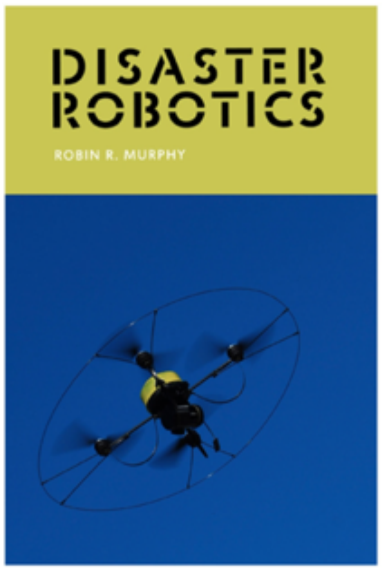
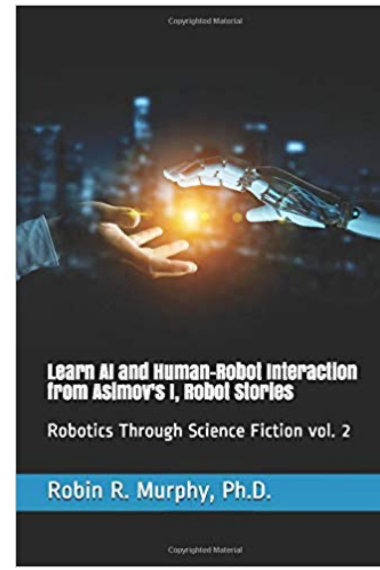
Role of Autonomy in DoD Systems and HADR



Dr. Robin R. Murphy
Texas A&M University



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Two Parts

1. Provide a briefing of the 2012 Defense Science Board Task Force on the Role of Autonomy in DoD Systems

2. Illustrate some of the concepts from Part 1 that explains the use of robots for humanitarian assistance and disaster relief (HADR)

Task Force on the
Role of Autonomy in DoD Systems

June 2012

Dr. Robin Murphy, Co-Chair
Mr. James Shields, Co-Chair

Terms of Reference

- Review relevant technologies to evaluate readiness for introduction into DoD
- Review current Service plans for integrating autonomy into near-term and next generation systems to identify missed opportunities
- Assess training and force structure impacts of autonomy improvements with a focus on reducing weapon system cost and personnel forward footprint
- Identify new opportunities for more aggressive application of autonomy and the associated benefits
- Comment on potential value of autonomy to both symmetric and asymmetric adversaries and where possible provide a net assessment
- Anticipate new vulnerabilities from reliance on pervasive autonomy and explore the value of autonomy as a hedge against weaknesses of net-centricity
- Identify systemic barriers to realizing full potential of autonomous systems
- Define special needs for testing and modeling & simulation for evaluating autonomous systems and their CONOPS
- Anticipate operational difficulties associated with rapid introduction of autonomous systems capabilities

Panel Members

- Brent Appleby
- Adele Howe
- Ken Israel, MG USAF (ret)
- Alexis Livanos
- James McCarthy, Gen UASF (ret)
- Ray Mooney
- Robin Murphy (co-chair)
- John Nathman, Adm USN (ret)
- Kevin Parker
- James Shields (co-chair)
- Robert Tenney
- David Woods

Impact

- Unmanned systems are having a worldwide impact (offensive and defensive) across the DoD, but we are operating in relatively benign conditions and at the initial stages of innovation for autonomy
  - Uses are primarily in air and ground applications to date
  - Marine systems have not achieved widespread usage
  - Space system benefits are primarily ground-based staff reduction and enhanced mission flexibility
- Main benefits of autonomous UxS* are to extend and complement human performance, not provide a direct replacement of humans
  - Extend human reach: perception, action, speed, persistence, size, scale, fatigue
  - Permit delegation and reduction of cognitive load – if explicitly designed to do so
  - Expand the adaptive capacity of the warfighter (e.g,. more options, more flexibility)
  - Synchronize activities of UxS, software, and warfighter over wider scopes and ranges
- Consequence of these systems include:
  - New forms of data overload
  - Gaps between responsibility and authority
  - Challenges in coordinating joint activity that may require more people or investment

* Unmanned ___X__ System, where X designates the domain – air, ground…

About Autonomy

- Common misperceptions
  - Autonomy is misunderstood as providing independent thought and action when in fact they are “self-governing”
  - Action is bounded by its programmed capability
  - Autonomy is a capability (or a set of capabilities) not a “black box”
- Challenges of autonomous systems
  - For **the commander**, the design space and tradeoffs for incorporating autonomy into a mission are not well understood and the result is new operational consequences
  - For **the operator**, must address human-machine collaboration, which often is overlooked during design
  - For **the developer**, autonomy is primarily software and presents challenges to hardware-oriented, vehicle-centric development and acquisition processes

Recommendations

Technology

- Abandon efforts to define levels of autonomy and develop an autonomous system reference framework that
  - Focuses on how autonomy supports specific capabilities
  - Identifies cognitive functional responsibilities to be delegated to the human or the computer
  - Makes visible the systems level trades inherent in the design of autonomous capabilities

Autonomous System Reference Framework

Framework for the Design and Evaluation of Autonomous Systems

Cognitive Echelon View

As component agent and roles increase in autonomy, critical issues shift to relationships and coordination across roles and echelons

Scope of Control

- MISSION
- SECTION
- VEHICLE

Mission Dynamics View

where cognitive functions can assist

INITIATION

Plan, including delegation and bounds

IMPLEMENTATION

Action failures,
Obsolete portions of plans

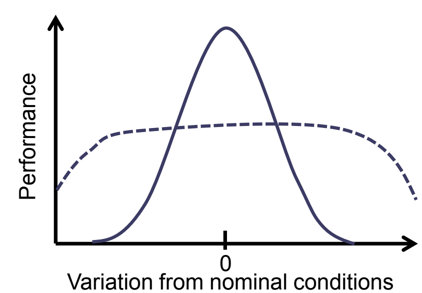
Mission Complete

TERMINATION

Complex System Trades Space View

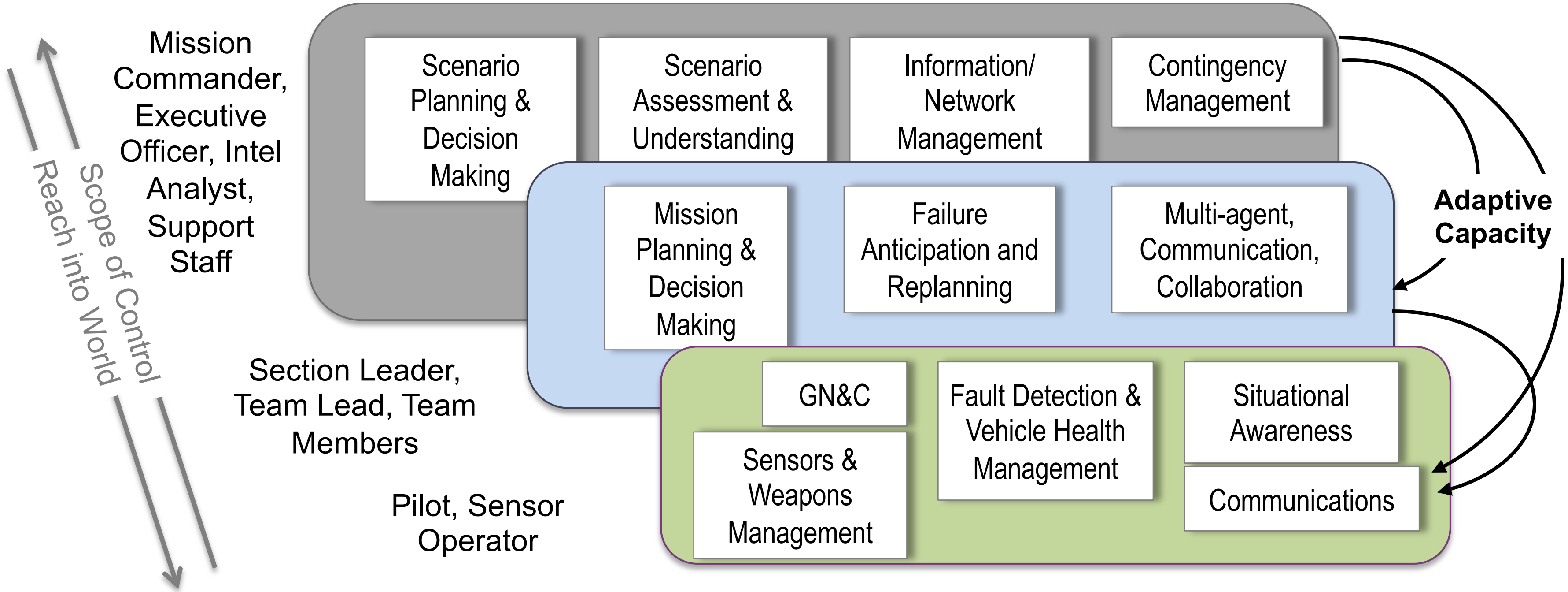
whether explicitly made or not, system level performance trades result from design

- **Responsibility: Short-Term vs. Long-Term Goals**
- **Perspectives: Local vs. Global Views**
- **Impact: Centralized vs. Distributed**
- **Plans: Efficiency vs. Thoroughness**
- **Fitness: Optimality vs. Resilience**



Scope of Cognitive Functionality Across Echelons

Scope of Cognitive Functionality Across Echelons



- Each cognitive function is performed by a mix of humans and/or computers
- Shifting a function from a human to a computer affects system performance, cost, and man power requirements

System Level Trades

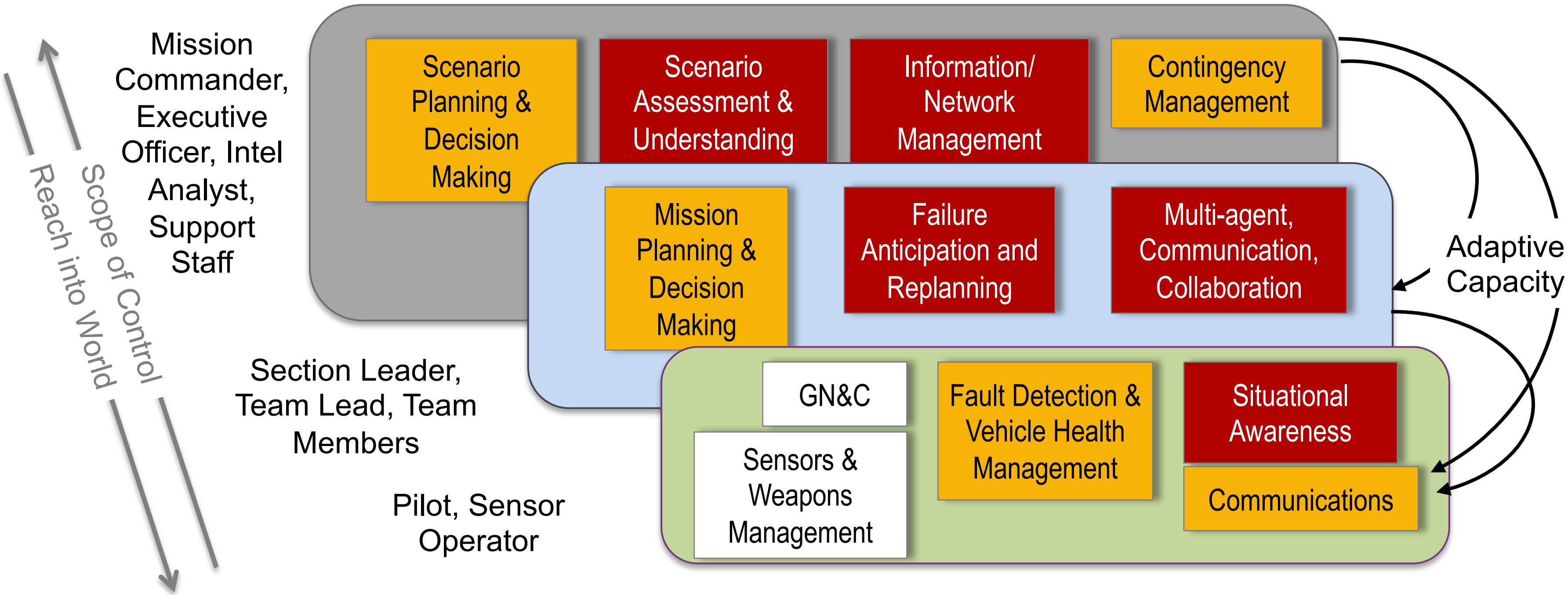
Trade Space	Trades	Benefits	Unintended Consequences
Fitness	Optimality vs. resilience	More precise results for understood situations	Increased brittleness
Plans	Efficiency vs. thoroughness	Balanced use of computational resources	Locked into wrong plan/difficulty revising plan
Impact	Centralized vs. distributed	Ability to tailor actions to appropriate echelon	High cost of coordination
Perspectives	Local vs. global views	Ability to balance scale/area of action with resolution	Data overload; reduced speed of decision making
Responsibility	Short-term vs. long-term goals	Builds trust tailoring risk management to goals, priorities, context	Break down in collaboration and coordination

Recommendations

Technology

- Abandon efforts to define levels of autonomy and develop an autonomous system reference framework that
  - Focuses on how autonomy supports specific capabilities
  - Identifies cognitive functional responsibilities to be delegated to the human or the computer
  - Makes visible the systems level trades inherent in the design of autonomous capabilities
- ASD(R&D) should work with Services to develop a coordinated S&T to strengthen autonomy technology with emphasis on
  - Natural user interfaces and trusted human-system collaboration
  - Perception and situation awareness to operate in a complex battle space
  - Large-scale teaming of manned and unmanned systems
  - Test and evaluation of autonomous systems
- Stimulate the S&T program with challenge problems motivated by operational experience and evolving mission requirements
  - Create focused on-site collaborations across academia, government/NFP labs and industry
- Strengthen the government technical workforce for autonomy by attracting AI and software engineering experts and establishing career paths and promotion opportunities that will retain them

Missed Opportunities, Needed Technology Developments



Under-utilized existing capability

Open technical challenges needing investment

Recommendations

Acquisition

- USD(AT&L) and Services to use reference framework in developing and evaluating new autonomous system designs
  - Direct that system designs explicitly address human-system interaction and delegation of decisions within the mission context
  - Separate autonomy (especially operator control and human supervision subsystems) development programmatically from vehicle development
  - Accelerate DoD and Service efforts to develop common, open software operator control systems leveraging proven human factors principles
- Joint Staff and Services should improve the requirements process to develop a mission capability pull for autonomous systems
  - Use autonomy framework to identify missed opportunities and future system capability, especially over echelons and timelines
  - Explicitly feed back operational experience with current unmanned/autonomous systems to develop future requirements
  - Create new methods for quantifying design trades, cost of coordination, and resilience and new T&E techniques for complex systems with non-deterministic behavior
- Each Service should initiate at least one open software design project for an existing or planned UxS platform that decouples autonomy from the vehicle and deploys proven technology to reduce manpower, increase capability and adapt to future missions
  - Strengthen government technical and acquisition capability by leveraging academia, not-for-profit laboratories and industry
  - Recognize that programming for autonomous systems is different than traditional software development

Recommendations

Operations/Culture

- Services should improve understanding of the role and benefits of autonomous systems
  - Develop short courses on autonomy for inclusion in professional military education
  - Include UxS concepts in war games
  - Ensure that lessons learned from use of unmanned systems in the current conflict are broadly disseminated
  - Develop operation training techniques that explicitly build trust in the autonomous system
- USD(AT&L) establish developmental and operational T&E techniques that focus on the unique challenges of autonomy
  - Coping with the difficulty of enumerating all conditions and non-deterministic responses
  - Basis for system decisions often not apparent to user
  - Measuring trust that the autonomous system will interact with its human supervisor as intended
  - Expanding the test environment to include direct and indirect users (human supervisors, higher level command, etc.)
  - Leverage the benefits of robust simulation

Recommendations

Avoid Capability Surprise

- Task DIA and the Intelligence Community to develop threat assessments for adversaries relative to the unmanned/autonomous systems capability
- Include adversary use of unmanned/autonomous systems in war games, training, simulations and exercises. Do not be constrained by U.S. system concepts and rules of engagement
- Services to develop tactics, techniques and procedures for countering adversary unmanned capabilities
- Task acquisition programs to assess vulnerabilities of U.S. systems to physical, jamming and cyber attacks
- Red team adversary responses to U.S. systems and actions

Summary

- Unmanned systems are having a worldwide impact (offensive and defensive) across the DoD, but we are operating in relatively benign conditions and at the initial stages of innovation of autonomy
- Main benefits of UxS* are to extend and complement human performance, not provide a direct replacement of humans
- Principal recommendation for capturing additional benefits of autonomous systems include:
  - Abandon definitions of levels of autonomy and replace with the autonomous systems reference framework. Use the framework to shape technology programs and to make key decisions for the design of future systems
  - ASD(R&E) should work with Services to establish a coordinated S&T program guided by feedback from operational experience and evolving mission requirements
  - Joint Staff and Services should improve the requirements process to develop a mission capability pull for autonomous systems
  - USD(AT&L) to create developmental and operational T&E techniques that focus on the unique challenges of autonomy
  - DIA and Intelligence Community to track adversary capabilities for autonomous systems. Include these threats in war games, training, simulations and exercises

Champlain Towers South Collapse, Surfside, FL

~600 flights by drones, flying 24/7 by squads from multiple agencies including MDFR, FLTF1 (FSU), FLTF2, MBPD, NIST

The Most Commonly Used Drone: DJI Mavic 2 Enterprise Duo

Autonomy at Surfside

- **Four general purposes: but only one "autonomous" and all are joint activities**
  - Tactical local and streaming- *remote presence*
  - Strategic mapping missions- *autonomous flight but manual post-processing*
  - Forensic structural analysis – *remote presence*
  - Public information – *remote presence*

font size proportional to #flights

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  - Tactical, local and streaming- *remote presence*
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  - Public information – *remote presence*
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- **Why didn't we use model X (made in America) which has the most advanced autonomous obstacle avoidance?**
  - Squads self-selected and used the most general purpose (indoor/outdoor, day/night, tactical/strategic), reliable, attritable, easiest to carry, easiest to operate, most reliable, easiest to recharge drones. Which happened to be made in China.

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<u>Cognitive Echelon View</u>

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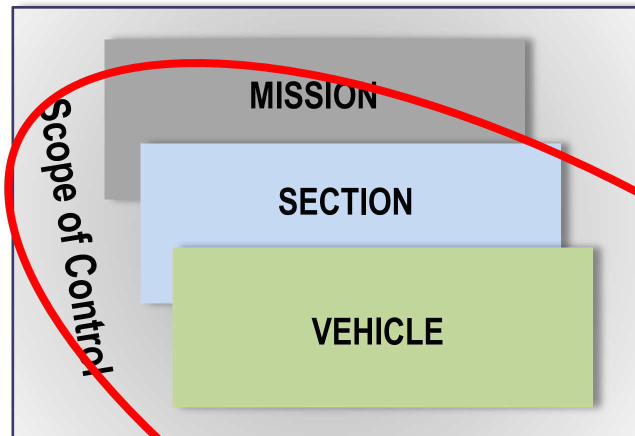
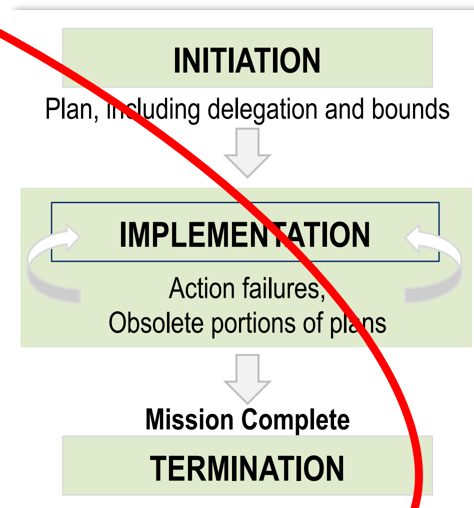


Flying was the easy part: data post-processing for rapid distribution and sharing was hard

<u>Mission Dynamics View</u>

where cognitive functions can assist



<u>Complex System Trades Space View</u>

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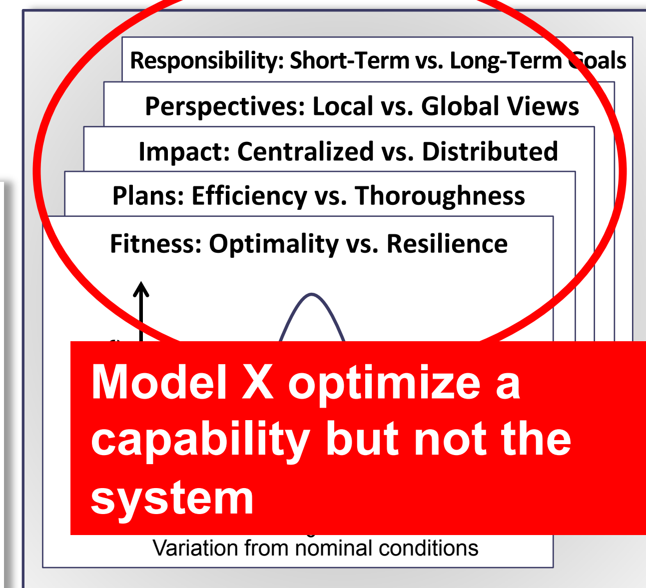

Model X optimize a capability but not the system

My Personal Assessment

- Human-AI Teaming is really about Human-AI **joint activity**
- AI offers **capabilities,** and supports human capabilities, but does not replace humans
- Those capabilities must fit the larger **system**
- A **cognitively oriented, system framework** is needed for design and evaluation and the one proposed in the DoD study is good start