A Framework for Supporting Teamwork between Humans and Autonomous Systems

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Human-Robotic Teamwork

- Future unmanned vision calls for up to 50% of all systems to be unmanned.
- Teamwork with a robot is different than teamwork with a human

Future combat tactics must support effective human-robot <u>communication</u> and <u>coordinated activity</u>

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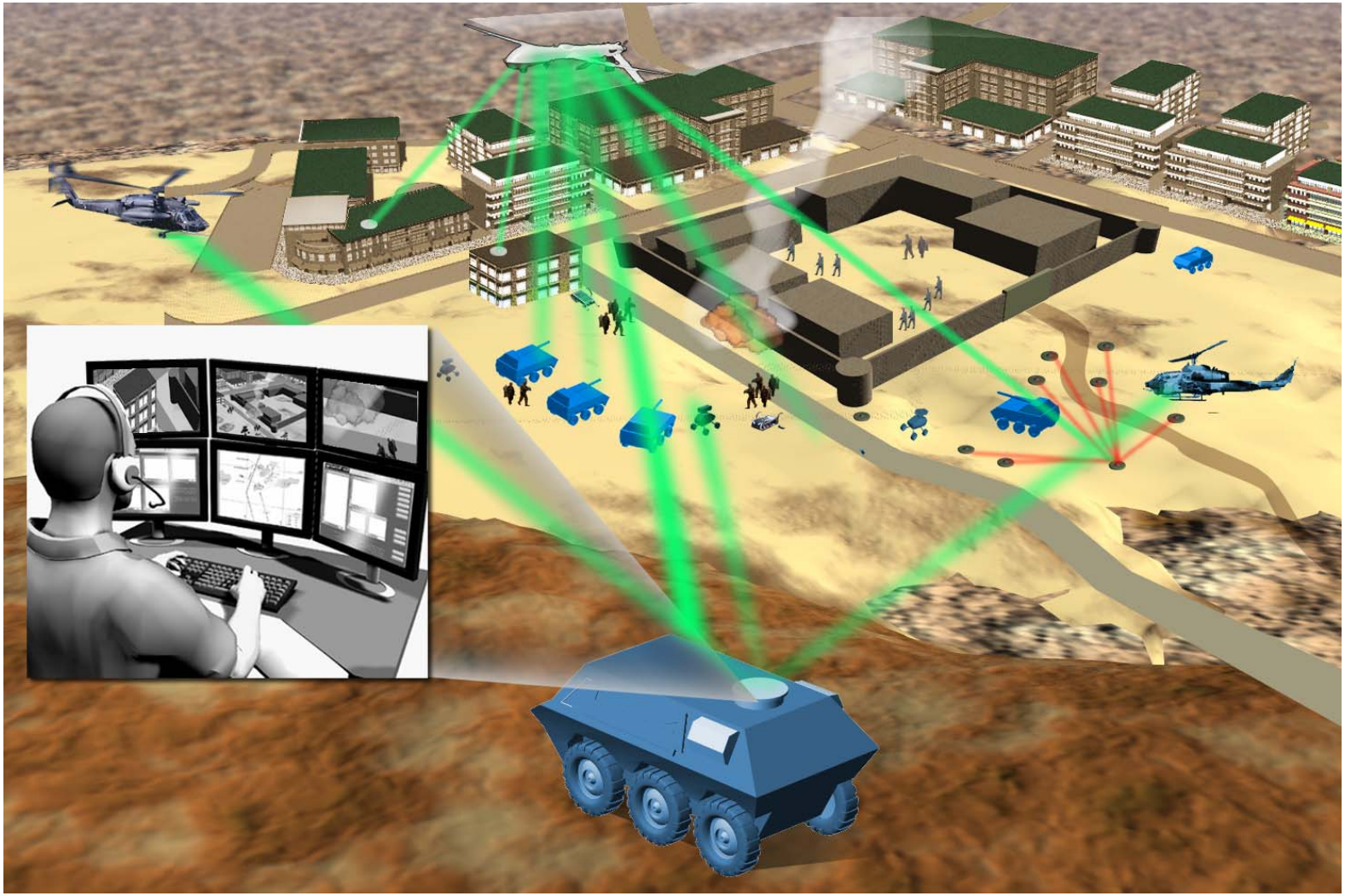
C2 of Human-Robotic Teams



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Automation is not enough

- Only some tasks can be delegated to autonomy
  - Rules of engagement (ROEs) require some decisions be made by the human operator (e.g. firing)
  - The user knows things the system doesn't, and has different reasoning abilities (e.g. target recognition)
- Ambiguity and uncertainty WILL arise (fog of war, multiple options, etc.)
- Helping the user on the wrong things or in the wrong way can be worse than not helping at all

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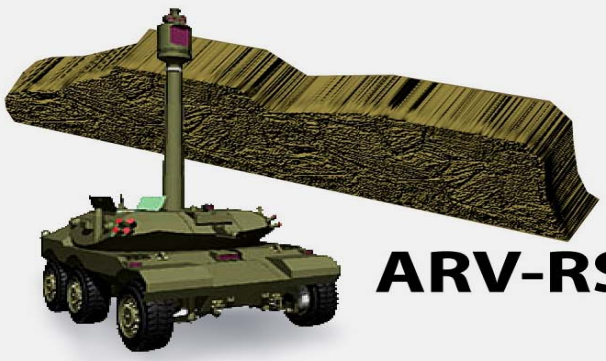
Act, Ask, or Wait?

Suspected IED Location

SUGV

ARV-Assault



ARV-RSTA

Some options:

- Move up ARV-A to intercept/engage
- Retreat SUGV
- Ignore

Act, Ask, or Wait?

Issues in the Design of Human-Robotic Teamwork

- User and System must continually *communicate* about current events and plans in order to *coordinate activity*
  - System must determine possible courses of action, and decide whether to act on one, ask the user or wait
    - System must know what the user wants (or ought) to do & how
    - Tasks must be delegated or assumed in line with user expectations, intent and preferences
  - User must be able to monitor the system's states, behaviors and intentions, along with mission status and current options
  - User & System must be able to intervene or make suggestions to one another mid-process (mixed-initiative planning & execution)

User interface <u>usability</u> and automation <u>usefulness</u> are key to effective human-robotic teamwork

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Intelligent Control Framework (ICF)

- Goals
  - Research and implement a framework for effective human-robot teamwork based on useful system automation
  - Explore usability issues concerning human-robotic communication about user intent and mission objectives, and coordination of actions in response to the current tactical situation

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ICF Reasoning for Collaborative Planning and Adjustable Autonomy

- *Dialogue management* for collaborative planning
  - Plan recognition based on cognitive task models
  - Dialogue-based HIA techniques for incorporating operator in system decision making (*act, ask or wait*)
- Heuristic *situation reasoning* for reactive planning
  - Tunable rules specific to mission and operating parameters
  - Explicit modeling of rules of engagement and ontological modeling of domain entities
- *Plan generation, execution* and *monitoring* for UV C2
  - Manage multiple-vehicle coordination
  - Support operator override of autonomous actions and operator awareness of mission progress

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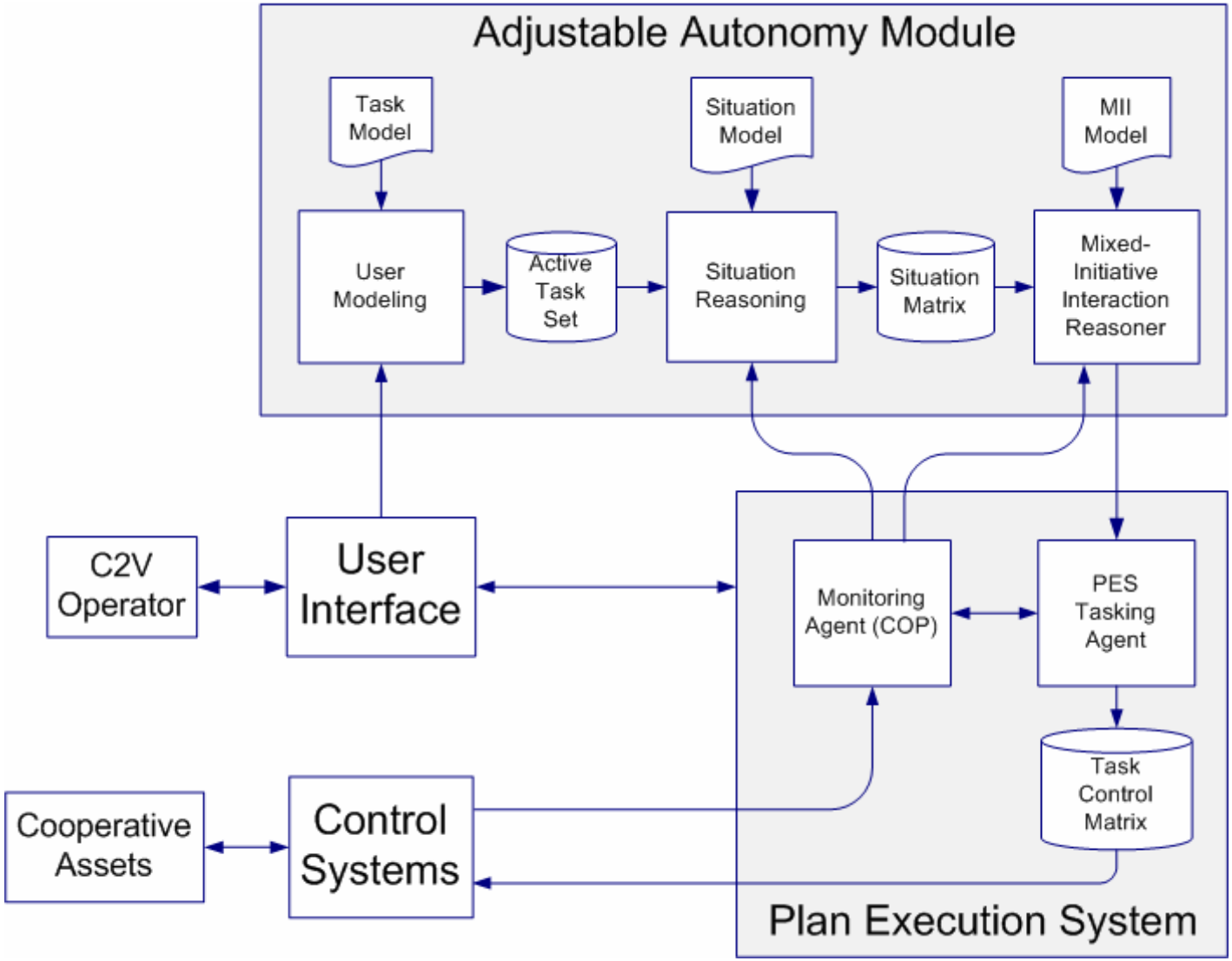
ICF Conceptual Architecture



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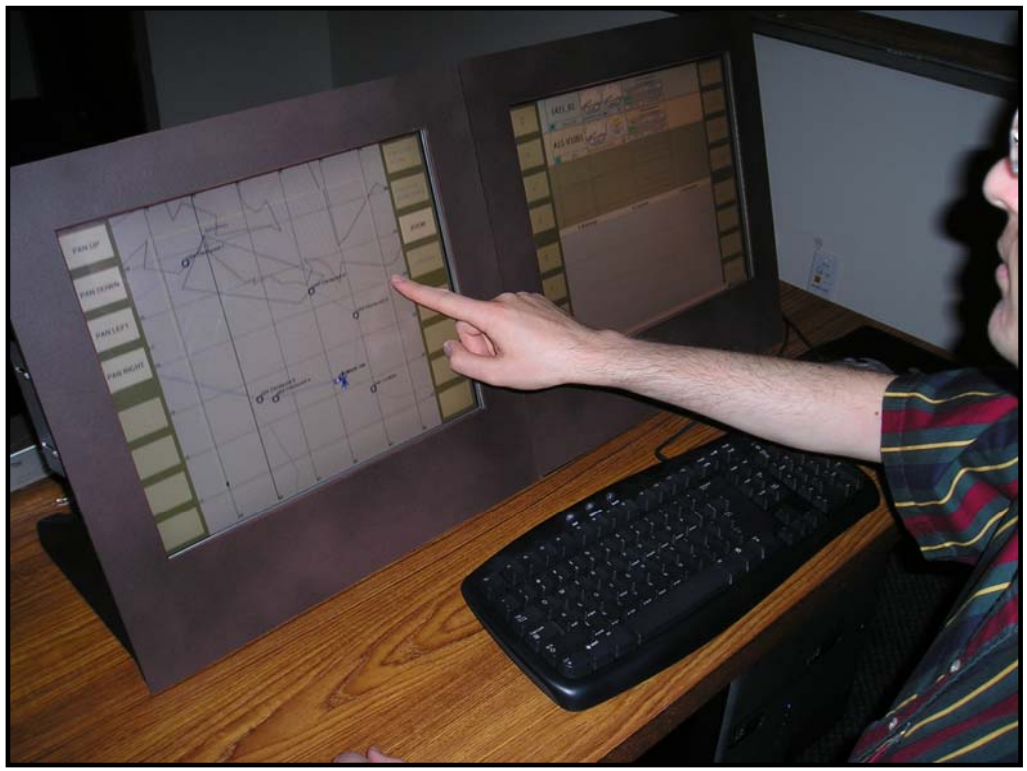
ICF Test Bed Objective

Test bed for iterative interface, reasoning, and collaborative behavior design



Transition to embedded evaluation

Support exploration of future vision

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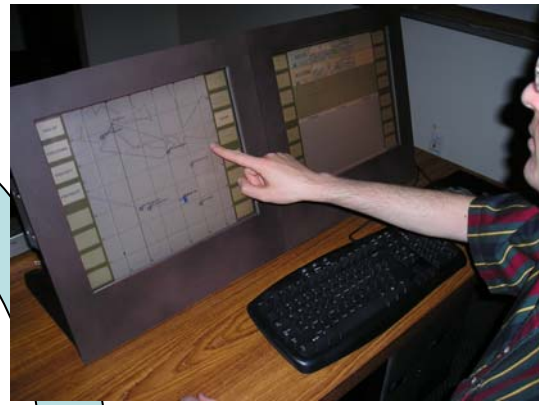
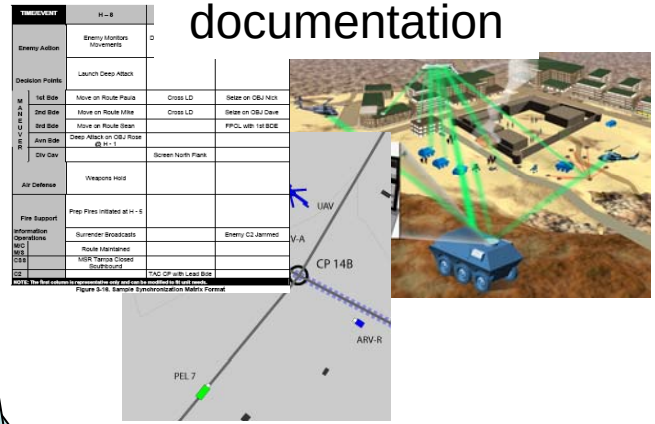
ICF approach: Iterative scenario development and simulation

Build

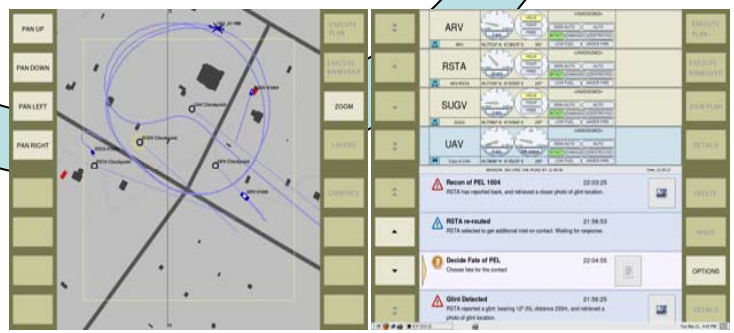


Scenario documentation



Evaluate

Rapid knowledge acquisition and design iteration before and after test bed implementation



Design

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Some lessons learned

- Situation reasoning rules require design and tuning
  - Different missions need different *types* of rules (e.g. attention vs. threat)
  - Experts describe domain issues differently than formal system models
- The user will not always be able to express intent to the system
  - Describe high-level goals and preferences to guide system decisions
  - Assume low-level control, removing it from plan, maneuvering it, and returning it to the task that existed before taking control (if possible)
- UI must support extended, structured user-system dialogue
  - The user should (usually) be able to override autonomous decisions
  - User/system situation interpretation may be out of synch, and each may know things that the other doesn't know
  - High-tempo situations could require multiple simultaneous dialogues

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Future work

- Increase capabilities for planning and prediction
- Identify useful automated behaviors for a variety of CONOPs involving multi-robot coordination
- User interface design and user testing
  - Identify the right times and means for user-system dialogue about autonomy, coordinated vehicle behaviors, and situation interpretation
- Dialogue management and UI design for multi-threaded user-system planning dialogues

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Questions?

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Extra Slides

Sheridan's 10 levels of automation:

1. The computer offers no assistance, human must do it all.
2. The computer offers a complete set of action alternatives, and
3. Narrows the selection down to a few, or
4. Suggests one, and
5. Executes that suggestion if the human approves, or
6. Allows the human a restricted time to veto before automatic execution, or
7. Executes automatically, then necessarily informs the human, or
8. Informs him after execution only if he asks, or
9. Informs him after execution if it, the computer, decides to.
10. The computer decides everything and acts autonomously, ignoring the human.

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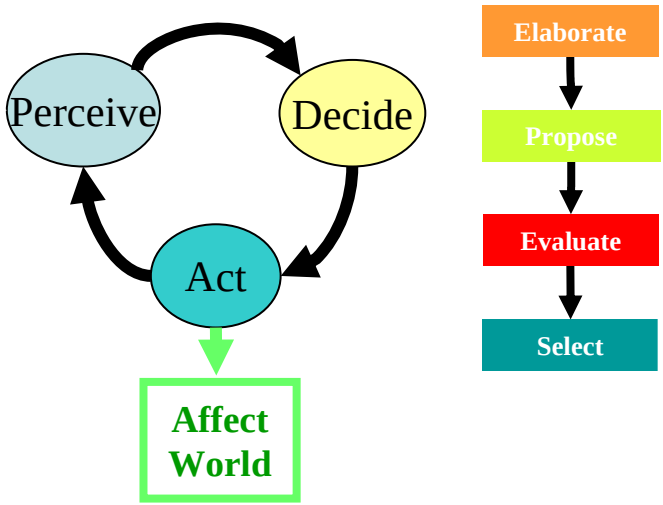
The Soar Cognitive Architecture

- An architecture for modeling and generating general intelligent behavior
  - Enables large-scale models of wide range of cognitive tasks
  - Supports explainable behavior
  - Employs wide range of problem solving methods
- A language and methodology for apply large amounts of knowledge to human-like problem-solving
- Principles of Operation
  - Parallel, associative memory
  - Belief maintenance
  - Preference-based deliberation
  - Automatic subgoaling
  - Goal decomposition
  - Adaptation via generalization of experience
  - Efficiency and performance



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Modern Battlefield Teamwork

- Modern warfare tactics call for teamwork involving distributed sensing and decision-making
- Flexibility requires collaborative planning and shared situation awareness

Effective teamwork requires <u>coordinated action</u> and frequent <u>communication</u>

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ICF is Based on Principled AI Reasoning and Interaction Design

- Simulated behaviors (BLUFOR and OPFOR) using *Soar* cognitive architecture
  - Includes domain knowledge
  - Supports both reactive and deliberative planning
- User interaction reasoning based on *SharedPlans* model of collaborative planning
  - Formally defines human-system interaction in terms of communication theory
  - Modular with respect to user interface, agent reasoning and domain knowledge

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