

Ogden Air Logistics Center



U.S. AIR FORCE

Trust on the Battlefield in an Age of Automation

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Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE APR 2010		2. REPORT TYPE		3. DATES COVERED 00-00-2010 to 00-00-2010	
4. TITLE AND SUBTITLE Trust on the Battlefield in an Age of Automation				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Ogden Air Logistics Center,520 SMXS/MXDEA,Hill AFB,UT,84056				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES Presented at the 22nd Systems and Software Technology Conference (SSTC), 26-29 April 2010, Salt Lake City, UT.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 35	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



Overview



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- Why Trust Matters
- Autonomy Defined
- Trust Defined
- Identifying Elements of Trust
- Simulating Trust
- Human-Robot Trust Games
- Web-based Game
- Diplomacy Agent
- Identifying Human-Agent Trust KPPs



Why Trust Matters

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■ Congressional Mandate

- The National Defense Authorization Act for Fiscal Year 2001, Public Law 106-398, Congress mandated in Section 220 that “It shall be a goal of the Armed Forces to achieve the fielding of unmanned, remotely controlled technology such that... by 2015, one-third of the operational ground combat vehicles are unmanned.”¹



Why Trust Matters

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■ Secretary of Defense Gates' Comments

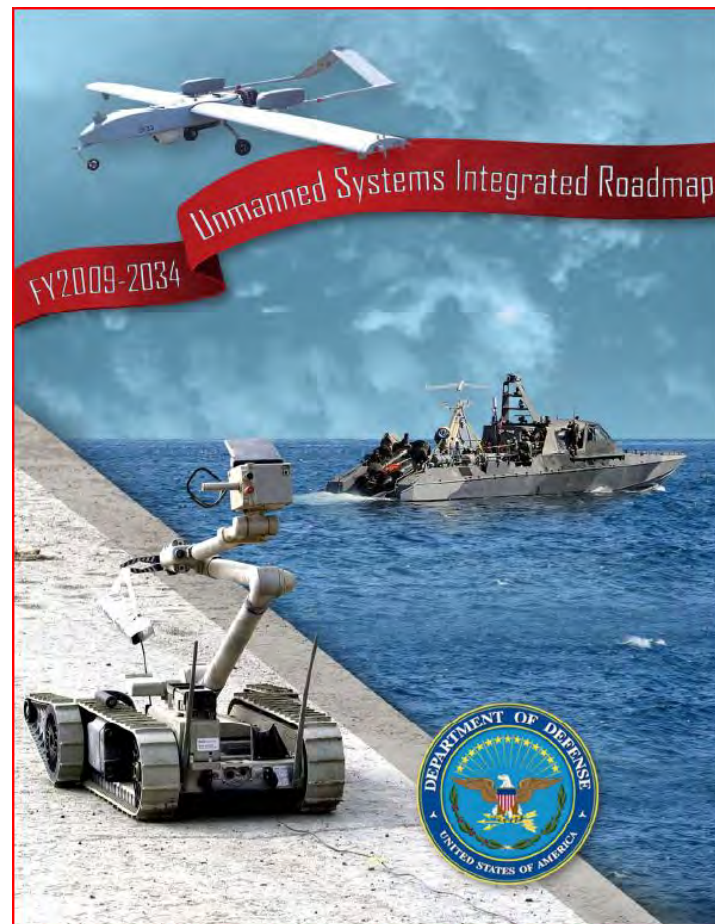
- On 21 April 2008, Secretary Gates made the following comment about unmanned systems

*"Unmanned systems cost much less and offer greater loiter times than their manned counterparts, making them ideal for many of today's tasks. Today, we now have more than 5,000 UAVs, a 25-fold increase since 2001. But in my view, we can do and we should do more to meet the needs of men and women fighting in the current conflicts while their outcome may still be in doubt. My concern is that our services are still not moving aggressively in wartime to provide resources needed now on the battlefield. I've been wrestling for months to get more intelligence, surveillance and reconnaissance assets into the theater. Because people were stuck in old ways of doing business, it's been like pulling teeth."*²



Why Trust Matters

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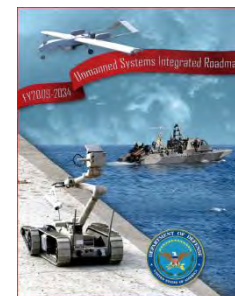
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Why Trust Matters

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■ President's Budget for Unmanned Systems³



PORs FY09PB (\$M)	Funding Source	FY09	FY10	FY11	FY12	FY13	TOTAL
UGV	RDT&E*	\$1291.2	\$747.5	\$136.2	\$108.7	\$68.9	\$2,353
	PROC*	\$33.4	\$42.3	\$53.5	\$59.5	\$21.1	\$210
	O&M*	\$2.9	\$3.9	\$3.0	\$12.8	\$10.1	\$33
UAS	RDT&E	\$1347.0	\$1305.1	\$1076.4	\$894.0	\$719.5	\$5,342
	PROC	\$1875.5	\$2006.1	\$1704.7	\$1734.3	\$1576.2	\$8,897
	O&M	\$154.3	\$251.7	\$249.0	\$274.9	\$320.2	\$1,250
UMS	RDT&E	\$57.3	\$73.8	\$63.2	\$70.1	\$76.9	\$341
	PROC	\$56.7	\$78.4	\$95.9	\$91.6	\$103.7	\$426
	O&M	\$5.0	\$4.5	\$11.3	\$13.5	\$13.9	\$48
TOTAL		\$4,823	\$4,513	\$3,393	\$3,260	\$2,911	\$18,900

* RDT&E = Research, Development, Test, and Evaluation; PROC = Procurement; O&M = Operations and Maintenance



Why Trust Matters

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■ Common Performance Envelope Across Domains³



	2009	Evolutionary Adaptation	2015	Revolutionary Adaptation	2034
Commands	Physical Human Machine Interfaces		Scripted Voice Command/Hand Signals		Natural Language Understanding
Collaboration	Individual System		Teaming w/in Domain Collaboration Across Domains		Teamed Collaboration
Frequency	Constrained RF		Frequency Hopping		Multi-Frequency Communications
Mission Complexity	Operator Controlled				Autonomous Adaptive Tactical Behaviors
Environmental Capability	Limited Environmental Difficulty		Expanded Environmental Difficulty		All-Weather Environmental Difficulty
Product Line	Mission Package Product Line Dependent				Product Line Independent
OPSEC	Signature High				Signature Low
Operational Control	1 Operator / Platform		1 Operator / Domain		1 Operator / Team
Bandwidth	Limited		Advanced Bandwidth Management		Autonomous Bandwidth
Mission Endurance	Hours		Days	Months	Years
Maintenance	Operator				Automated
Awareness	Sensor Data		Situational Awareness		Actionable Information



Why Trust Matters

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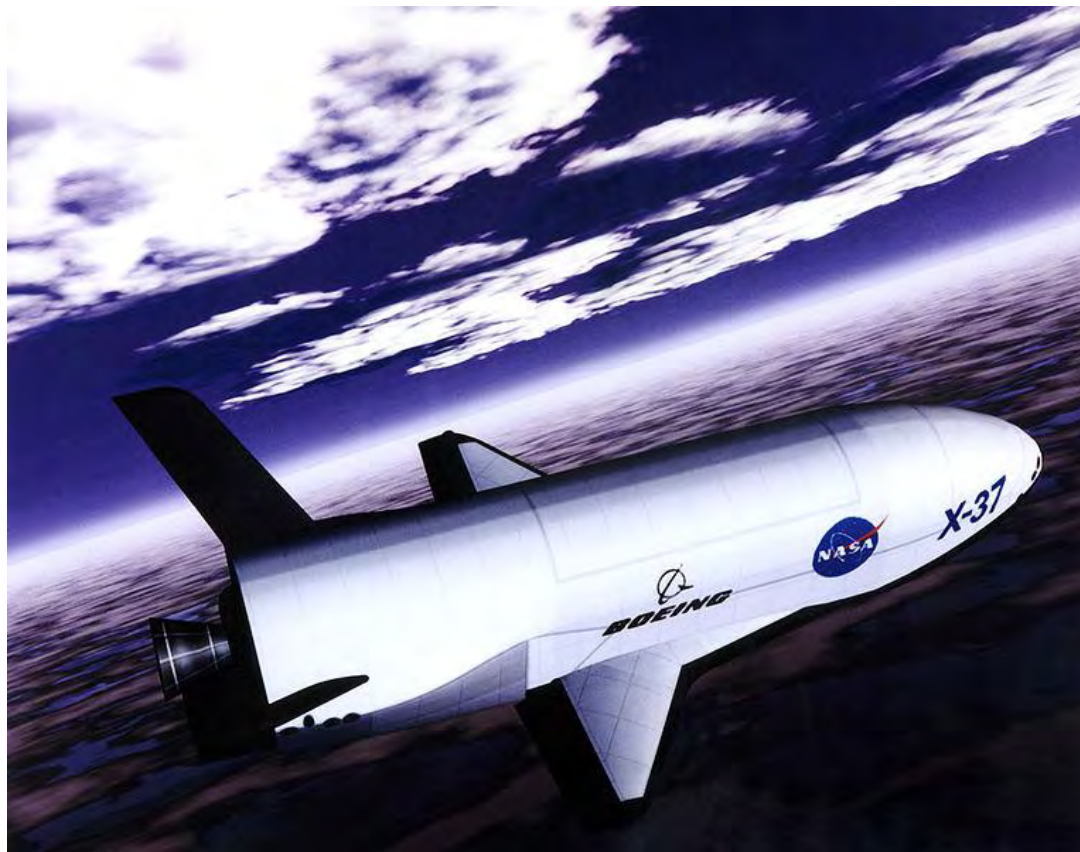
- P.W. Singer of the Brookings Institution stated the following in an article published in 2009
 - *“So, despite what one article called „all the lip service paid to keeping a human in the loop,“the cold, hard, metallic reality is that autonomous armed robots are coming to war. They simply make too much sense to the people that matter.”*⁴



Why Trust Matters

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- From recent news, the X-37B Orbital Test Vehicle was launched on 22 April 2010 and received a fair amount of media attention
 - Who is in control?
 - What are its capabilities?
 - How long will it remain in orbit and what is it doing?



NASA



Why Trust Matters

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- An article in the February 2010 issue of *Popular Mechanics* asked “Can We Trust Robots?”⁶
 - The primary point of the article was that humans may be too trusting of robots because they anthropomorphize them
 - We humans think we understand a robot's “thought processes” and “motivations”
 - This could become worse as robots become ubiquitous and as we begin to rely upon them more



Autonomy Defined

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- The American Heritage Dictionary defines *autonomy* as
 - *“Independence.”* ⁷
- Wikipedia defines an *autonomous agent* as
 - *“A system situated in, and part of, an environment, which senses that environment, and acts on it, over time, in pursuit of its own agenda. This agenda evolves from drives (or programmed goals). The agent acts to change the environment and influences what it senses at a later time.”*
 - *“Non-biological examples include intelligent agents, autonomous robots, and various software agents, including artificial life agents, and many computer viruses.”* ⁸



Autonomy Defined

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- There are varying degrees of autonomy
 - None – System is completely manually controlled
 - Partial – Some functions are automated
 - Sliding – The amount of autonomy is selectable
 - Full – The system operates entirely without human control
- With any autonomy the user gives up some level of control
- Wikipedia has a good definition of the abilities of a fully autonomous robot
 - *“A fully autonomous robot has the ability to
 - Gain information about the environment
 - Work for an extended period without human intervention
 - Move either all or part of itself throughout its operating environment without human assistance
 - Avoid situations that are harmful to people, property, or itself unless those are part of its design specifications.”⁹*



Autonomy Defined

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■ Examples of Degrees of Autonomy

Increasing Autonomy

**No Autonomy
(Remote-control
EOD robot)**



US Air Force Photo

**Partial Autonomy
(ISS assembly
robot)**



NASA Photo

**Sliding Autonomy
(UAS)**



US Air Force Photo

**Full Autonomy
(ALCM)**



Boeing Photo



Trust Defined

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- The “classic” definition of trust comes from Diego Gambetta
 - **“trust (or, symmetrically, distrust) is a particular level of the subjective probability with which an agent assesses that another agent or group of agents will perform a particular action, both *before* he can monitor such action (or independently of his capacity ever to be able to monitor it) *and* in a context in which it affects *his own* action. When we say we trust someone or that someone is trustworthy, we implicitly mean that the probability that he will perform an action that is beneficial or at least not detrimental to us is high enough for us to consider engaging in some form of cooperation with him.”¹⁰**



Research Objective

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- Assuming that autonomous agents are coming to hazardous environments, like disaster areas and combat zones, how can we trust them?
- This research project is attempting to identify the factors that contribute to trust in autonomous agents, in order to develop a set of key performance parameters (KPPs) for trusted agents
 - These KPPs can be used by intelligent agent developers to verify the trustworthiness of their agents and to convince users of their trustworthiness



Research Objective

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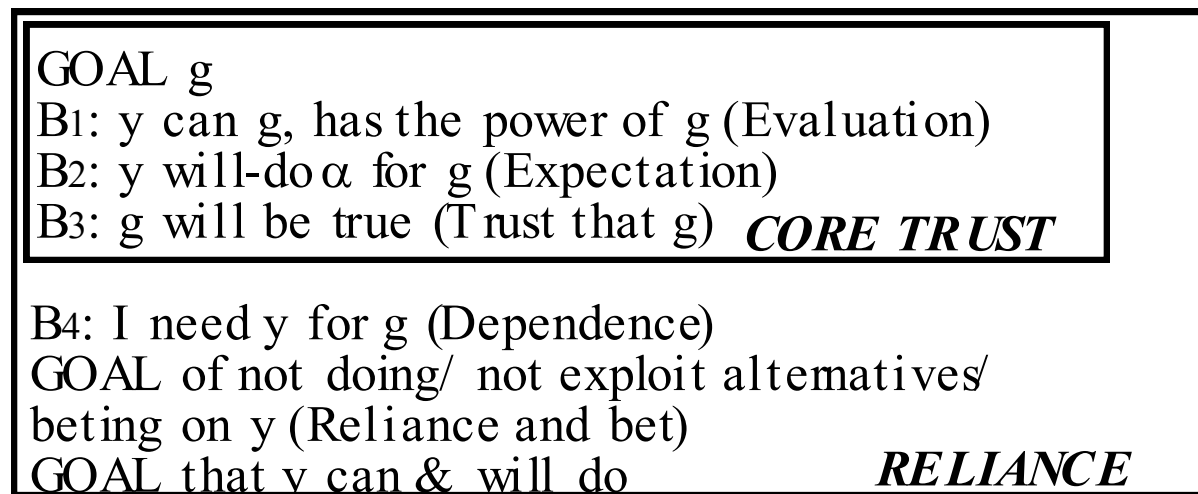
- Three elements to the research
 - Identify factors of trust published in the literature
 - Simulate human-agent interactions
 - Collect data on human interactions with autonomous agents
- The ultimate objective is to develop a process that can be validated in field trials



Identifying Trust Factors

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- Cristiano Castelfranchi and Rino Falcone argue that *Only agents endowed with goals and beliefs (cognitive agents) can “trust” another agent*¹¹
- They define the elements of trust with the following diagram



Mental ingredients of TRUST



Identifying Trust Factors

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- Sarvapali Ramchurn, et al., identified two principle components of trust in an agent¹²
 - Confidence – Do I believe the agent can perform the desired task?
 - Reputation – Has this agent been successful in the past and have others trusted this agent, with good results?



Identifying Trust Factors

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- Karen Fullam and Suzanne Barber focused on the importance of reputation when dealing with agents (either human or artificial) in the development of the ART Testbed¹³



Identifying Trust Factors

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- Just in these three research papers, the following potential trust factors were identified
 - Evaluation
 - Expectation
 - Trust
 - Dependence
 - Reliance
 - Bet
 - Confidence
 - Reputation
- Which factors are the key factors?



Simulating Trust

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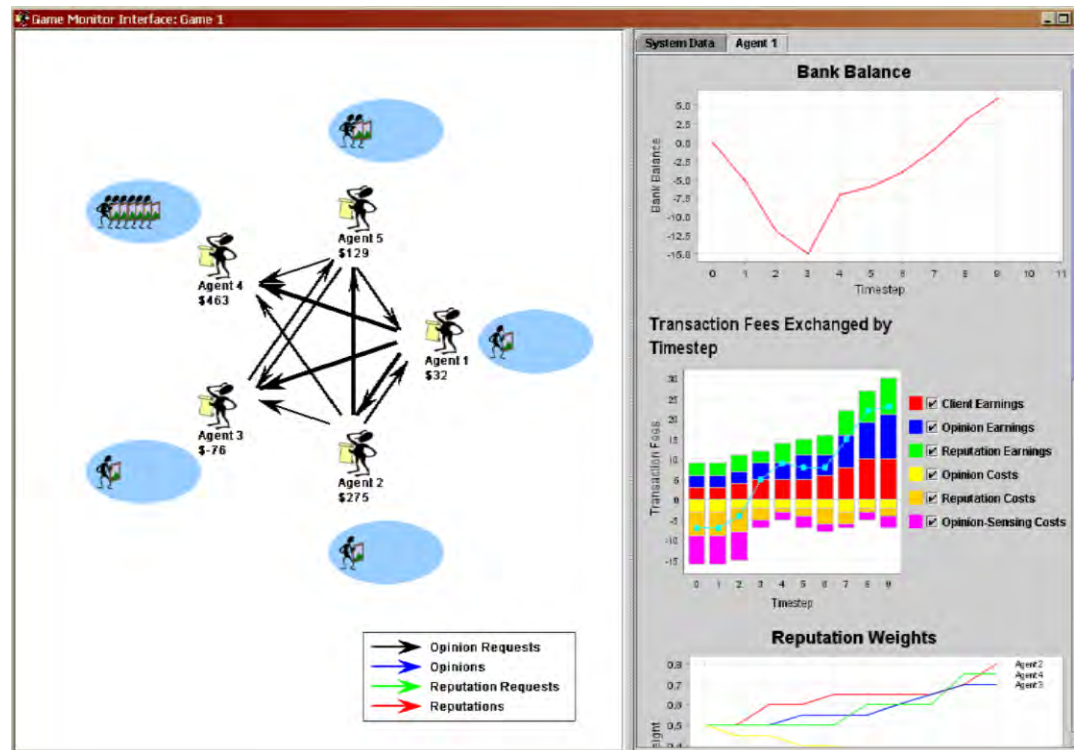
- Trust of autonomous systems is an active area of research
- Much of the research uses simulations to explore issues of trust and to compare approaches
- The simulations tend to take two forms
 - Simulations designed specifically for examining issues of trust
 - Simulations that were designed for other areas of research that have been extended or adapted to trust research
- The following are some examples of both types of simulation



Simulating Trust

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- Agent Reputation and Trust (ART) Testbed¹⁴
 - A simulation of multiple art appraising agents specifically designed for agent trust research

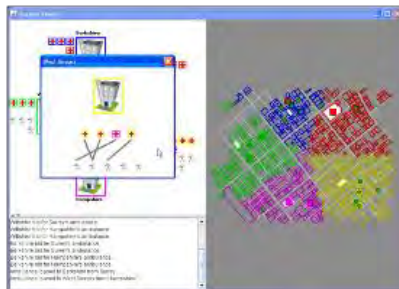




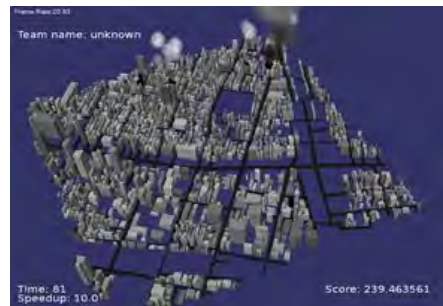
Simulating Trust

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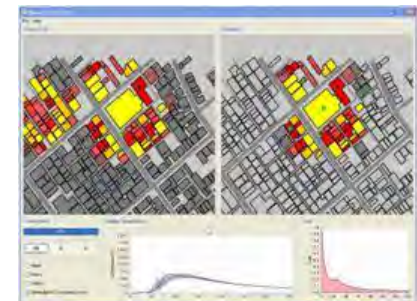
- RoboCup Rescue Simulation¹⁵
 - An agent simulation system that has been used for trust research¹⁶



Coalition Formation



Resource Allocation



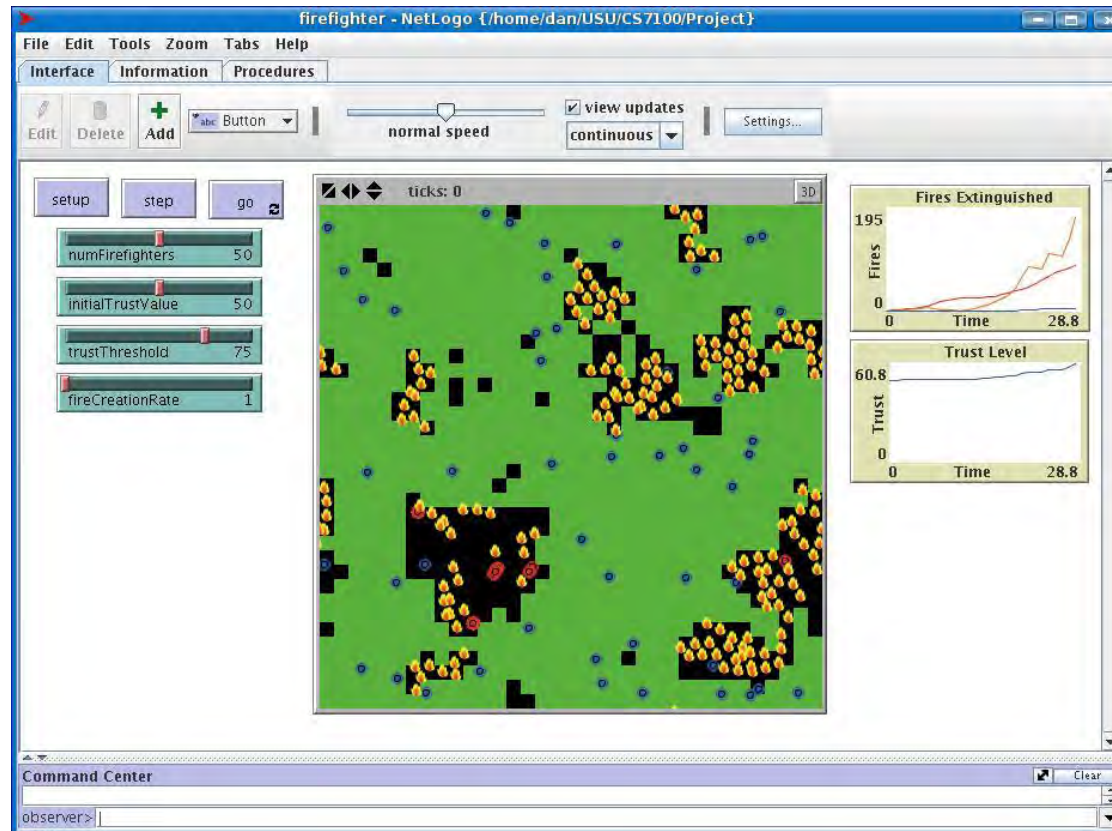
Estimation with Faulty Sensors



Simulating Trust

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- Firefighting Simulation
 - A simulation of human-robot trust relationships





Human-Robot Trust Game Prototype



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- A prototype of a game for collecting user interaction data was created in NetLogo
- The objective of the prototype was to evaluate playability and design elements for data collection





Human-Robot Trust Game Prototype



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- Last year a paper-based firefighting game was play tested at the RoboCup International Rescue Robotics Workshop
 - Based on feedback from the playtesting, a print and play game is being developed to gain wider feedback on the game mechanics
 - A print and play game simulating employment of UASs is also in preliminary development, with a working title of *Battle for Marjeh*
 - Links to both games and a wiki for feedback will be posted to the project web page when they are ready (see contacts slide at end of presentation)



Web-based Game

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- To collect data from a variety of users, a web-based game will be developed, based on feedback from the print and play game, providing tools for collecting data on how game players utilize the robots



Diplomacy Agent

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- As a parallel research effort, an autonomous *Diplomacy* playing agent is going to be developed to explore trust elements in an environment intended to encourage distrust
- *Diplomacy* games are available as play-by-email and via Internet play with a number of variants
- There is also a Diplomacy AI Centre in the UK that is open to all researchers to test *Diplomacy* agents in play against each other in a test environment called the Diplomacy AI Development Environment (DAIDE)¹⁷

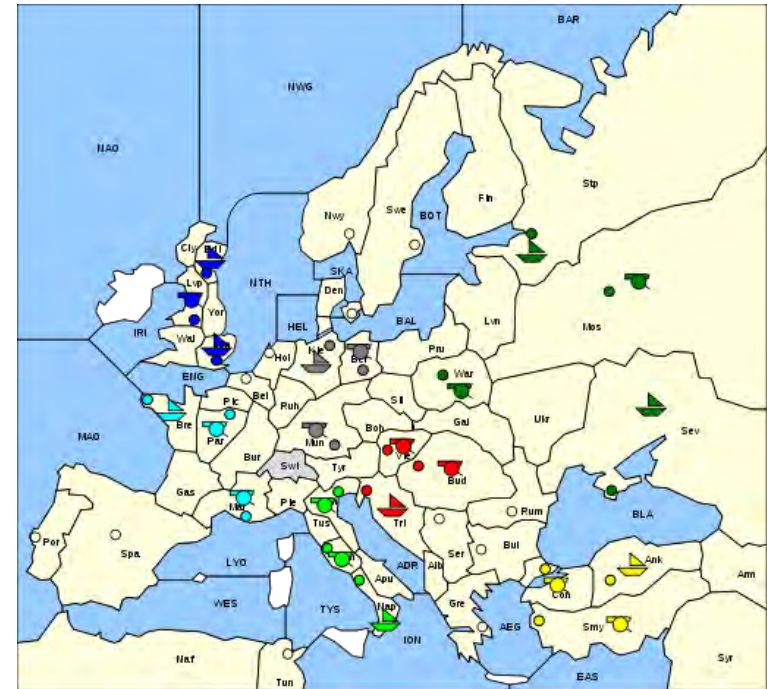


Diplomacy Agent



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- *Diplomacy* was created in 1954 by Allan B. Calhamer as a simulation of the diplomacy between the major powers prior to World War I in Europe
- The game typically has seven players
- In each turn, players participate in a negotiation phase, then all movements are resolved simultaneously¹⁸



Diplomacy Map by Martin Asai



Identifying Human-Agent Trust KPPs



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- The final objective for this project is to develop Key Performance Parameters that can be used by autonomous agent designers
 - Serve as design guidelines for agents
 - Provide verification parameters for testing
 - Provide validation parameters for field testing



Summary



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- Why Trust Matters
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- Trust Defined
- Identifying Elements of Trust
- Simulating Trust
- Human-Robot Trust Games
- Web-based Game
- Diplomacy Agent
- Identifying Human-Agent Trust KPPs



Project Contact Info

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**Human-Robot Trust Project webpage:
[https://sites.google.com/a/aggiemail.usu.edu/
human-robot-trust-project/](https://sites.google.com/a/aggiemail.usu.edu/human-robot-trust-project/)**



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Questions?



References

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1. DARPA, *DARPA Urban Challenge*. Online: [<http://www.darpa.mil/GRANDCHALLENGE/>]
2. Robert Gates, Secretary Gates Remarks at Maxwell-Gunter Air Force Base, Montgomery Alabama, *DefenseLink News Transcript*, April 21, 2008. Online: [<http://www.defenselink.mil/utility/printitem.aspx?print=http://www.defenselink.mil/transcripts/transcript.aspx?transcriptid=4214>]
3. OSD, *Unmanned Systems Roadmap, 2009-2034*, April 6, 2009. Online: [<http://www.acq.osd.mil/uas/docs/UMSIntegratedRoadmap2009.pdf>]
4. P.W. Singer, "In the Loop? Armed Robots and the Future of War," *Defense Industry Daily*, January 28, 2009. Online: [<http://www.defenseindustrydaily.com/In-the-Loop-Armed-Robots-and-the-Future-of-War-05267/>]
5. "Drone attacks in Pakistan," *Wikipedia*, Online: [http://en.wikipedia.org/wiki/Drone_attacks_in_Pakistan]
6. Erik Sofge, "Can Robots Be Trusted?," *Popular Mechanics*, February 2010, pp. 54-61.
7. "Autonomy," *American Heritage Dictionary*, Online: [<http://www.answers.com/topic/autonomy>]
8. "Autonomous Agent," *Wikipedia*, Online: [http://en.wikipedia.org/wiki/Autonomous_agent]
9. "Autonomous Robot," *Wikipedia*, Online: [http://en.wikipedia.org/wiki/Autonomous_robot]
10. Diego Gambetta, ed., *Trust: Making and Breaking Cooperative Relations*, New York, NY: Basil Blackwell Ltd., 1988. Online: [http://www.nuffield.ox.ac.uk/users/gambetta/gambetta_trust%20book.pdf]
11. Cristiano Castelfranchi and Rino Falcone, "Principles of Trust for MAS: Cognitive Autonomy, Social Importance, and Quantification," *Proceedings of ICMAS 1999*. Online: [<http://aois.org/99/castelfranchi-ICMAS-paper.rtf>]
12. Sarvapali Ramchurn, "Devising a Trust Model for Multi-Agent Interactions using Confidence and Reputation," *Applied Artificial Intelligence*, 18:833-852, 2004. Online: [<http://users.ecs.soton.ac.uk/nrj/download-files/jaai04.pdf>]
13. Karen Fullam and K.Suzanne Barber, "Learning Trust Strategies in Reputation Exchange Networks," *The Fifth International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS-2006)*, Hakodate, Japan, May 8-12, 2006, pp. 1241-1248. Online: [<http://megatron.iia.csic.es/art-testbed/pdf/FullamAAMAS2006.pdf>]
14. *ART Testbed*. Online: [<http://www.art-testbed.net/>]
15. RoboCup Rescue, *Rescue Agents*. Online: [<http://www.robocuprescue.org/agentsim.html>]
16. ALADDIN, *Technologies*. Online: [<http://www.aladdinproject.org/technologies.html>]
17. Diplomacy AI Centre. Online: [<http://www.daide.org.uk>]
18. "Diplomacy (Game)," *Wikipedia*, Online: [[http://en.wikipedia.org/wiki/Diplomacy_\(game\)](http://en.wikipedia.org/wiki/Diplomacy_(game))]



Acronym List

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■ AI	Artificial Intelligence
■ ALCM	Air Launched Cruise Missile
■ ART	Agent Reputation and Trust
■ DAIDE	<i>Diplomacy</i> AI Development Environment
■ DARPA	Defense Advanced Research Projects Agency
■ ISS	International Space Station
■ KPP	Key Performance Parameter
■ NASA	National Aeronautics and Space Administration
■ OSD	Office of the Secretary of Defense
■ SMXS	Software Maintenance Squadron
■ UAS	Unmanned Aerial System
■ UAV	Unmanned Aerial Vehicle
■ UGV	Unmanned Ground Vehicle
■ UMS	Unmanned Maritime System