



DoD Priorities for Autonomy Research and Development

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21 October 2011

NDIA Disruptive Technologies Conference

November 8-9, 2011

Washington, DC

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 21 OCT 2011		2. REPORT TYPE		3. DATES COVERED 00-00-2011 to 00-00-2011	
4. TITLE AND SUBTITLE DoD Priorities For Autonomy Research And Development				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) U.S. Air Force,Wright Patterson AFB,OH,45433				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 NDIA Disruptive Technologies Conference, November 8-9, 2011, Washington, DC					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 12	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



DOD Challenges Addressed by Autonomy



Decentralization, Uncertainty, Complexity...Military Power in the 21st Century will be defined by our ability to adapt – this is THE hallmark of autonomy

Manpower efficiencies: Insufficient manpower to support complex missions such as command and control and surveillance across relevant battlespace

Harsh environments: Operational environments that do not reasonably permit humans to enter and sustain activity

New mission requirements: Need adaptive autonomous control of vehicle systems in face of unpredictable environments and challenging missions





Autonomy—Technical Challenges

Working definition of “Autonomy” from recent DOD workshops: Having the capability and freedom to self-direct. An autonomous system makes choices and has the human’s proxy for those decisions. This does not mean the autonomous system is making decisions in isolation from humans, just that the system makes the choices. The balance between human and system decision making is defined by policy and operational requirements.

1. Machine Reasoning and Intelligence
2. Human/Autonomous System Interaction and Collaboration
3. Scalable Teaming of Autonomous Systems
4. Testing and Evaluation (T&E) and Verification and Validation (V&V)

All address Two Sources of Uncertainty/Brittleness:

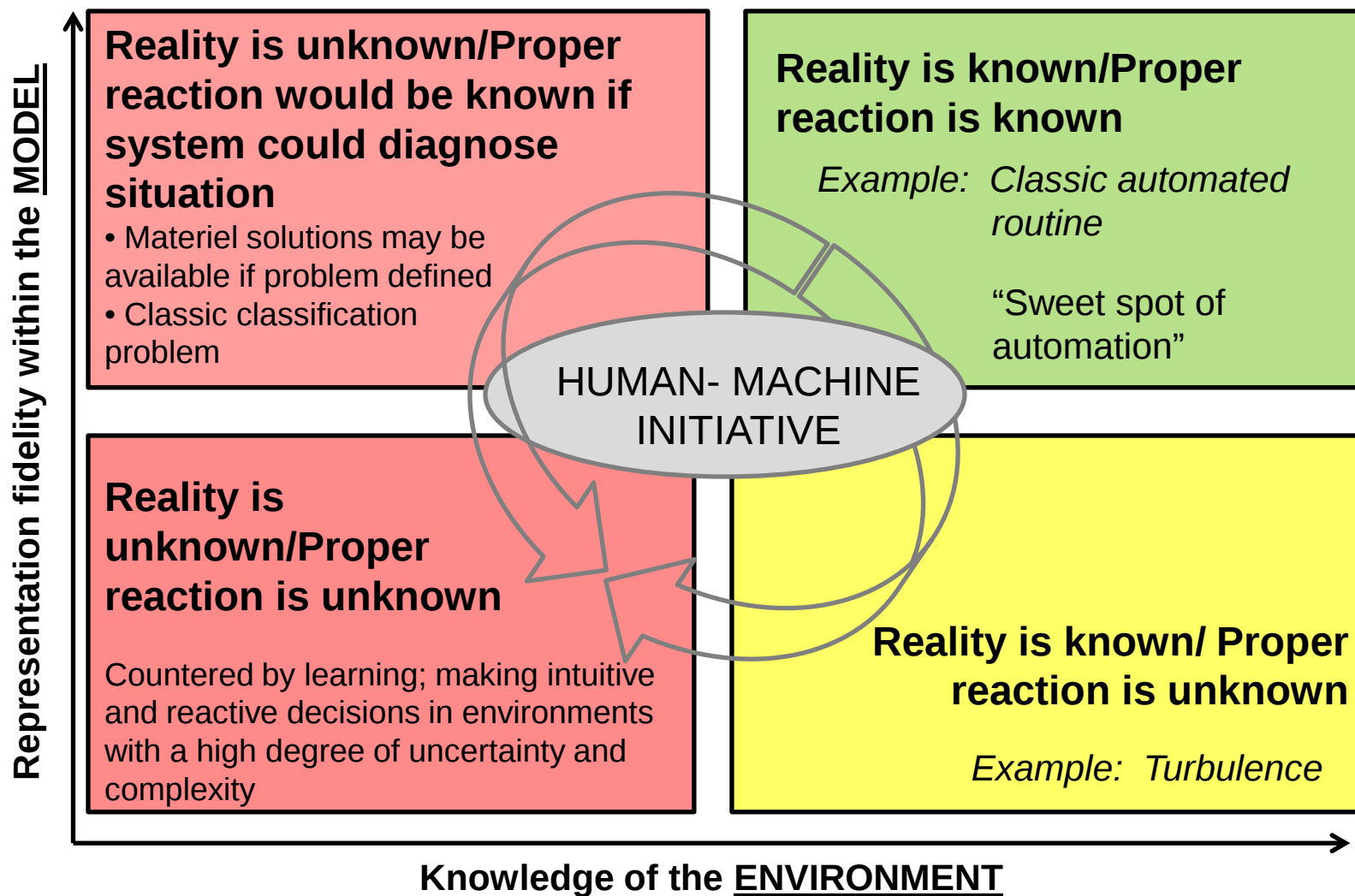
1. Dynamic and Complex Mission Requirements
2. Dynamic and Complex Operational Environments

Overarching Problem Statement:

In a static environment, with a static mission, automation and autonomy converge. However, in reality, where dynamic environments collide with dynamic missions, automation can only support a small fraction of autonomy requirements.



Autonomy Parameter Space





The diagram is organized into three columns representing time horizons: **Near term (FYDP)**, **Mid term (FYDP x 2)**, and **Far term (FYDP x 3)**.

Human/Autonomous System Interaction and Collaboration (purple box) is positioned at the top, spanning the Near and Mid terms. It has arrows pointing to the **NDIA Opportunity** (yellow oval) in the Near term and the **Machine perception, reasoning, and intelligence** (white box) in the Mid term.

Machine perception, reasoning, and intelligence (white box) is in the Mid term. It has arrows pointing to the **NDIA Opportunity** in the Near term and the **Scalable Teaming of Autonomous Systems** (orange box) in the Far term.

Link to Data to Decisions PSC (light blue rounded rectangle) is in the Near term. It has a double-headed arrow connecting it to the **NDIA Opportunity** in the Near term.

Scalable Teaming of Autonomous Systems (orange box) is in the Far term. It has an arrow pointing down to the **NDIA Opportunity** (yellow oval) in the Far term.

There are three **NDIA Opportunity** (yellow oval) nodes: one in the Near term, one in the Mid term, and one in the Far term.

Testing and Evaluation (T&E) and Verification and Validation (V&V) (green box) is at the bottom, spanning all three time horizons.

$$m/n < 1$$



Opportunities for NDIA: Coordinated Platform Reasoning



Human/Autonomous System Interaction and Collaboration	Machine perception, reasoning and Intelligence
• <u>Collaborative approaches</u> to enable humans to flexibly shape and redirect the plans, behaviors, capabilities of highly complex distributed autonomous systems in real time to meet the ever changing requirements of warfighters operating in a dynamic battlespace • More natural, cognitively compatible, and effective <u>multi-modal interactions between humans and autonomous systems</u> for rapid coordination and collaboration • <u>Intent-understanding</u> relative to team members, adversaries and bystanders • <u>Adaptable levels of autonomy</u> • <u>Transparency</u> (link to Human Systems initiatives)	• <u>Perception and comprehension</u> (includes ATR as relevant to autonomy) • <u>Onboard processing</u> to reduce bandwidth requirements • <u>Assessment/Planning in uncertain and unstructured environments</u> (e.g. common sense reasoning, abductive reasoning, planning with partial goals, etc) • <u>Learning, experience, adaptation</u>: includes the ability to enhance the networks capability to rapidly achieve perception and assessment • <u>Implementation</u>: includes issues of computational platforms, computational and reasoning architectures, etc. • <u>Distributed decision making</u> coordination to mission completion
Notional examples: Multi-vehicle coordinated object discrimination and distributed decision making	



Opportunities for NDIA: TEVV of Autonomous Systems



Scalable Teaming of Autonomous Systems

- Robust self-organization, adaptation, and collaboration among highly heterogeneous platforms and sensors in a dynamic battlespace
- Decentralized mission-level task allocation/assignment, planning, coordination and control of heterogeneous systems for safe navigation, sensing, and mission accomplishment
- Space (air, land, water) management operations in proximity to manned systems and units
- Sensing/synthetic perception across large numbers of distributed entities

Future solicitations to be determined

Testing and Evaluation, Verification and Validation

- Test and evaluation and Verification and validation approaches that support exponential growth projected in software lines of code as well as new algorithms types (e.g. non-deterministic)
- Analysis tools that work with realistic assumptions including supporting timely and efficient certification (and recertification) of intelligent and autonomous control systems
- Common architecture

Test Methodology— Assess machine reasoning in dynamic environments (Phase 1) and under dynamic mission requirements (Phase 2). Largely service-specific.



Examples of BAA's, MURI's, and SBIR's that Support DOD Requirements for Autonomy-related R&D



Organization	Opportunity	Contact
AFOSR (Reliance Optimization for Autonomous Sys)	BAA-AFOSR-2012-02	Joseph Lyons
AFRL/RW (Armament Technology)	BAA RWK-10-0001	Judie Jacobson
AFRL/711 HPW (Warfighter Interface Tech Adv R&D)	BAA 09-04-RH	Ronald Yates
ONR (Behavior of Complex ...Autonomous Systems)	BAA/MURI 11-026	Marc Steinberg
ONR (Long Range BAA for Navy and Marine Corps S&T)	ONRBAA12-001	Cheryl Nagowski
DTRA (Scalable Teaming of Autonomous Systems)	BRBAA08-Per5-C-008	Robert Kehlet
DTRA (TEV&V)	BRBAA08-Per5-c-0020	Robert Kehlet
DTRA (TEV&V)	BRBAA08-Per5-c-0027	Michael Robinson
ARL /ARO (Basic Scientific Research)	W911NF-07-R-0001-05	Varies by topic



Summary

- **DoD will be investing in and advancing the state-of-the-art in autonomy research**
- **DoD will be one of many players in this rapidly expanding area**
- **Investment represents significant opportunity for broad range of industrial partners, such as:**
 - **Transport**
 - **E-commerce**
 - **Healthcare**
 - **Public Safety**
 - **Non-traditional Defense Industries**
- **Autonomous technology will fill a major role in future DoD operations**



Autonomy Priority Steering Council Membership



- **USAF/AFRL – Morley Stone (Lead)**



- **US Army/TARDEC - James Overholt**



- **US Army/ARL- Jonathan Bornstein**



- **US Navy/ONR – Marc Steinberg**

- **DTRA – Stephen Dowling**