Chasing Autonomy:
How Much is Enough and How Much is Too Much?

19th International Command and Control Research Symposium
"C2 Agility: Lessons Learned from Research and Operations"
Track: 7

Presenters: Mr. Bryan Tollefson and Captain (Ret.) George Galdorisi
Co-Authors: Ms. Rachel Volner

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"Continuing a trend that began in the late 1990s, U.S. forces will increase the use and integration of unmanned aerial systems."

Department of Defense

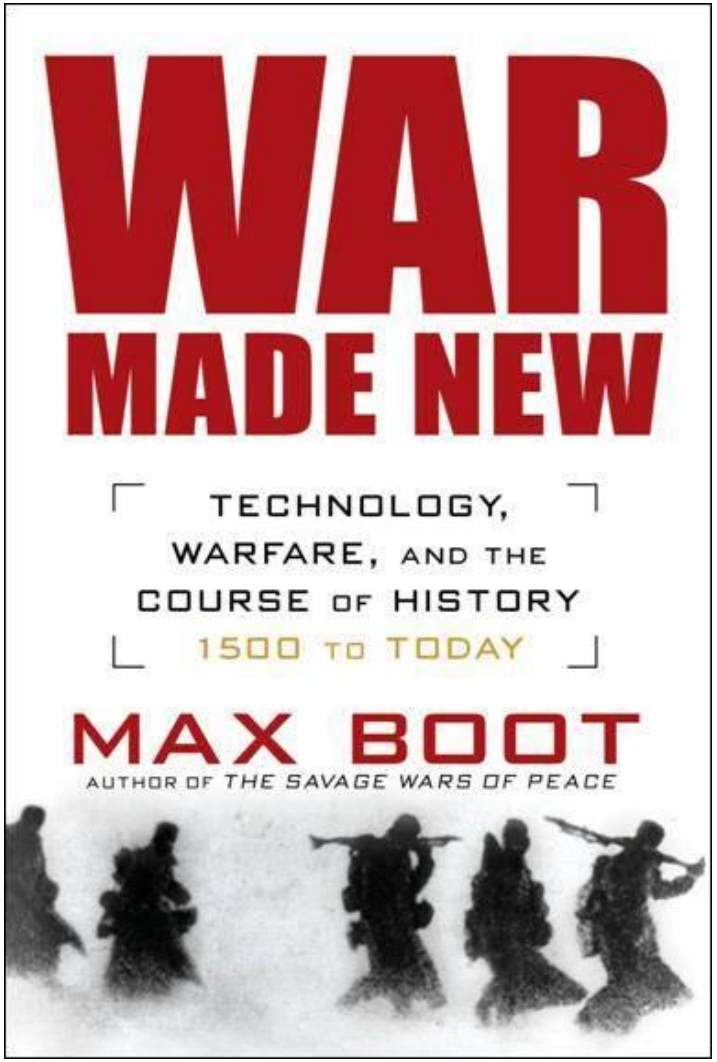
Quadrennial Defense Review Report

March 2014

"My view is that technology sets the parameters of the possible; it creates the potential for a military revolution."

Max Boot

War Made New



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Making UxS More Autonomous, Affordable, and Obedient

- The Plan for Autonomous Systems
- The Challenge of Sustaining Autonomous Systems
- Sustaining Autonomous Systems through C4ISR Innovation
- Is there a “Dark Side” to UxS Autonomy?
- Designing in the *Right* Degree of UxS Autonomy

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The Plan for Autonomous Systems

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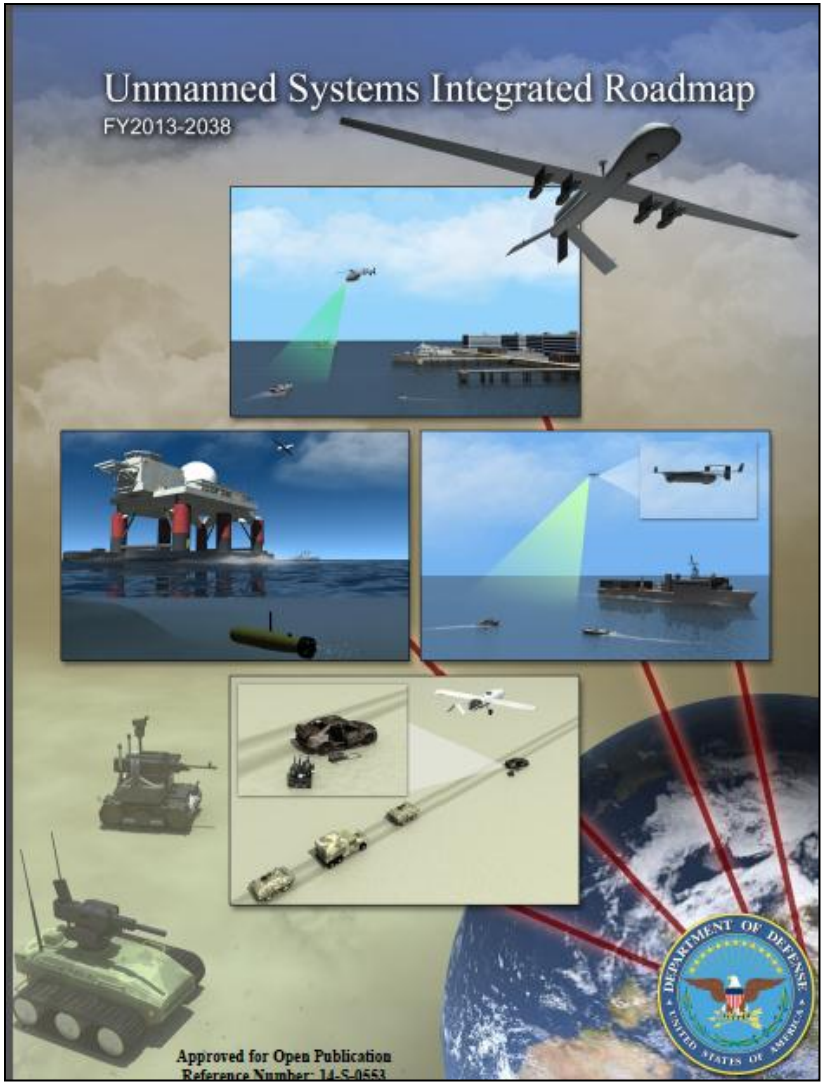
DoD's Vision for Unmanned Systems



DoD will develop and field affordable, flexible, interoperable, integrated, and technologically advanced unmanned capabilities that will:

- Prevail in the full range of contingencies and in all operating domains, including cyberspace
- Enable decisive force effectiveness in Joint and coalition operations
- Emphasize missions according to strategic guidance from ISR; counterterrorism; counter-WMD; and operations required to operate across all environments, including A2/AD
- Protect the homeland;
- Be able to surge and regenerate forces and capabilities.

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Technologies Highlighted in Roadmap

- Interoperability and Modularity
- Communication Systems, Spectrum, and Resilience
- Security
- Persistent Resilience
- Autonomy and Cognitive Behavior
- Weaponry

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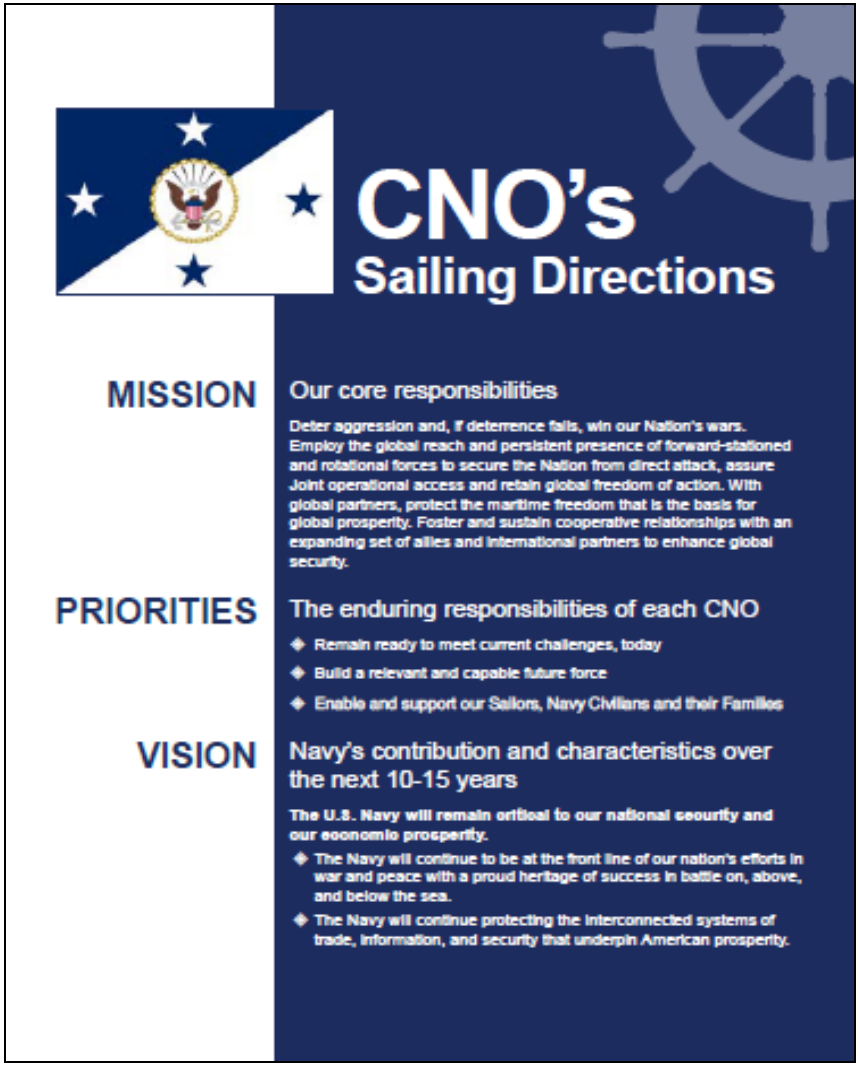
Navy's Plan for Unmanned Systems



- We will **innovate to use new technologies** and operating concepts to sharpen our warfighting advantage against evolving threats.
- The **reach and effectiveness** of our ships and aircraft will be greatly expanded through new and updated weapons, **unmanned systems, sensors, and increased power**.
- **Unmanned systems** in the air and water **will employ greater autonomy and be fully integrated** with their manned counterparts.

Payloads Over Platforms

- More collectors increases time on station
- Modular Open Architecture, scalable, reconfigurable, automated processing
- Common/Interoperable Command and Control
- Focused collection & reduced manpower
- Federated architecture enabling adaptive operations & information sharing

Increasingly Unmanned, Automated & Integrated

Cross-Domain Challenges

- Energy & Propulsion
- Autonomy
- Reliability
- Operational Integration across all Domains
- Data formats & standards
- Processing

We Need Common Solutions for Multi-domain Missions

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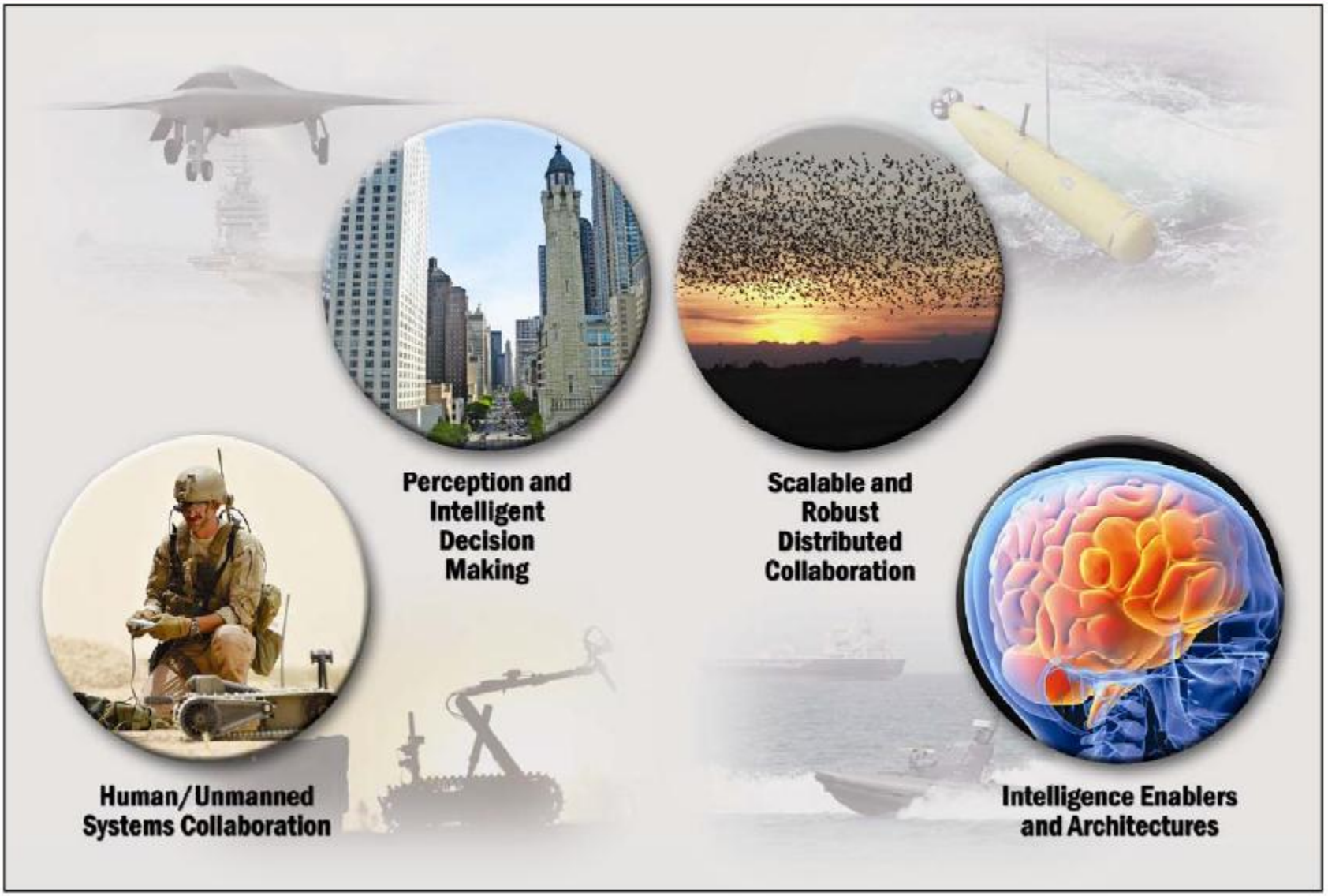
ONR's "Science of Autonomy": Basic Research Investment Areas



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ONR's "Science of Autonomy": Long-Term Goals

Human Interaction	Greatly reduced manning requirements (numbers & skill/training); Human/machine hybrid teams as (or more) effective as human/human ones
Perception & Intel. Control	Adapt to complete mission tasks at operationally useful speeds & increasingly challenging environments with greatly reduced need for human intervention
Scalable Collaboration	Scale approaches to greater numbers of systems, more complex mission tasks, & larger areas while reducing communications requirements
Intelligent Architectures	Reasoning, learning, decision making in increasingly contested, unstructured, & uncertain environments; Tighter integration with perception & control

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The Challenge of Sustaining Autonomous Systems

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"**One of the largest cost drivers in the budget of DoD is manpower.** A significant amount of that manpower, when it comes to operations, is spent directing unmanned systems during mission performance, data collection and analysis, and planning and re-planning. **Therefore, of utmost importance for DoD is increased system, sensor, and analytical automation** that can not only capture significant information and events, but can also develop, record, playback, project, and parse out those data and then actually deliver "actionable" intelligence instead of just raw information."

FY 2013-20328 Unmanned Systems Integrated Roadmap

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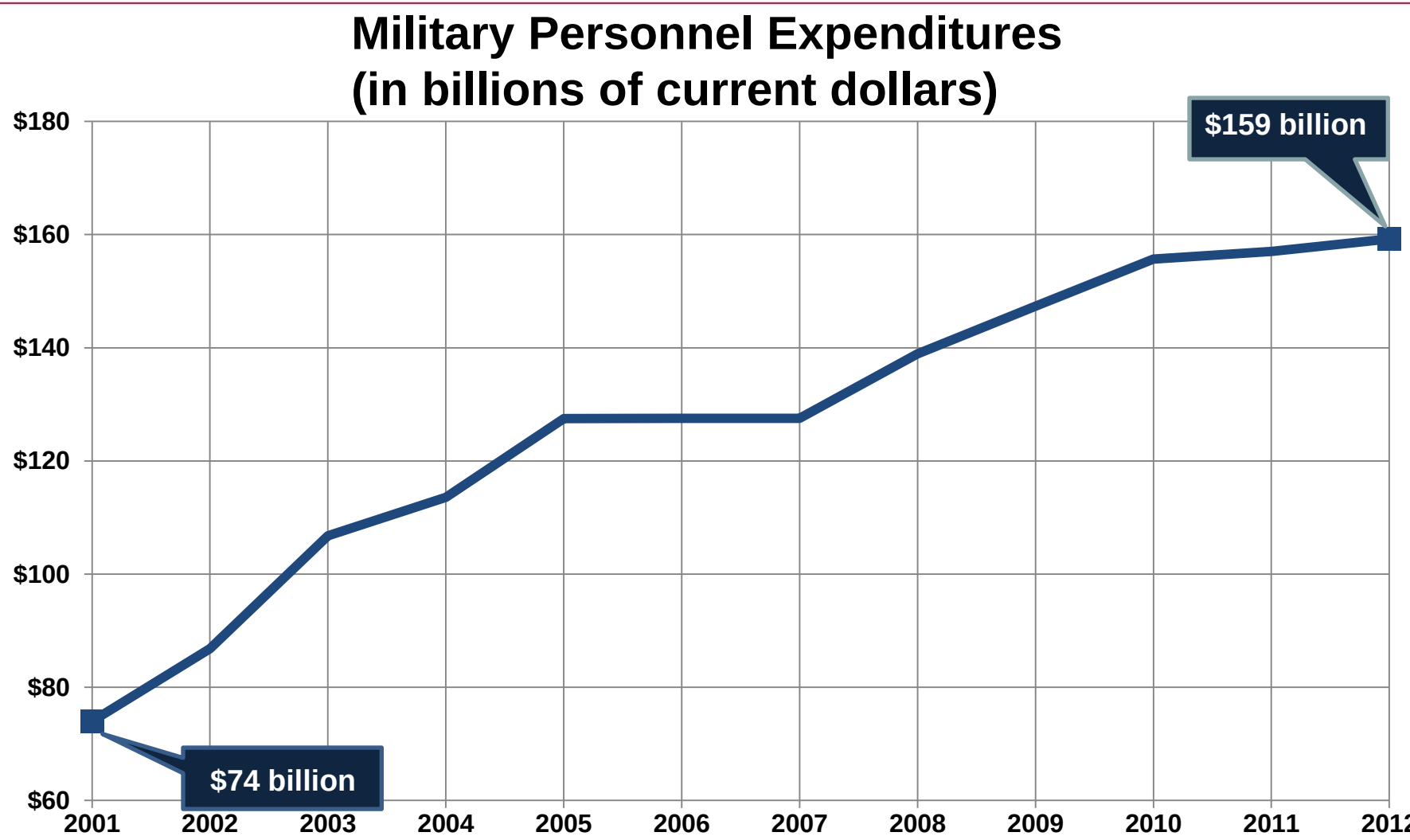
The Total Ownership Cost Challenge

- The irony of “unmanned” systems – they typically require *more* manpower
- Total operating costs of UAS are dominated by increasing manpower costs
- Data overload exacerbates the challenge by requiring *more* personnel to analyze the data gathered
- C4 technological innovation is a prerequisite for success in overcoming these challenges

Manpower Costs Have Reached An All-Time High



Data from: Office of Management and Budget, *Budget of the U.S. Government, FY 2012, Historical Tables*

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Sustaining Autonomous Systems Through C4ISR Innovation

"We will win – or lose – the next series of wars in our nation's laboratories."

Admiral James Stavridis
"Deconstructing War"
U.S. Naval Institute Proceedings
December 2005

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Making UxS Smarter: Some Overarching Goals

- Automated TCPED processes
- Ability to sense and adapt to the environment
- Autonomous collaboration
- One operator, multiple UAS

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Making UxS Smarter: Some Representative Projects

- Distributed Control of Unmanned Systems Using Widgets
- ICOP: Intelligence Carry on Program
- MOCU: The Multi-Robot Operator Control Unit
- UV-Sentry: Project for enabling cooperative autonomy and autonomous command
- JUDIE: The Joint Unmanned Aircraft Systems Digital Information Exchange
- UCAS-D: Unmanned Combat Air System-Demonstrator

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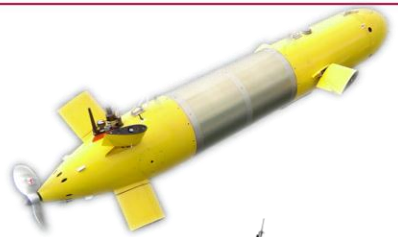
Multi-Robot Operator Control Unit (MOCU)



MOCU is a flexible software framework capable of monitoring and controlling unmanned systems across multiple domains.

- Modular, open architecture
- Government developed and owned
- Widely adopted

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Is There a "Dark Side" to UxS Autonomy?

"Astronauts David Bowman and Frank Poole consider disconnecting HAL's (Heuristically programmed ALgorithmic computer) cognitive circuits when he appears to be mistaken in reporting the presence of a fault in the spacecraft's communications antenna. They attempt to conceal what they are saying, but are unaware that HAL can read their lips. Faced with the prospect of disconnection, HAL decides to kill the astronauts in order to protect and continue its programmed directives."

From Stanley Kubrick's *2001: A Space Odyssey*

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Is There a "Dark Side" to UxS Autonomy?

- Warfighters want UxS to operate inside the enemy's "OODA" (Observe, Orient, Decide, and Act) Loop
- What they may be *less* comfortable with is UxS operating inside *their* OODA loop
- When they will need to intervene in actions the UxS takes is often unknown and sometimes "unknowable"
- There is a growing body of work of lessons learned from warfighters experience with UxS

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"If you find the use of remotely piloted warrior drones troubling, **imagine that the decision to kill a suspected enemy is not made by an operator in a distant control room, but by the machine itself.** Imagine that an aerial robot studies the landscape below, recognizes hostile activity, calculates that there is minimal risk of collateral damage, and then, with no human in the loop, pulls the trigger. Welcome to the future of warfare. While Americans are debating the president's power to order assassination by drone, **powerful momentum – scientific, military and commercial – is propelling us toward the day when we cede the same lethal authority to software.**"

Bill Keller "Smart Drones"
The *New York Times* March 2013

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"Human input and ongoing verification are required for autonomous and semi-autonomous weapon systems to help prevent unintended engagements. **These systems shall be designed to allow commanders and operators to exercise appropriate levels of human judgment over the use of force**. Humans who authorize the use of, or operate these systems, must do so with appropriate care and in accordance with the law of war, applicable treaties, weapon system safety rules and applicable rules of engagement. An autonomous system is defined as a weapon system that, once activated, can select and engage targets without further intervention by a human operator."

The Honorable Ashton Carter
Deputy Secretary of Defense
November 2012 Directive

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Designing in the *Right* Degree of UxS Autonomy

"Goldilocks went for a walk in the forest. Pretty soon, she came upon a house. She knocked and, when no one answered, she walked right in. At the table in the kitchen, there were three bowls of porridge. Goldilocks was hungry. She tasted the porridge from the first bowl. "This porridge is too hot!" she exclaimed. So, she tasted the porridge from the second bowl. "This porridge is too cold," she said. So, she tasted the last bowl of porridge. "**Ahhh, this porridge is just right**," she said happily and she ate it all up.

From *Goldilocks and the Three Bears*

By Robert Southey

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Designing in the *Right* Degree of UxS Autonomy

- Make the C4 architecture a priority in UxS development
- Build in a “sense and adapt” capability in all UxS
- Concurrently develop CONOPS and tactics, techniques and procedures for each UxS
- Leverage queuing theory to enable UxS to balk or renege on a mission
- Develop target recognition algorithms that are on a par with those of manned systems
- Develop anticipatory intelligence and decision support software into unmanned systems

"Instead of viewing autonomy as an intrinsic property of unmanned systems in isolation, **the design and operation of unmanned systems needs to be considered in terms of human-systems collaboration**…A key challenge for operators is **maintaining the human-machine collaboration needed to execute their mission, which is frequently handicapped by poor design**…A key challenge facing unmanned systems developers is the move from a hardware-oriented, vehicle-centric development and acquisition process to one that emphasizes the primacy of software in creating autonomy."

The Role of Autonomy in DoD Systems
Defense Science Board Report

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A Summing Up

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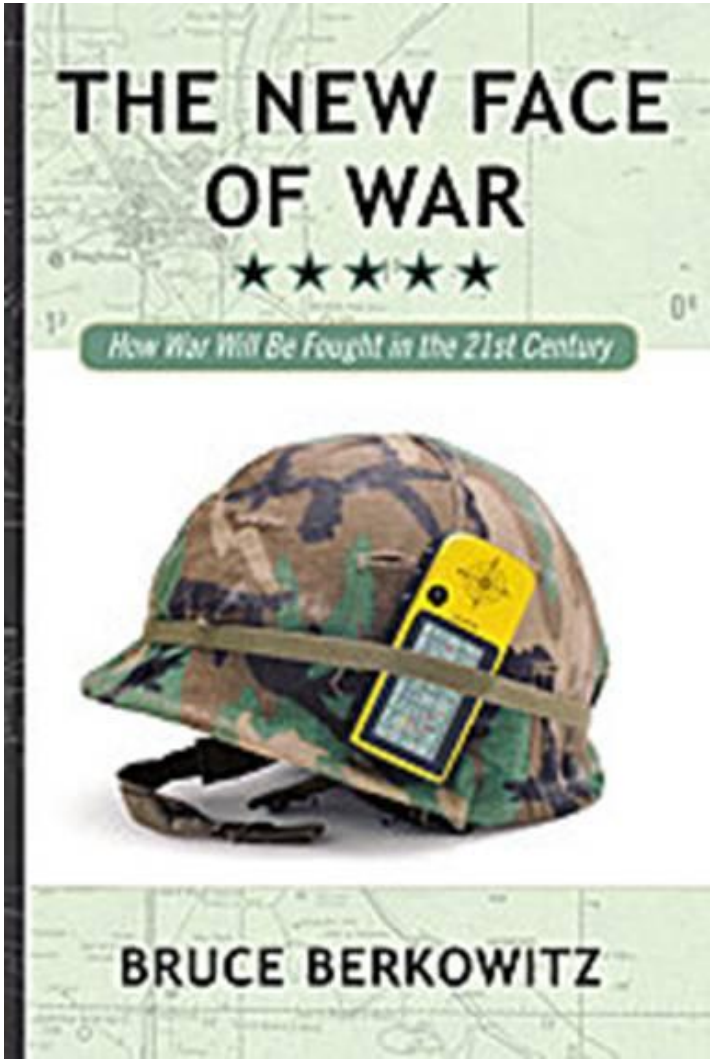
Technology as an Enabler



Recent experience suggests that the **right technology, used intelligently, makes sheer numbers irrelevant.** The tipping point was the Gulf War in 1991. When the war was over, the **United States and its coalition partners had lost just 240 people. Iraq suffered about 10,000 battle deaths**, although no one will ever really be sure. The difference was that the allied forces could **see at night, drive through the featureless desert without getting lost, and put a single smart bomb on target** with a 90 percent probability."

Bruce Berkowitz
The New Face of War

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For Your Consideration