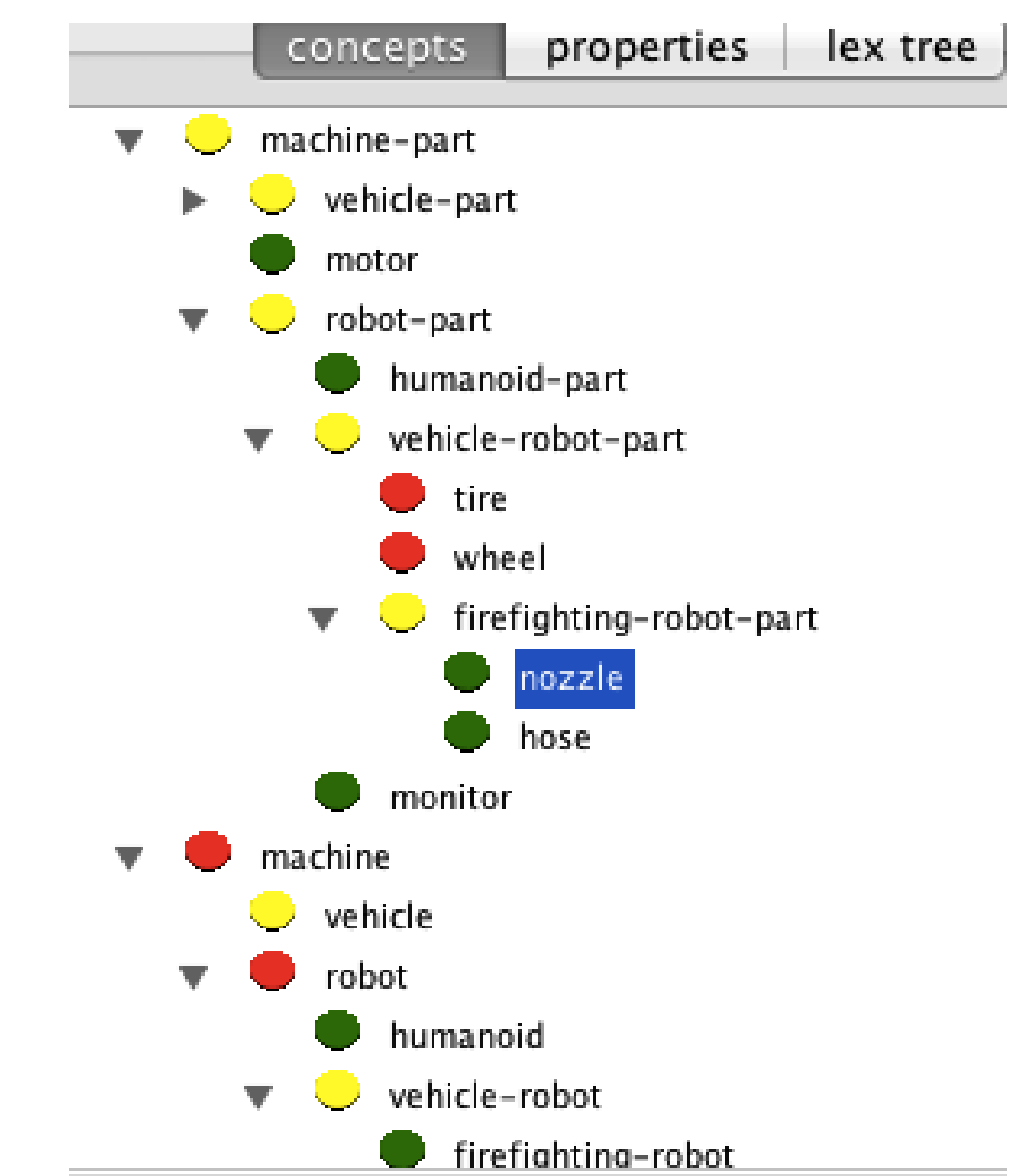


Knowledge Representation

- Ontological Semantics Technology
- Common Sense Knowledge & Fuzzy Logic
- Automatic knowledge acquisition
- Reasoning

NL Communication in Different Contexts

- NL communication with robots (firefighting domain, English & Korean)
- Processing information of various grain sizes, including anonymization of records
- Handling non-serious communication, including humor



Victor Raskin,
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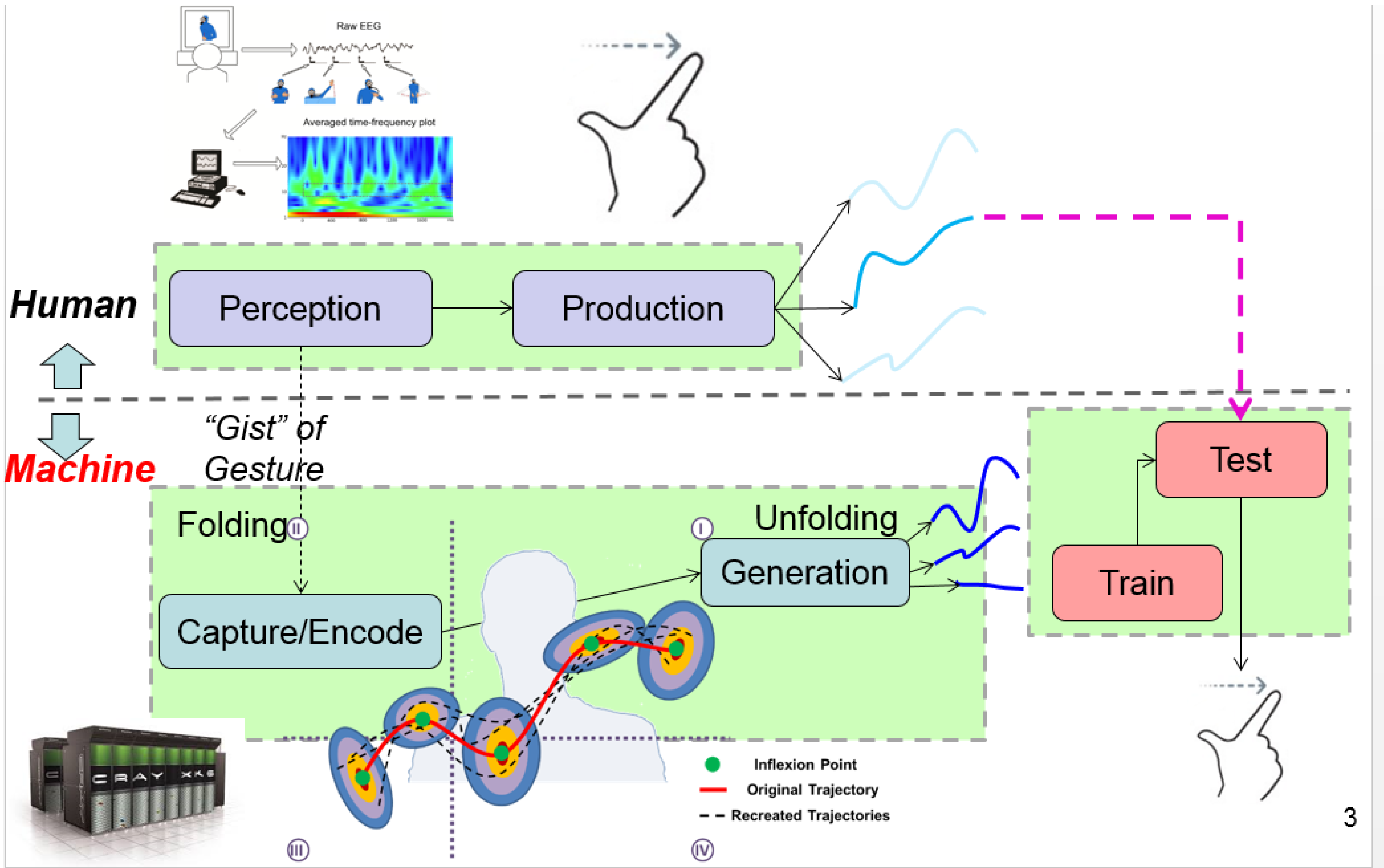
Julia Taylor
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Gestures and Speech for Whole-Body Communication

- Model the variance of the gesture generation process
- Create an artificial (human-like) dataset from one given example, designated to **portray the variability of human behavior**
- Train a generic classifier in real-time.

Our hypothesis is that including context information (body shape, kinematics and, ergonomic and biomechanical constraints), robust recognition of spontaneous gestures can be achieved.

Methodology



Motivating Questions

- How to interpret fleeting or novel gestures in one instance for more natural interaction?
- How to validate intention with whole-body communication?

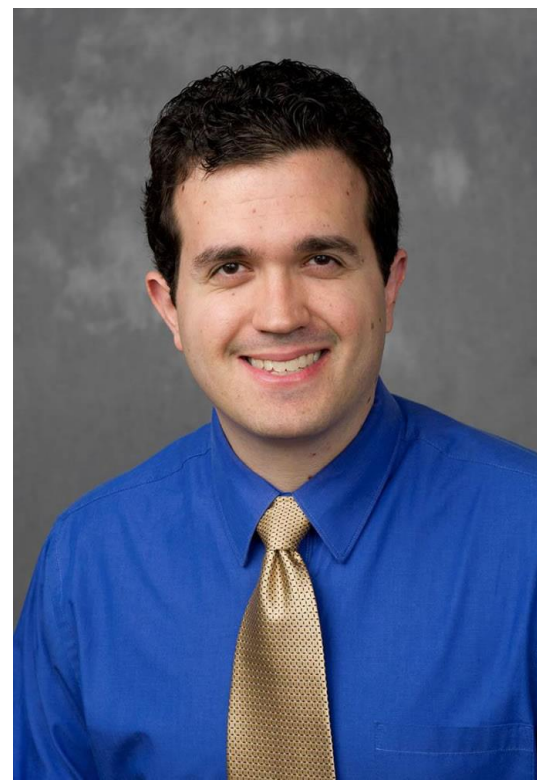
Interdisciplinary Team



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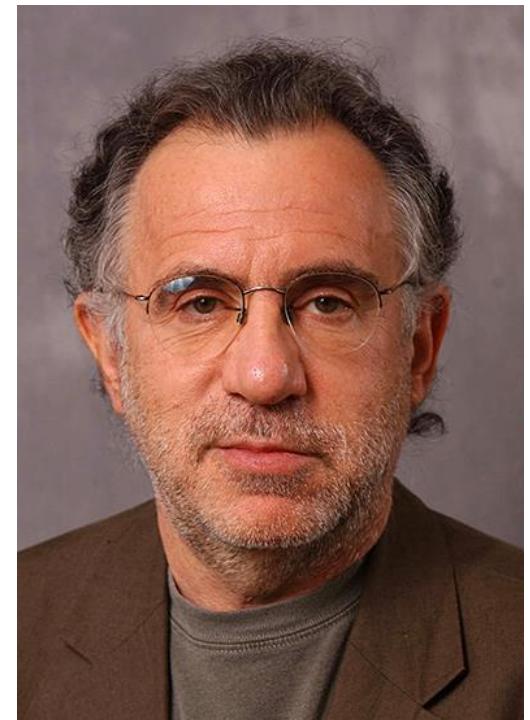
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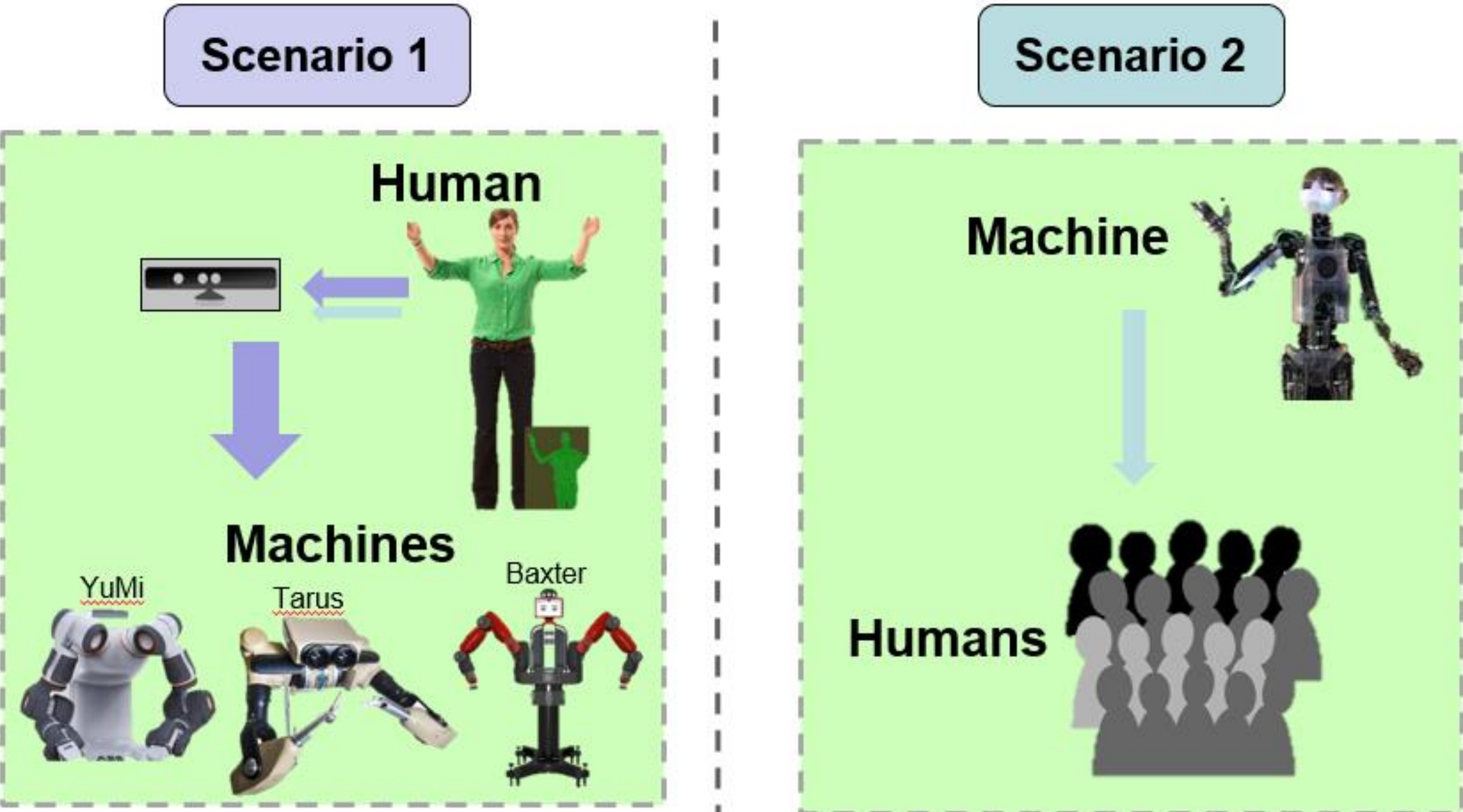
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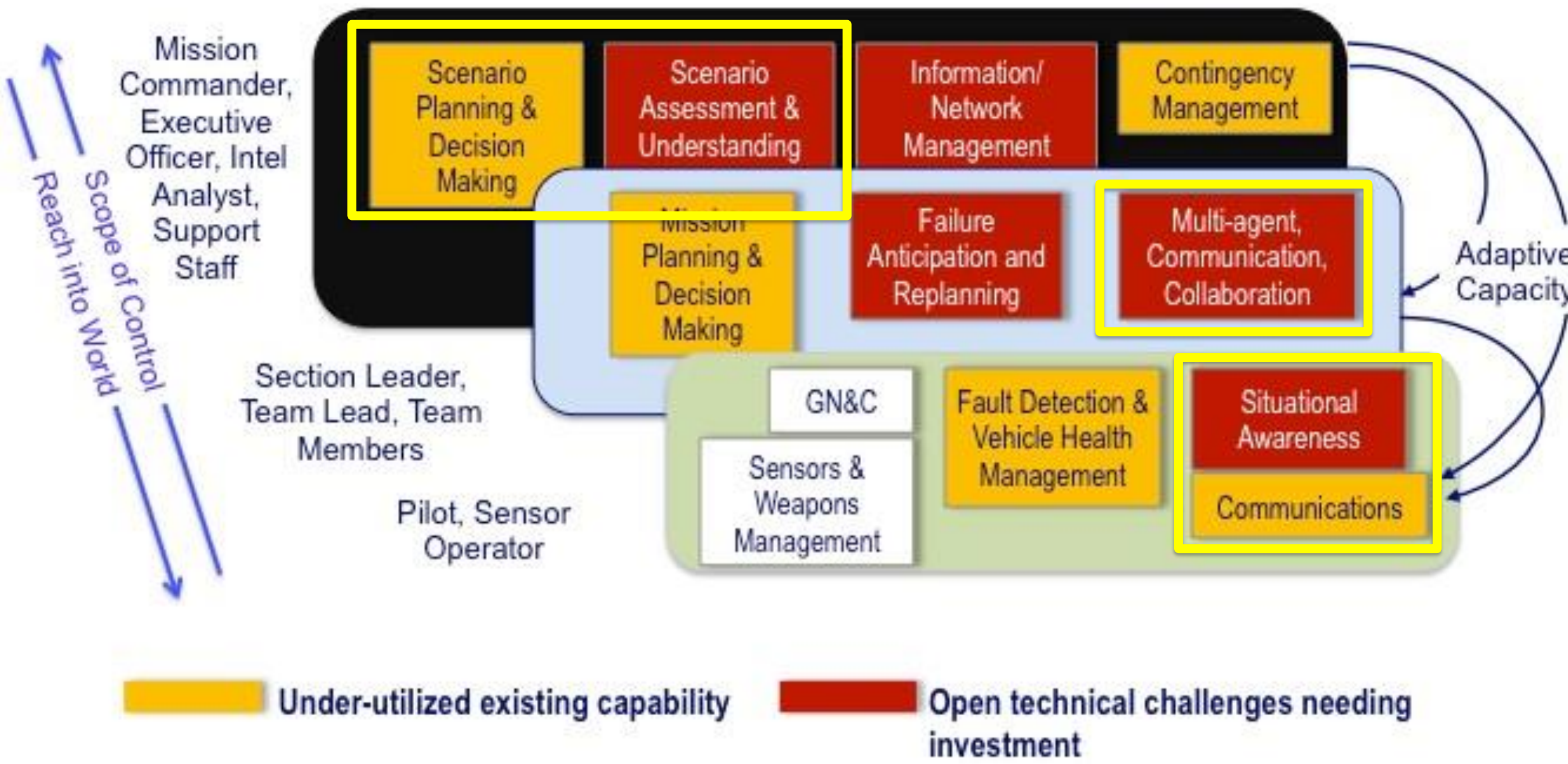
Experimental Validation

Two scenarios were considered to test the trained classifier using “the gist of the gesture”.

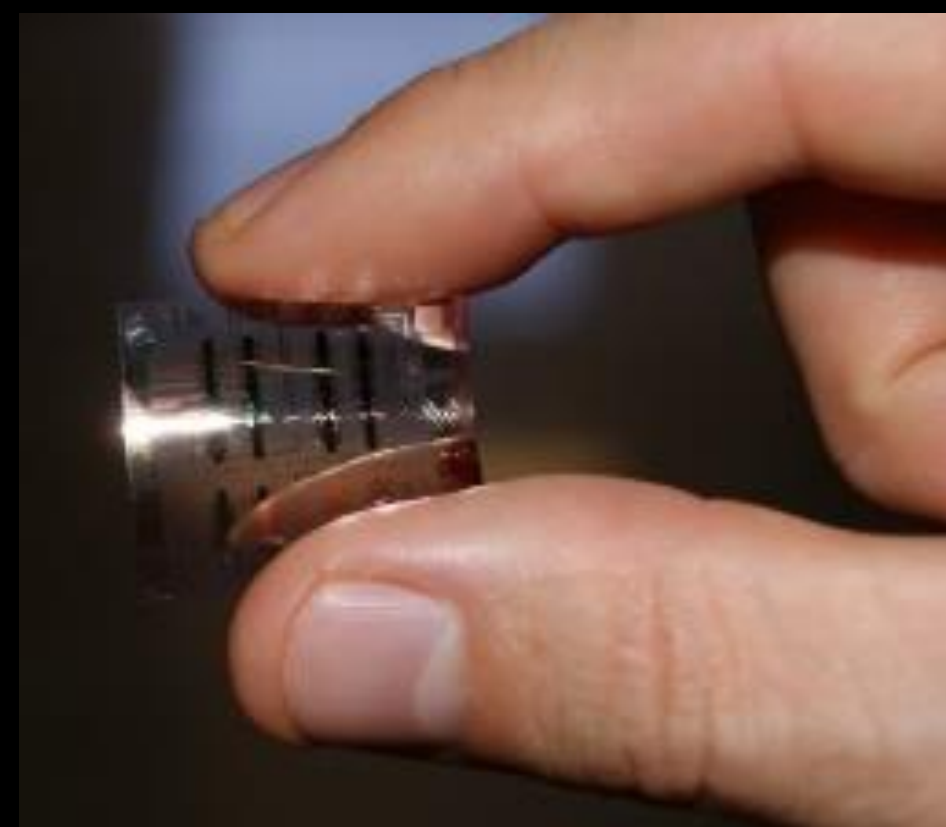
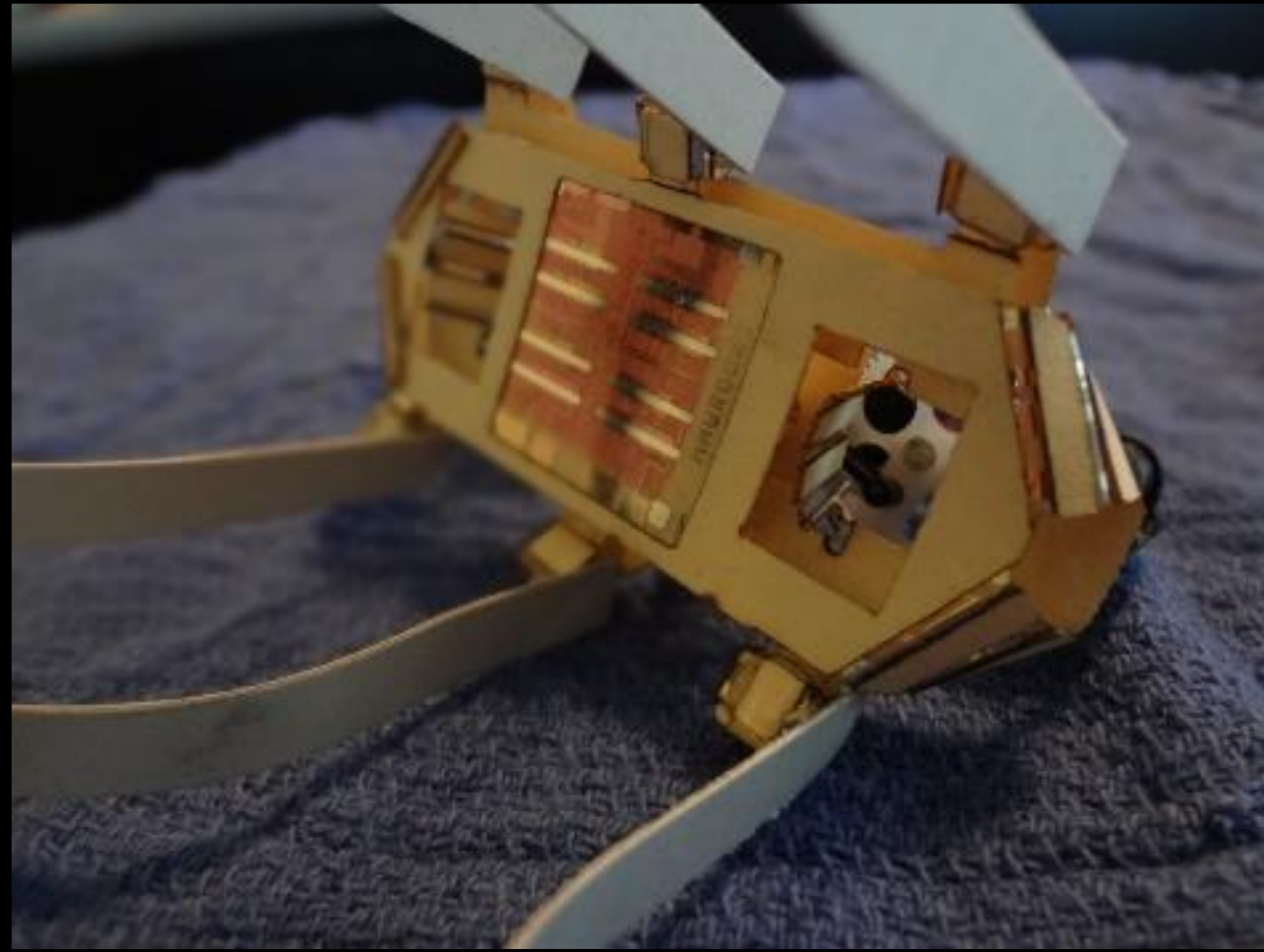


- Skeleton joints of user (torso, hand gestures) detected with Kinect
- 3D point in Kinect’s coordinates for each of Baxter’s end effectors

Areas for Automation in Air/Space/Logistics



What will Robotics 3.0 Bring?

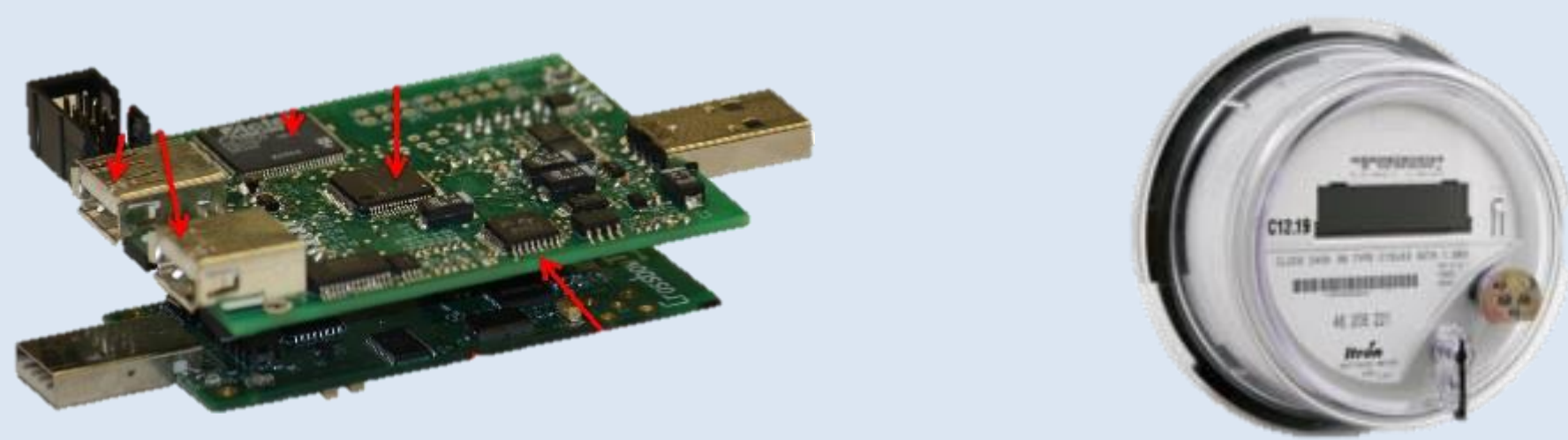


PURDUE WIDE – SUPER BAXTER

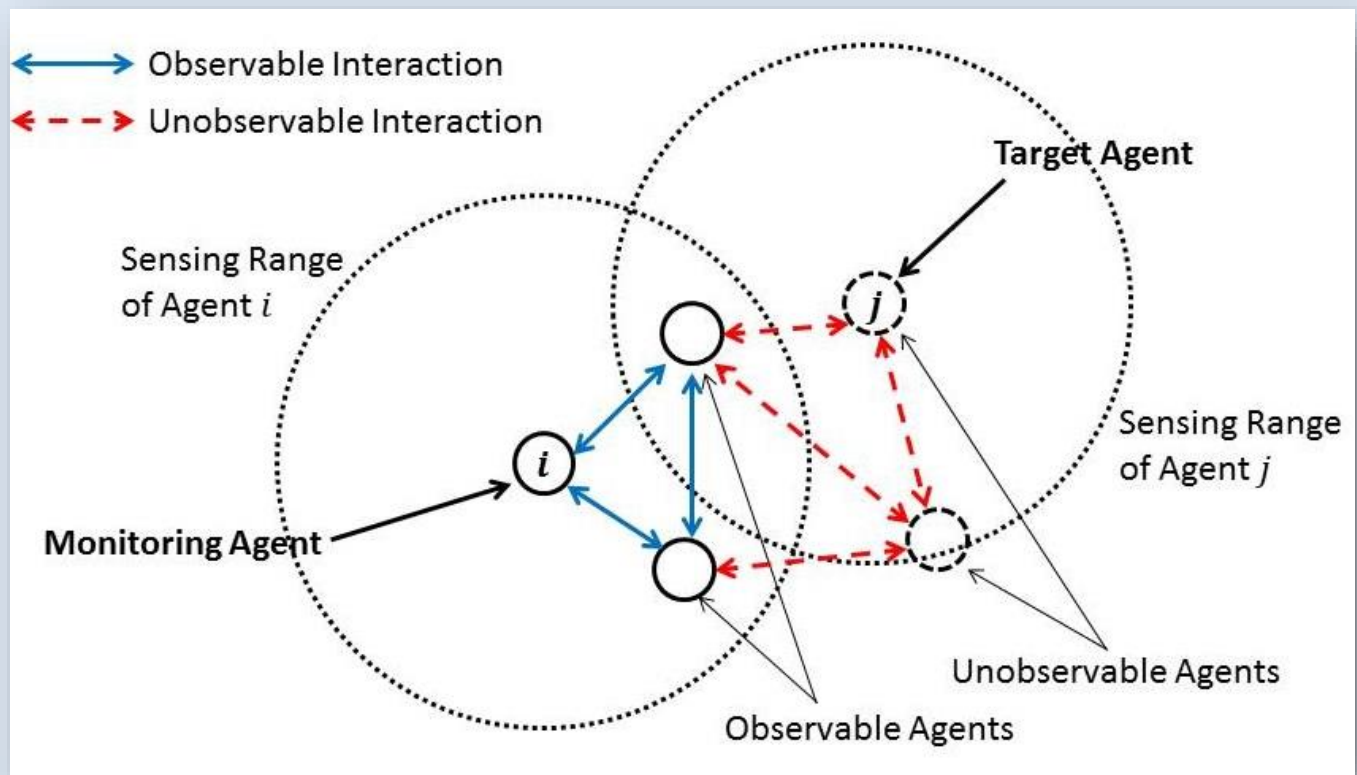


REAL-TIME DIAGNOSTICS

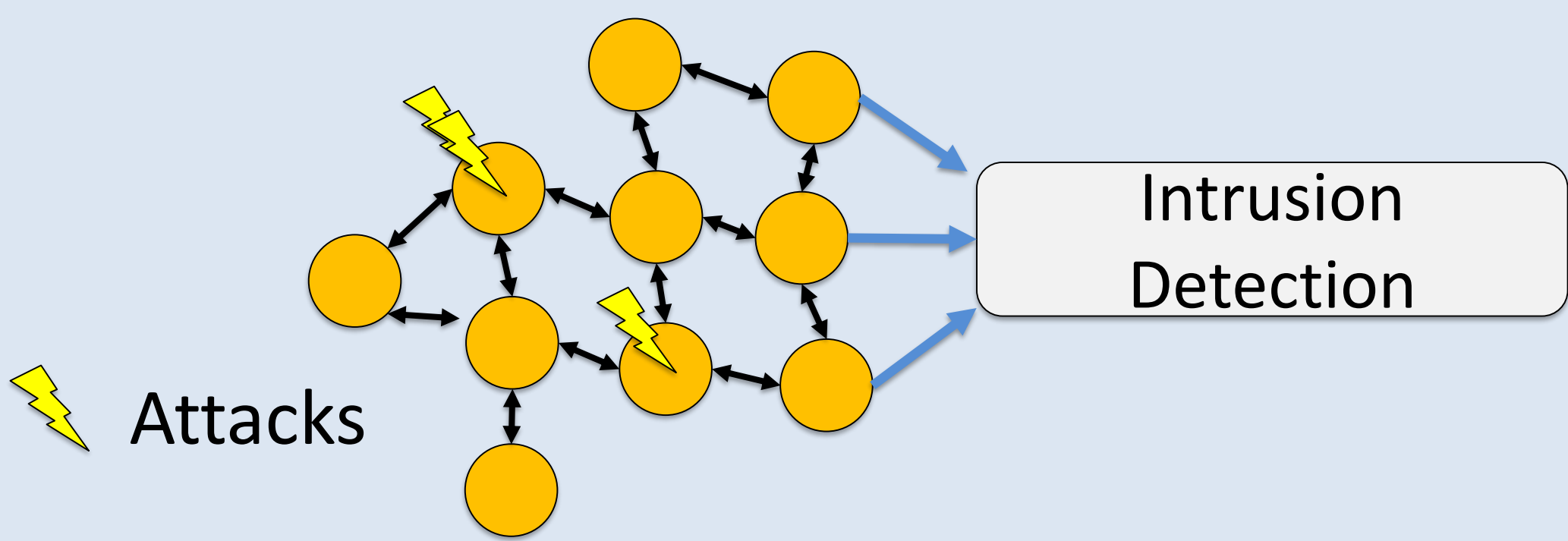
High-fidelity record and replay for debugging and diagnosis of embedded devices (SB)



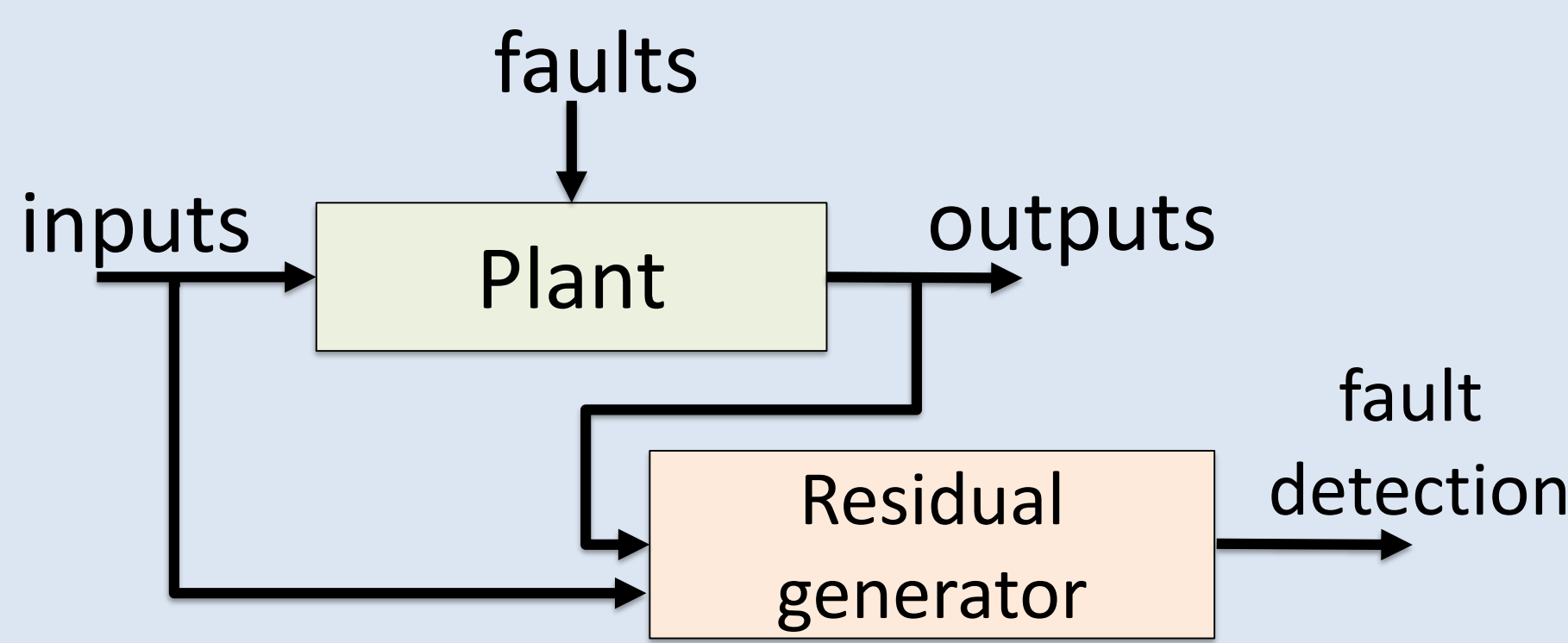
Real-time security and safety diagnosis for autonomous systems (IH, JH, SS)



Theory and distributed algorithms for intrusion detection (SB, SS)

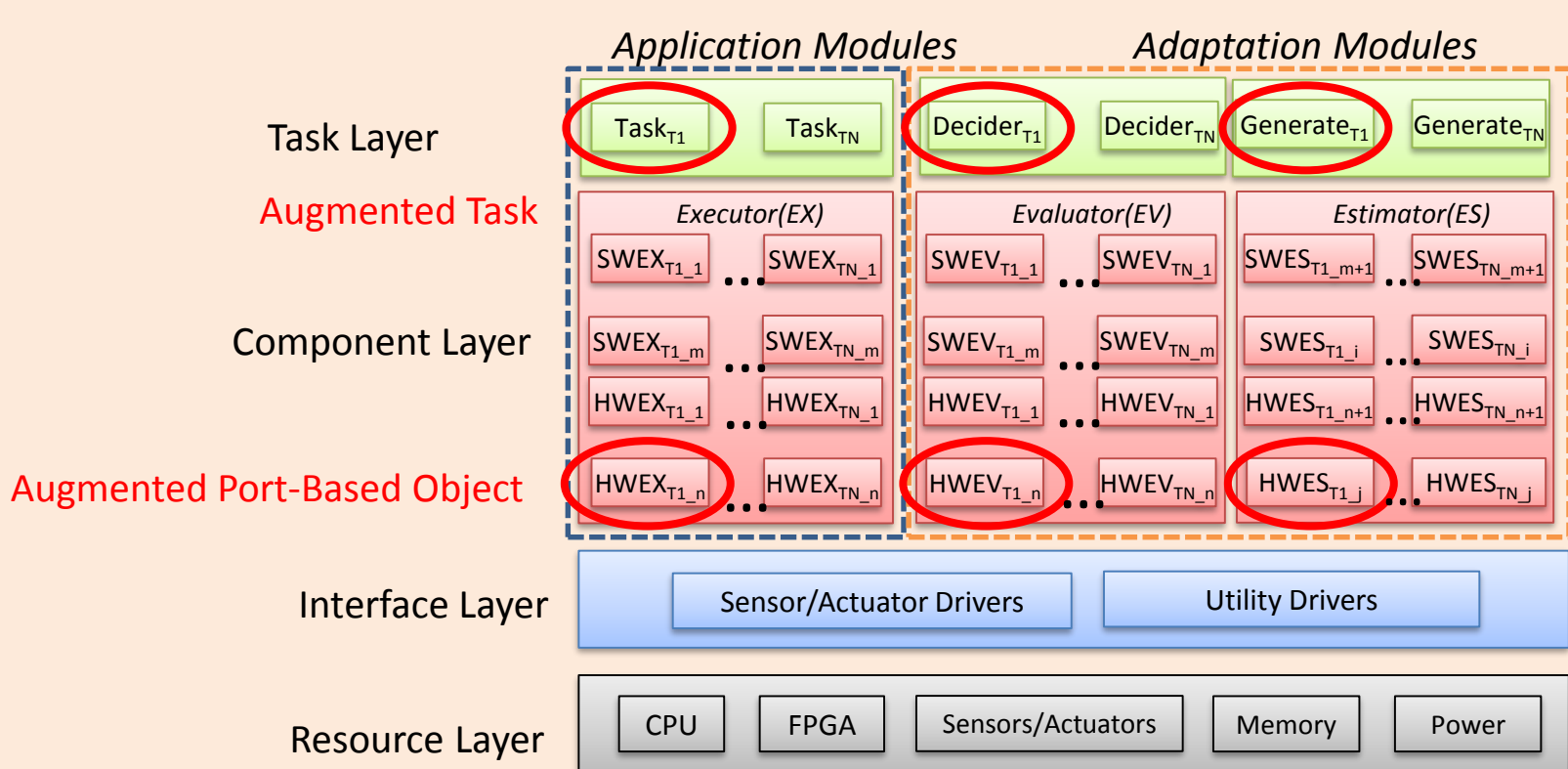


Model-based fault and attack detection for control systems (IH, SS)

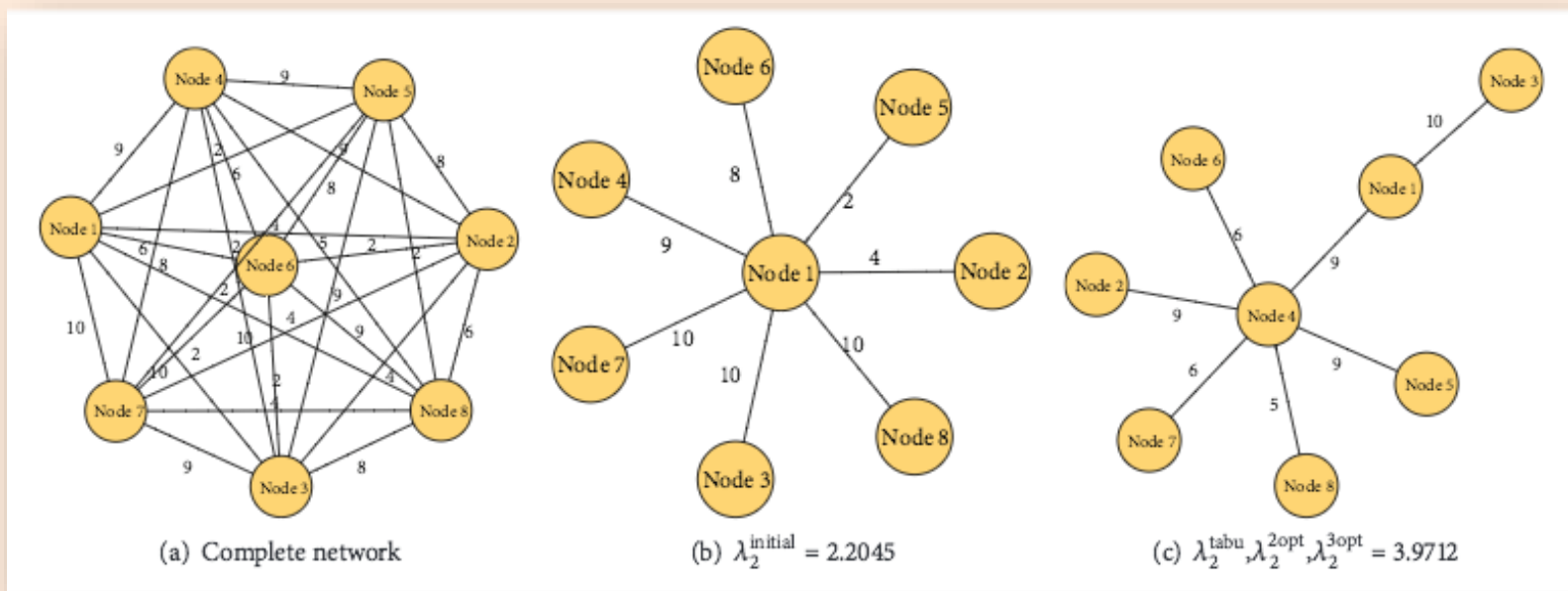


SELF-HEALING, REAL-TIME ADAPTATION AND CONTROL

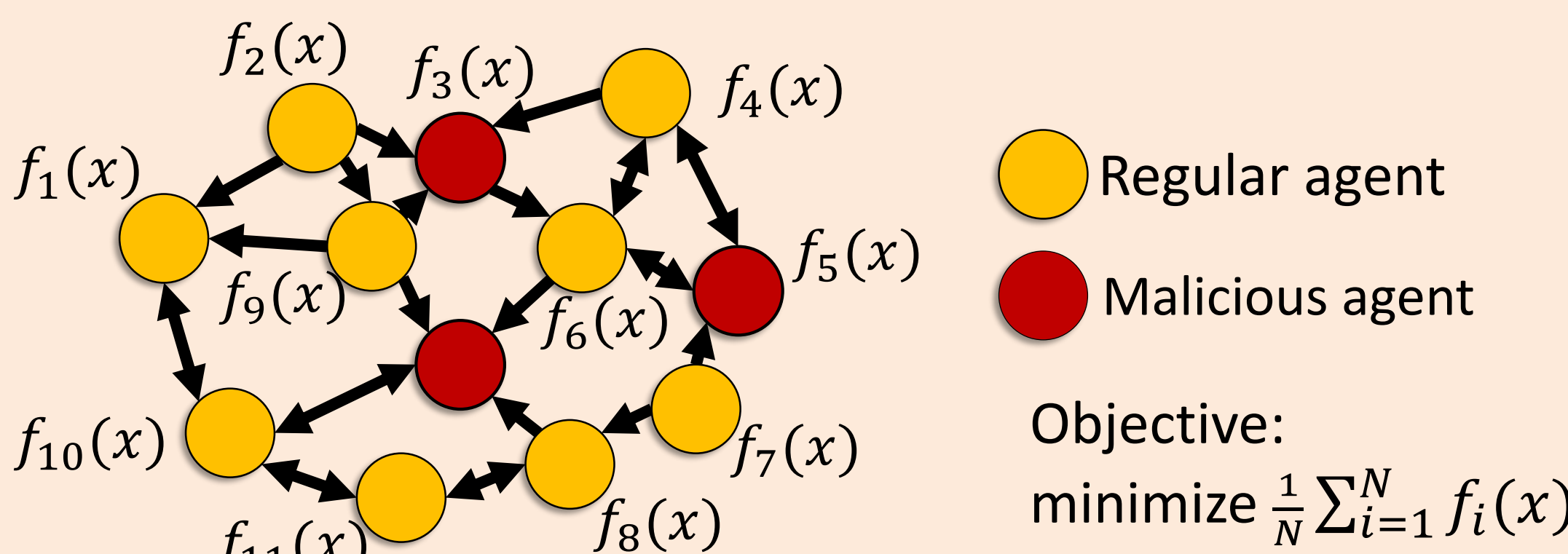
Middleware and Embedded Virtual Machine framework for self-adaptive applications and S/W and H/W reconfigurations (RV)



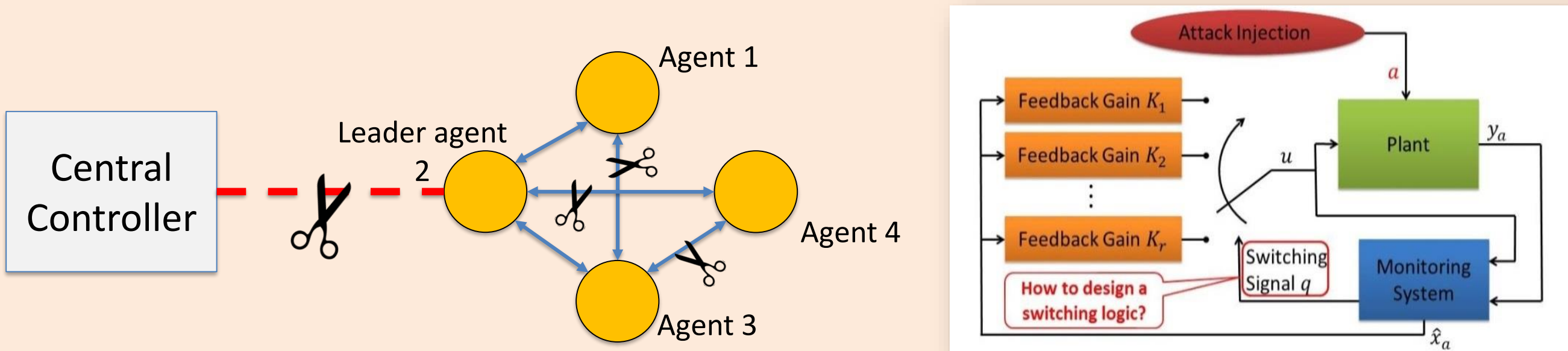
Connectivity analysis of UAS networks subject to communication failures and/or diameter constraints (DS, SM)



Secure distributed algorithms for coordination, optimization, and machine learning (SS, SB, SM)

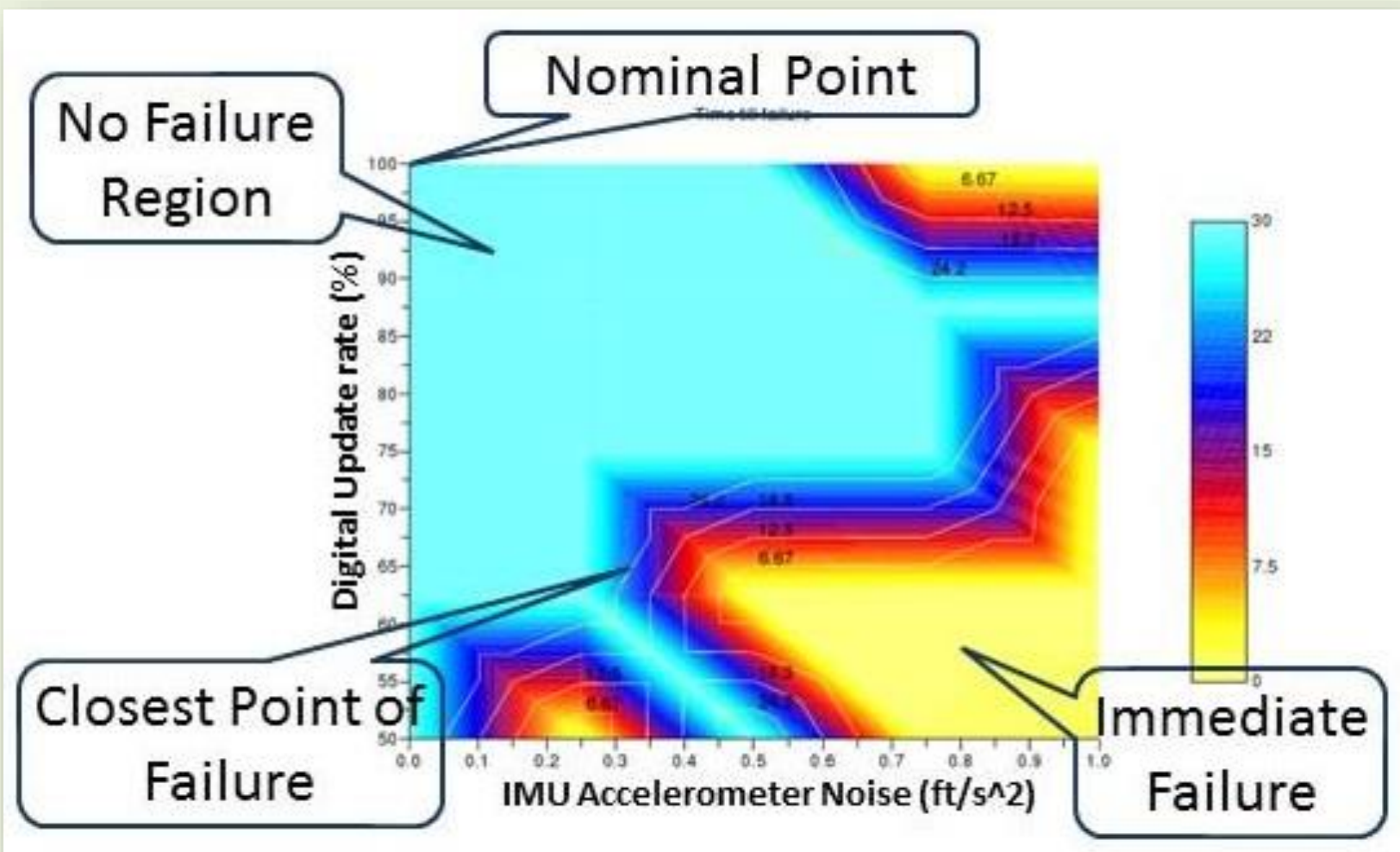


High assurance estimation and control strategies for cyber-physical and autonomous systems under faults and attacks (JH, IH, SS)

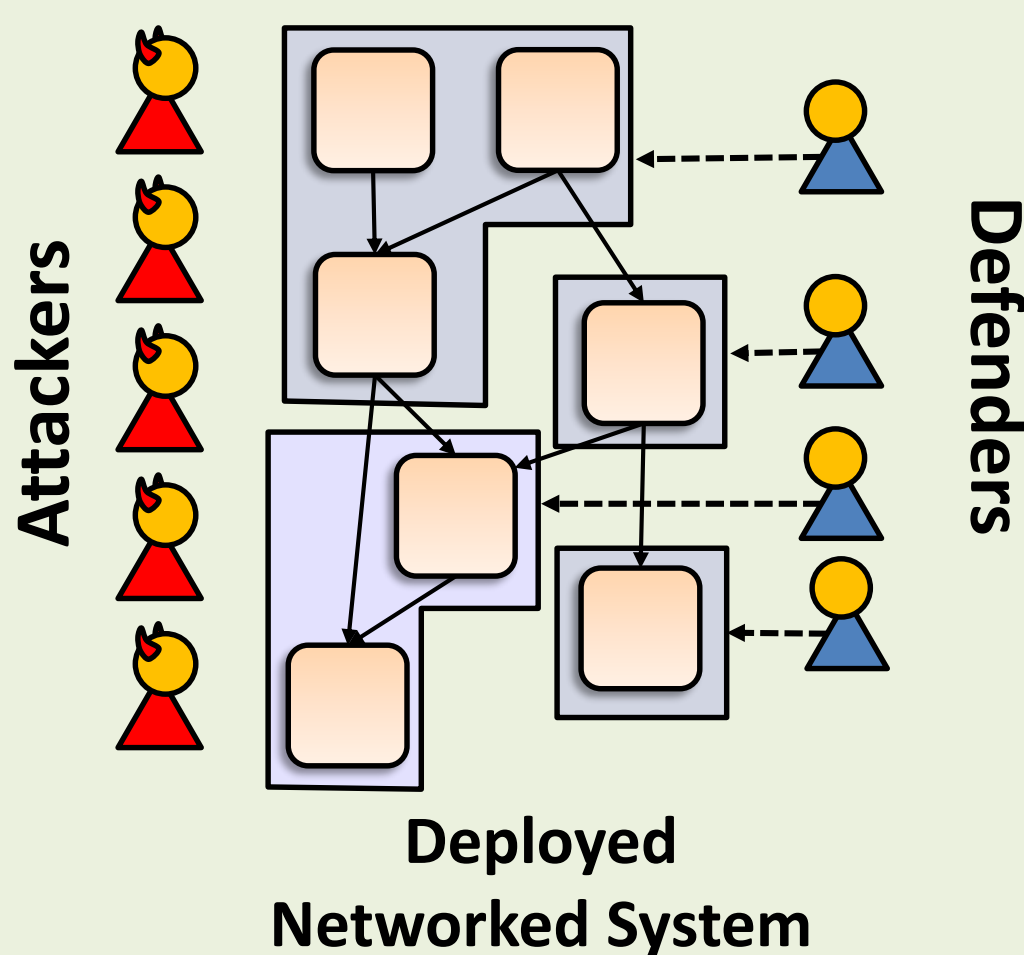


DESIGN PRINCIPLES FOR SECURE AND RESILIENT AUTONOMOUS SYSTEMS

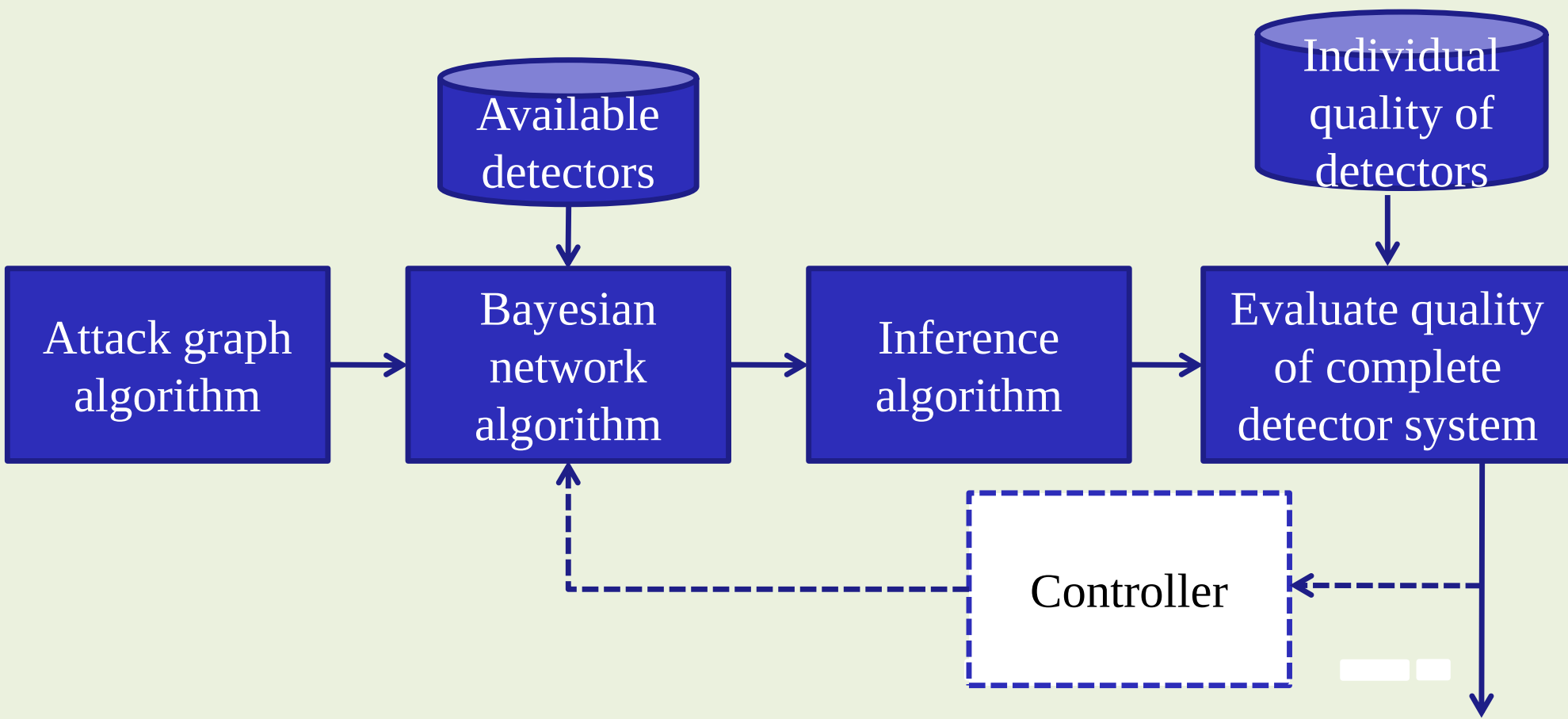
Hybrid systems framework for vulnerability analysis of intelligent networked systems (IH, JH)



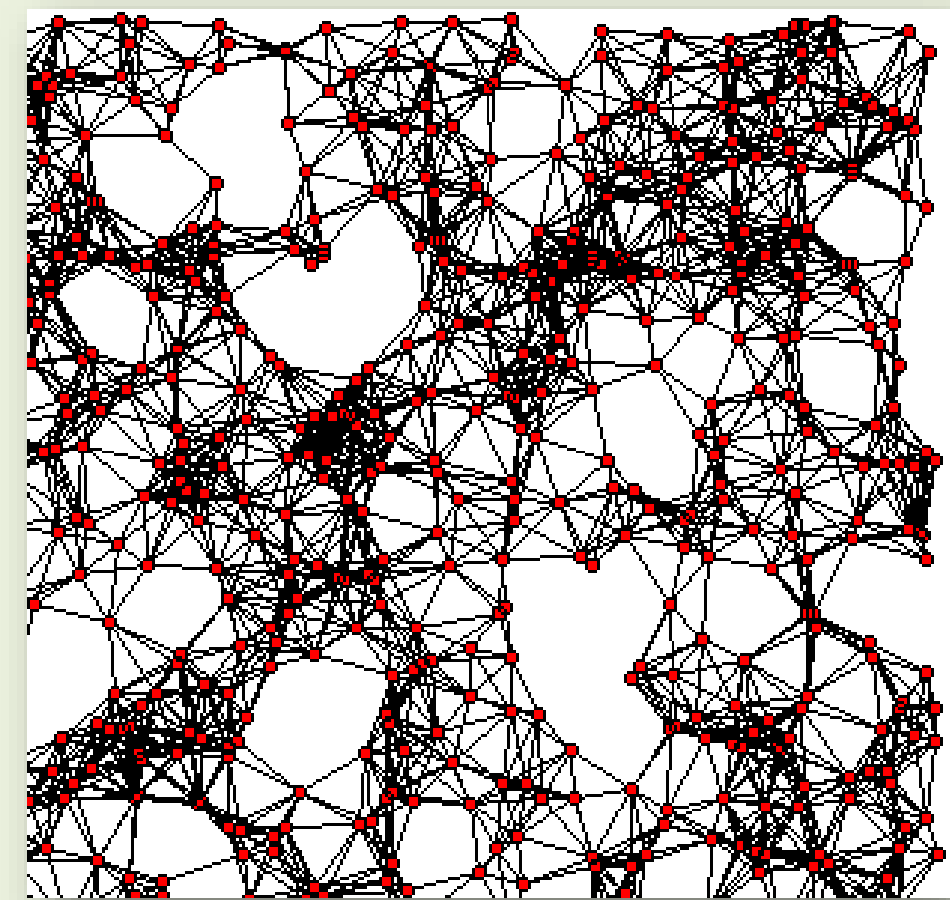
Game-theoretic analysis of human decision-making on failure and security of systems (SS, SB)



System-of-Systems approach to selecting security technologies under specified cost and resilience constraints (SB)

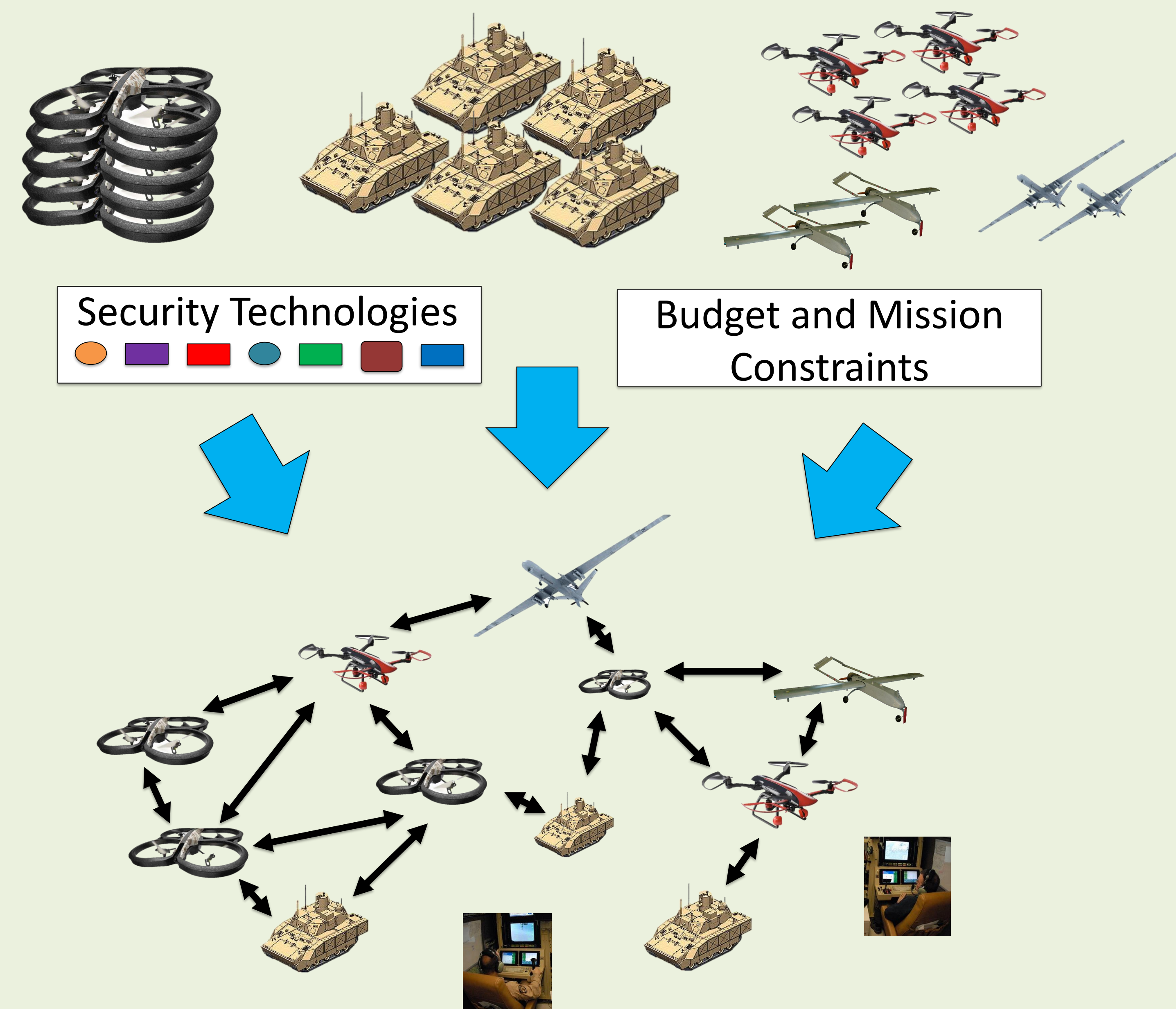


Algorithms to design resilient large-scale networks for information dissemination and distributed coordination (DS, SS)



OPEN CHALLENGES AND VISION FOR AUTONOMOUS SYSTEMS

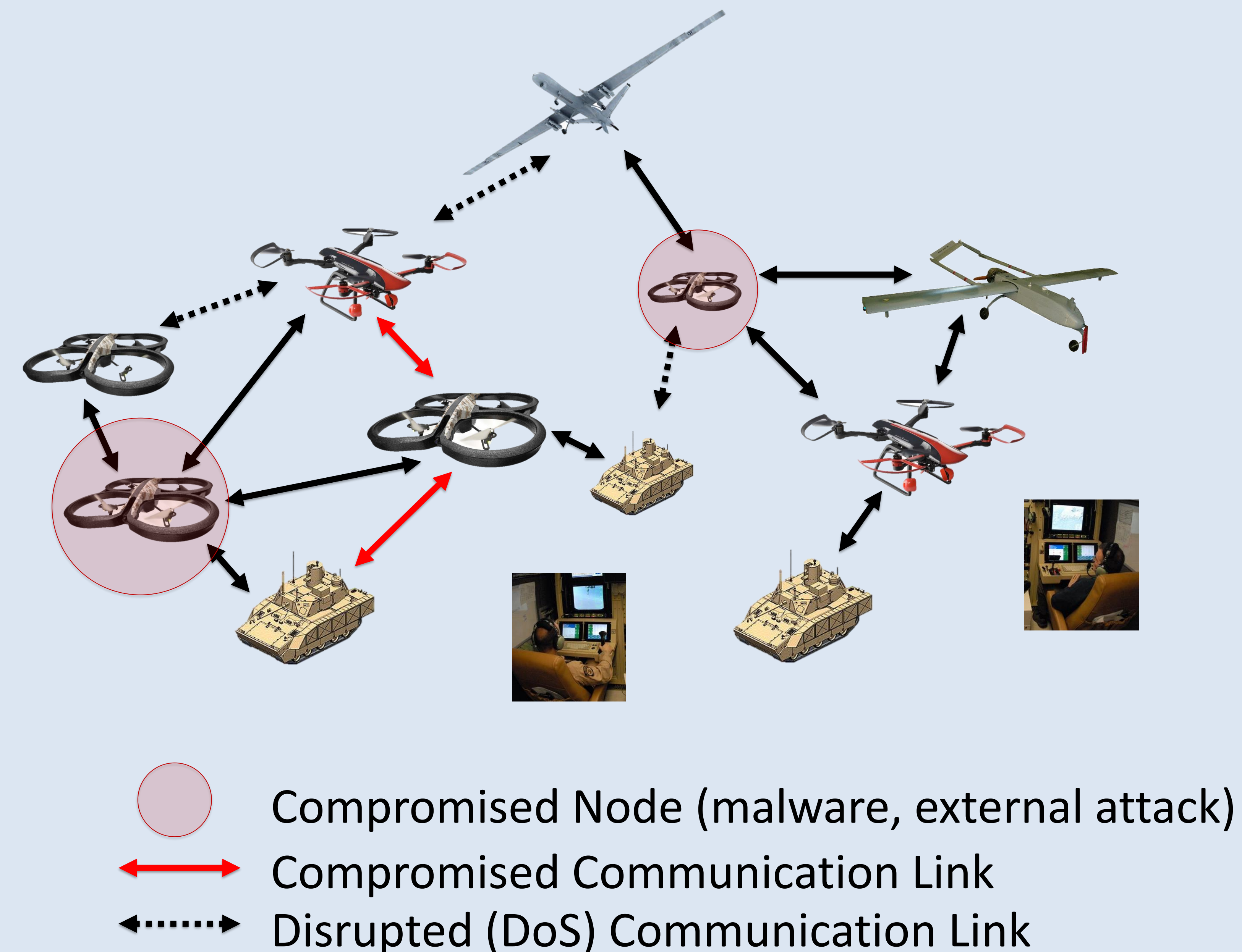
DESIGN PRINCIPLES FOR SECURE AND RESILIENT AUTONOMOUS SYSTEMS



Research Challenges and Objectives

- Formulate systematic principles for optimal composition of autonomous teams for security, reliability, and mission effectiveness
- Communication/coordination network must be designed for redundancy, reliability, and reconfigurability
- Rigorous optimization-based methodologies for selective deployment of security technologies and analysis of cost/benefit tradeoffs
- Proactive design philosophy: anticipate attacks and human decision-making during the design process

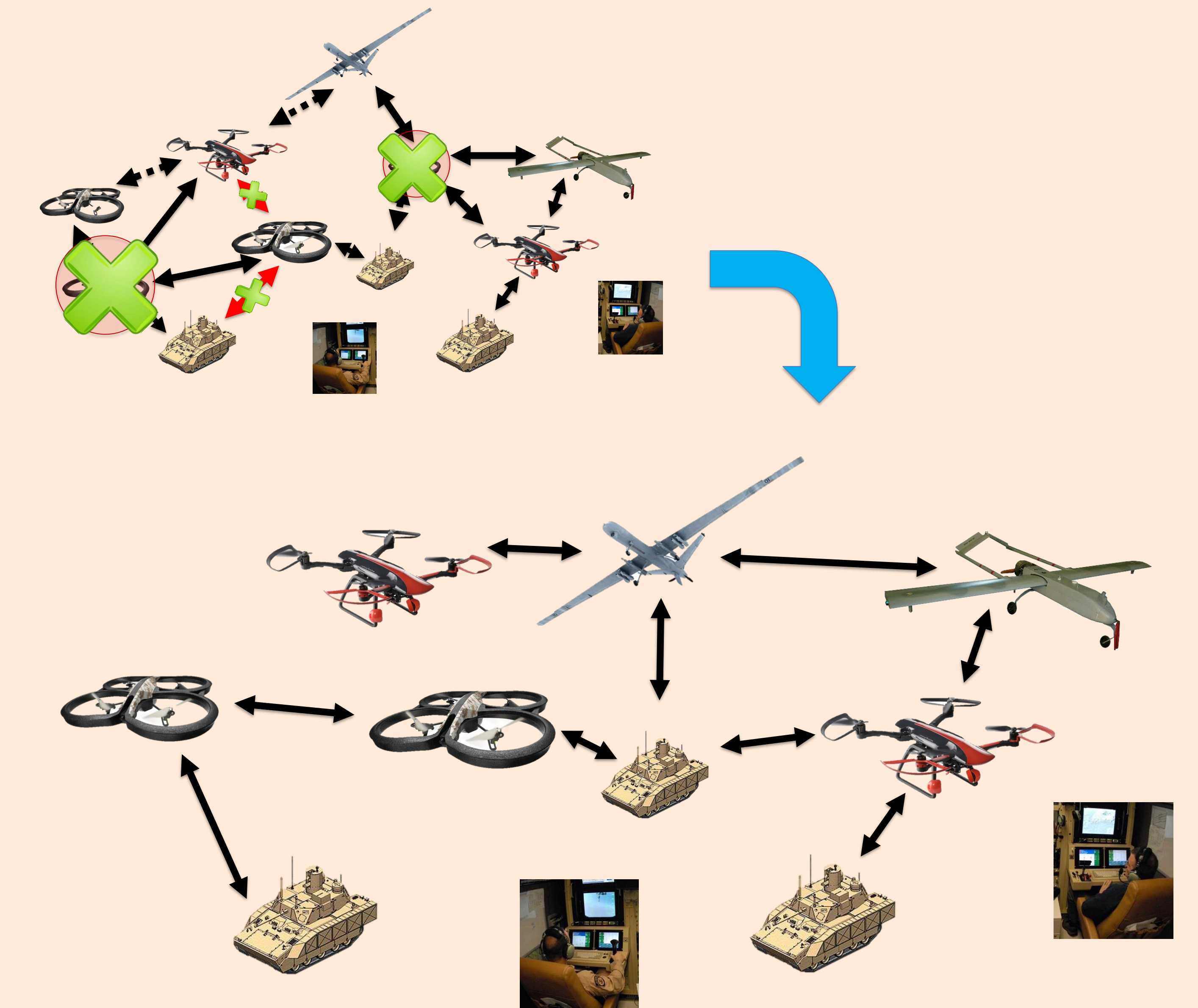
REAL-TIME SELF-DIAGNOSTICS



Research Challenges and Objectives

- Diagnostics algorithms need to perform well under a multitude of scenarios, information structures, threats, and stochastic uncertainties, which are all not known a priori
- Systematic principles are needed to evaluate tradeoff between speed and accuracy of detection
- Large-scale hierarchical systems and time-varying network topologies must be explicitly handled
- Overcome computational complexity to enable millisecond scale diagnostics
- Design algorithms that *learn* from detected threats to predict and diagnose future attacks

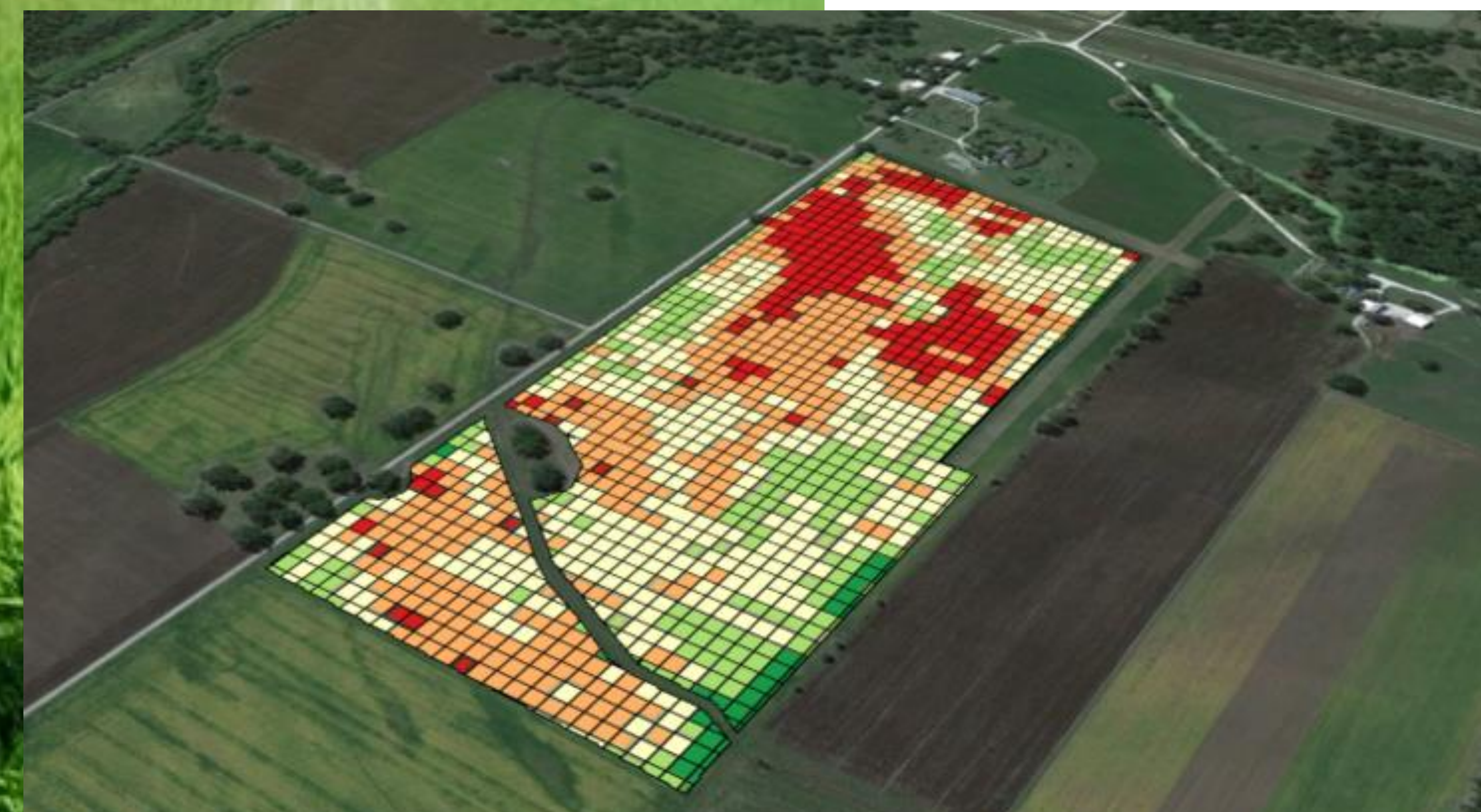
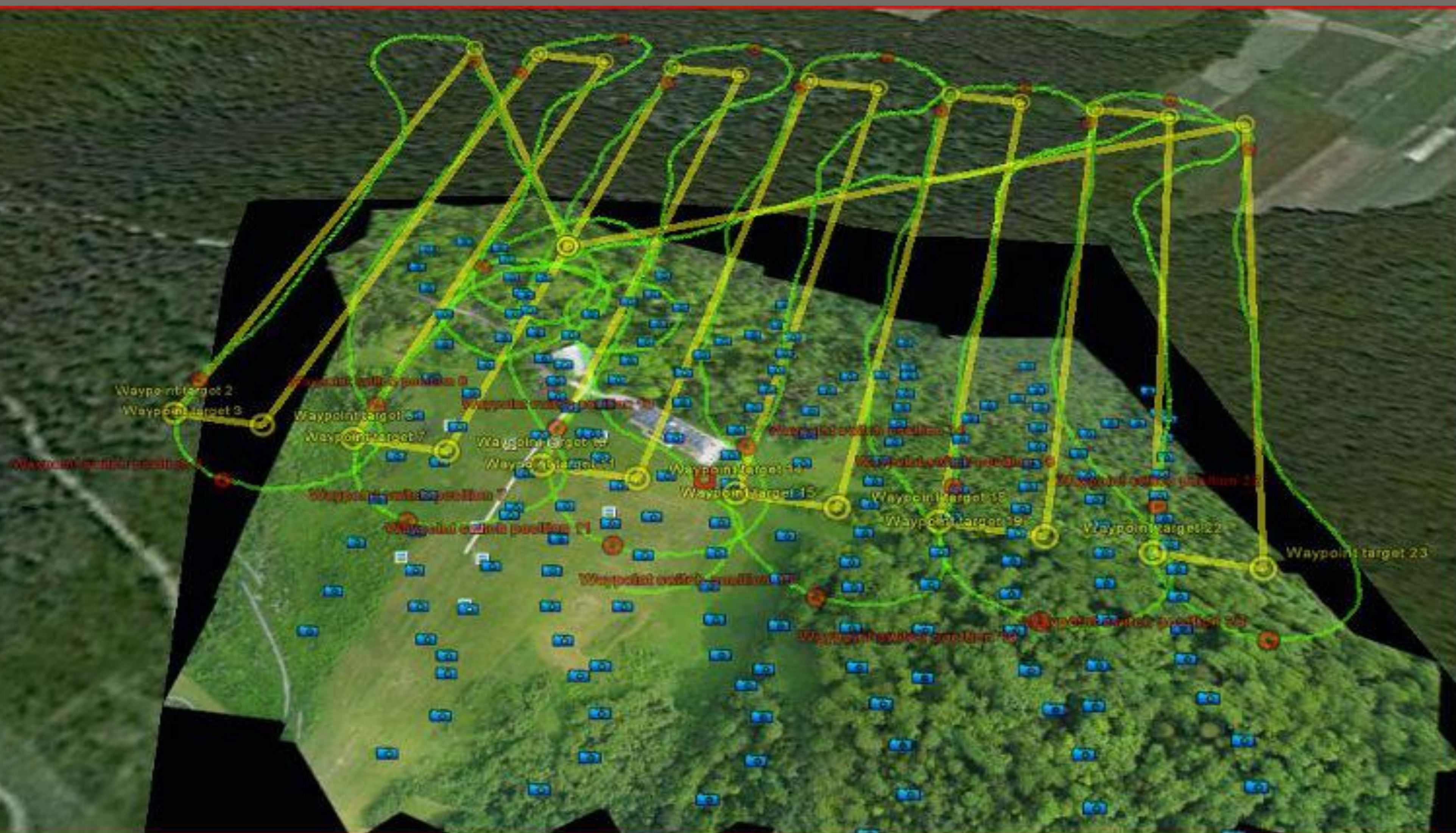
SELF-HEALING, REAL-TIME ADAPTATION AND CONTROL

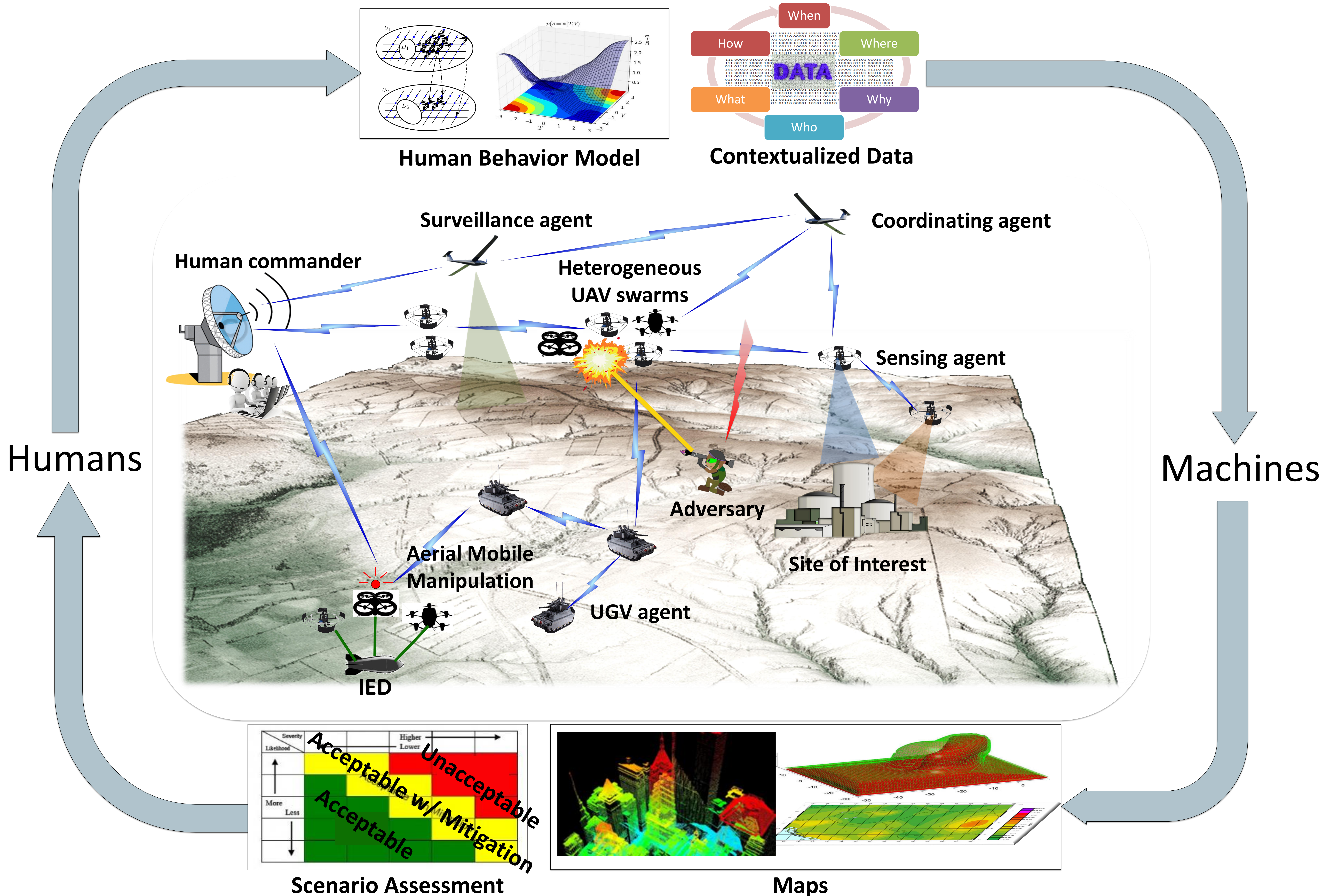


Research Challenges and Objectives

- Require scalable distributed algorithms for coordination, formation control, optimization, and decision making
- Resilient control algorithms must achieve a balance between safety and performance
- Reconfiguration algorithms must account for decentralized information pertaining to global structure, mission objectives, and situational awareness
- Require a rigorous mathematical framework to incorporate human-in-the-loop decision-making during reconfiguration

INTUITIVE AUTONOMY AGROBOTICS





- Scenario Assessment & Understanding
- Information/Network Management
- Multi-Agent Communication Collaboration
- Situational Awareness
- Scenario Planning & Decision Making
- Mission Planning & Decision Making



Robotics 1.0



Dull, Dirty, Dangerous Tasks
done by
Dull, Dirty, Dangerous
Robots

“Lights-Out Factories”



INTUITIVE AUTONOMY AGROBOTICS

