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U.S. Army Research Institute
for the Behavioral and Social Sciences

Evaluation of Intelligent Agent Technology for C2 of Human and Robotic Entities

CCRTS
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CIANC^3: Cooperative Interface Agents for Networked C^3

- Army Phase II SBIR project
  - See CCRTS 2004 - An Intelligent Interface-Agent Framework for Supervisory Command and Control (Wood, Zaientz)
  - Final Report - Available on DTIC
- Formative usability evaluation to assess
  - Design of Functionality
  - Supervisory Control Issues
  - Situation Awareness

The CIANC^3 Project Team

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Problem: Warfare Getting More Complex

- System Complexity
  - Systems of systems, Joint operations, Micro-models of automation
- Proliferation of Uninhabited Elements
  - UV's, sensor nets, national assets, raw data
- Demanding Environments
  - MOUT, SASO, Asymmetric threats
- Rapid Operational Tempo
  - Changing environments, windows of opportunity

- **How can we use intelligent software agents overcome inherent human limitations?**

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CIANC^3 Project Summary

- Goals
  - Design intelligent C3 system tools that will increase combat effectiveness while reducing training costs.
  - Understand the training implications for C3 of mixed teams of robotic and human elements.
- Objectives
  - Analyze FCS company-level assault mini-vignette (15 mins)
  - Create team of knowledge-rich intelligent agents (KRIAs) to simplify command tasks
  - Create framework to explore new C3 methods
  - Develop instrumented evaluation testbed
  - **Evaluate system wrt training and operational need**

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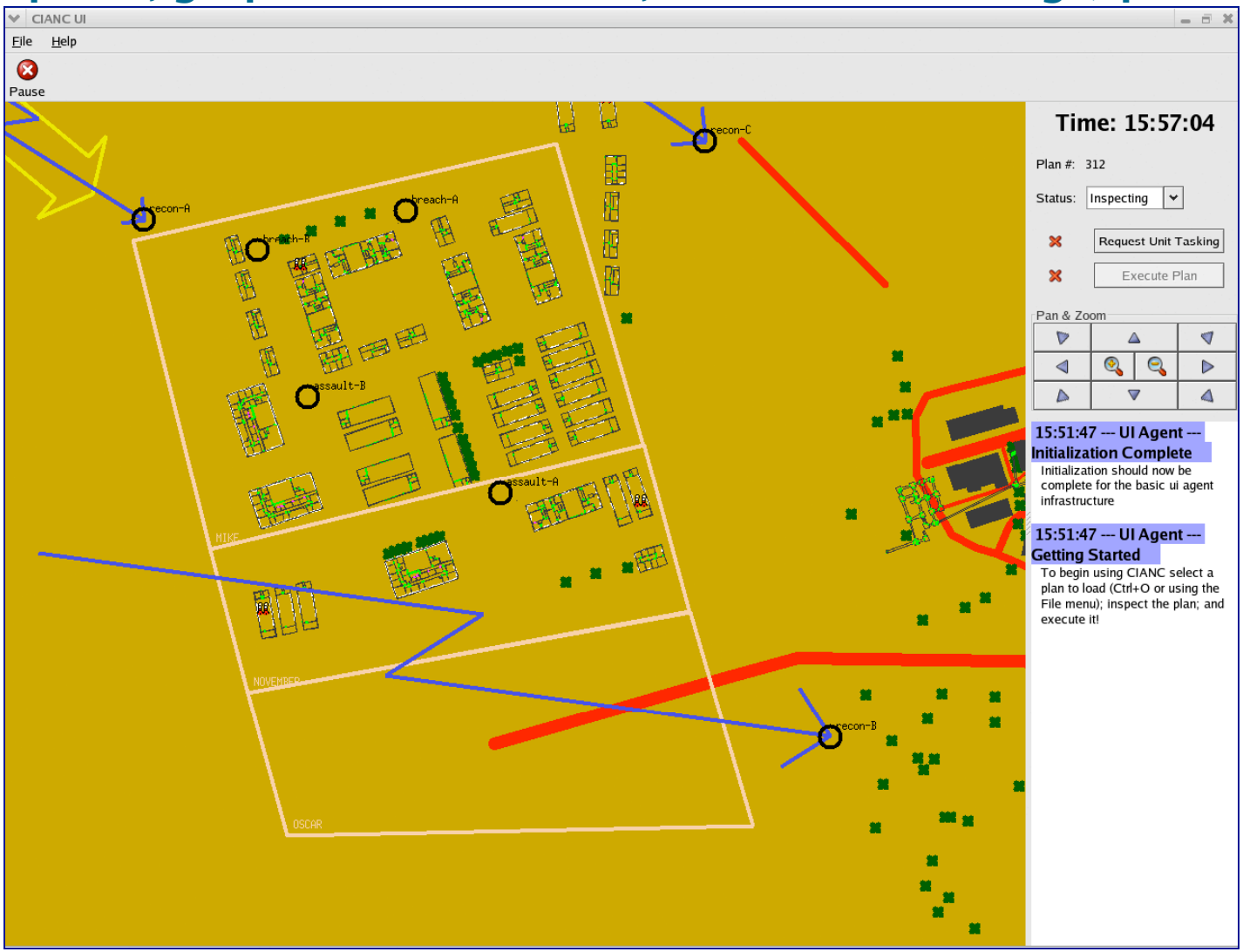
Map Display

Spatial, graphical information, real-time event log (spot reports)



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Plan Display

Plan execution, decision points, drill-down info

CIANC Details

Objectives

Number	Activity	Action	Units	Ck. Pts.	Tasks	Dec.
1	Allocate Resources	allocate-resources	{ 7 vehicles }			
2	Execute Plan	maintain-sequential-goals	{ 0 vehicles }			
3	Recon Objective A	recon-objective	{ 1 vehicle }			DP1
			Class-I UAV	recon-A	recon	
4	Recon Objective B	recon-objective	{ 1 vehicle }			DP2
			Class-I UAV	recon-B	recon	
5	Recon Objective C	recon-objective	{ 1 vehicle }			DP3
			Class-I UAV	recon-C	recon	
6	Main Assault Goal	maintain-sequential-goals	{ 0 vehicles }			
7	Call Indirect Fire	call-indirect-fire	{ 0 vehicles }			
8	Breach Objective A	breach-at-point	{ 1 vehicle }			DP4

Points

Name	Latitude		Longitude		Altitud
Homebase	32.377875	[Edit]	-84.81478333	[Edit]	0 [
recon-A	32.371389	[Edit]	-84.809444	[Edit]	100 [
recon-B	32.3691667	[Edit]	-84.806111	[Edit]	100 [
recon-C	32.371667	[Edit]	-84.806667	[Edit]	100 [
breach-A	32.371405	[Edit]	-84.80815277	[Edit]	10 [
breach-B	32.37125	[Edit]	-84.80888889	[Edit]	0 [
assault-A	32.3702111	[Edit]	-84.80771111	[Edit]	0 [
assault-B	32.37063333	[Edit]	-84.80865556	[Edit]	10 [
Indirect-Fire-A	TBD	[Edit]	TBD	[Edit]	TBD[
Indirect-Fire-B	TBD	[Edit]	TBD	[Edit]	TBD[

Decision Points

Number	Description	Continue	Branch	Halt	Note
1	Move UAV to point recon-A Criteria: Maintain situational awareness Branch: Assign additional recon elements	☐	☐	☐	
2	Move UAV to point recon-B Criteria: Maintain situational awareness Branch: Assign additional recon elements	☐	☐	☐	
3	Move UAV to point recon-C Criteria: Maintain situational awareness Branch: Assign additional recon elements	☐	☐	☐	
4	Breach compound at Breach A Criteria: Enemy resistance permits continuation of operation Branch: Destroy enemy force concentration	☐	☐	☐	
5	Breach compound at Breach B Criteria: Enemy resistance permits continuation of operation Branch: Destroy enemy force concentration	☐	☐	☐	
6	Reinforce Breach A with Assault Team Criteria: Enemy resistance permits continuation of operation Branch: Destroy enemy force concentration	☐	☐	☐	
7	Reinforce Breach B with Assault Team Criteria: Enemy resistance permits continuation of operation Branch: Destroy enemy force concentration	☐	☐	☐	
8	Assault compound at Assault A Criteria: Enemy resistance permits continuation of operation Branch: Destroy enemy force concentration	☐	☐	☐	
9	Assault compound at Assault B Criteria: Enemy resistance permits continuation of operation	☐	☐	☐	

Units

Name	Type	Task	Dest.	ET
US1-M3B-V1014	ICV		N/A	N/
US1-UAVA-V1007	Class-I UAV		N/A	N/
US1-UAVB-V1019	Class-I UAV		N/A	N/
US2				
US2-M3C-V1015	ICV		N/A	N/
US2-M3D-V1016	ICV		N/A	N/
US2-UAVC-V1005	Class-I UAV		N/A	N/
US2-UAVD-V1021	Class-I UAV		N/A	N/
US3				
US3-M3E-V1017	ICV		N/A	N/
US3-M3F-V1018	ICV		N/A	N/
US3-UAVE-V1006	Class-I UAV		N/A	N/
US3-UAVF-V1004	Class-I UAV		N/A	N/
US4				
US4-M3F-V1012	ICV		N/A	N/
US4-M3G-V1011	ICV		N/A	N/
US4-UAVG-V1008	Class-I UAV		N/A	N/
US4-UAVH-V1009	Class-I UAV		N/A	N/
US5				
US5-M109A-V1010	MCS		N/A	N/
US5-UAVI-V1020	Class-I UAV		N/A	N/

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Core CIANC^3 Agent Capabilities

- System selection of assets
- System tasking of assets
- System monitoring of sensor reports
- System makes sensor signals available to be reasoned on
  - Provide details re entity types, entity mobility and lethality percentages from UV reports
- System re-planning based on limited set of mission events

- Infrastructure and Agent Organization is Functional… Agents are Limited Primarily by Domain Knowledge

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Allocation of Functionality: Recon Example

Agent system acts as assistant

User Actions	Agent Actions
Issue Command Event	
	Trigger Event, Assign Asset, Get Approval
Approve Assignment	
	Issue Movement Cmd, Monitor/Report Progress
Monitor Significant Evts	
	Notify when Cmd complete or relevant CCIR met
Adjust Cmds, CCIR, SOP	

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Participants & Evaluation Criteria

- 9 Active-Duty Army Officers
  - 8 Lieutenants, 1 Captain
  - Most in armor specialty
  - Most with combat command experience
- Evaluation Measures
  - Ability to successfully complete mission
  - Performance, such as task accuracy and completion time
  - Error rate, error type and error-inducing task methods
  - Situation awareness
  - Potential impact on mission performance

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Method

- 6 4-hour evaluation sessions over 3 days
  - 3 Single-participant, think-aloud sessions
  - 2 Single-participant, SAGAT sessions
  - 1 Multi-participant, group session
- Apparatus
  - Dual monitor with map and information views arranged side-by-side.
  - FCS MOUT assault scenario running on OTB 2
  - Instrumented for user actions
  - Video-recorded sessions, over-shoulder

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Procedure & Data Collection

- Procedure
  - Conduct interview & experimental brief
  - Read and brief evaluation OPORD
  - Conduct CIANC3 system training
  - Conduct evaluation using puckster
  - Questionnaire & outbrief
- Collection Instruments
  - Background questionnaire
  - SAGAT
  - Observation
  - Think-aloud
  - Individual Questionnaire
  - Focus Group Discussion

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Evaluation Scenario & Tasks

- Scenario
  - XO for Unit of Action company
  - Orders received and battle plan in place
  - CO killed by sniper. Job: execute the plan.

Tasks & DPs	Criteria
Recon Obj A, B, C	Maintain SA
Call for Effects (indirect fire)	Resistance permits mission continuation
Breach Obj A, B	Resistance permits mission continuation
Reinforce Obj A, B	Resistance permits mission continuation
Assault Pts A, B	Resistance permits mission continuation

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General Tasks

- Use prototype to inspect, approve, execute plan
- Evaluate, approve assigned assets & asset routes
- Use prototype to initiate battle sequence
- Use displayed information and markers to maintain awareness of current battle progress
- Interact with prototype to react to decision points as they arrive
- Respond to prototype-generated CCIR notifications
- Change the "Acceptable UAV Loss Ratio"
- Move, delete recon points

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Observation Results

- Usability Issues - no showstoppers
  - Interface design
    - Key enabler - decision-process oriented (see Taylor, CCRTS 2005)
    - Main issue - why can't I override?
  - Information design
    - Key enabler - information presented contextually (CCIRs, DPs)
    - Main issue - why isn't it all linked together?
  - Automation design
    - Key enabler - anticipating need, applying contextual info
    - Main issue - why did it do that?

- Getting it right requires mix of A.I., user/task needs, contextual information, interface transparency

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Discussion

- Shifting User Focus
  - Initially, P's focused on map movement, then focused on information displays.
- Human-Agent ≈ Human-Human?
  - Trust, competence seem key; may be similar to team training issues.
- Human Model = Agent Model is essential
  - Performance better where GUI designs and agent interactions mapped fairly well to soldiers' conceptual structures (decision points & objectives).
- Low-fidelity sims can still be effective for training
  - Soldiers with no unmanned-systems experience rapidly developed appropriate tactics for their use when not distracted by details of their control.

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Lessons Learned

- Flexible, accurate automation
  - The system needs to provide flexible and doctrinally correct automation (diff user styles, even with simple scenario)
- Mixed-initiative, adjustable-autonomy
  - The system needs to provide manual access to results of automation (perception of user control)
- Aggregate information and detailed data
  - The system needs to provide raw data or quick access to details to support aggregate information displays (drill-down)
- Design to the task
  - Task-centric design and application of automation contributed to user performance and system acceptance.
- Maintain a user model
  - Designing to the user's mental model reduced learning time.

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Conclusions

- High potential for human-agent cooperation
- Human-level knowledge and reasoning is critical
- Explanation is critical for trust & “control” perception
- Need science base for design of multi-agent teams
- Need more formalized representation of knowledge
- Easier to use standard knowledge base
- Participatory design, but with caveats

- “No limits on automation, we need all the help we can get”

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