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Taking the Next Step: From "Unmanned" to True Autonomy

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14. ABSTRACT

Unmanned systems have come to be used so extensively that it is almost impossible to imagine tomorrow?s military operating without the strategic, operational, and tactical advantages that they offer. However, today most unmanned systems have yet to advance towards true autonomy; instead, they require extensive manpower support, which escalates Total Ownership Costs to unsustainable levels. As the DoD?s Unmanned Systems Integrated Roadmap 2011 ? 2036 states, ?the increased manpower to operate unmanned systems is adding stress to the overall workload of the armed forces. This stress highlights the need to transition to a more autonomous, modern system of warfare.? Future C4ISR development to make this vision a reality must reduce manpower while expanding complexity of missions these systems are able to carry out. A particularly urgent focus area is the need for unmanned intelligence, surveillance, and reconnaissance (ISR) systems to conduct onboard processing of data to address the ?information overload? crisis that the U.S. military is facing today. We will present examples of ground-breaking work being conducted in the DoD laboratory community, highlighting systems such as the Intelligence Carry On Program (ICOP) that are paving the way for a completely new paradigm ? multiple unmanned systems controlled by one operator.

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As the DoD's *Unmanned Systems Integrated Roadmap 2011 – 2036* states, "the increased manpower to operate unmanned systems is adding stress to the overall workload of the armed forces. This stress highlights the need to transition to a more autonomous, modern system of warfare." Future C4ISR development to make this vision a reality must reduce manpower while expanding complexity of missions these systems are able to carry out. A particularly urgent focus area is the need for unmanned intelligence, surveillance, and reconnaissance (ISR) systems to conduct onboard processing of data to address the "information overload" crisis that the U.S. military is facing today.

We will present examples of ground-breaking work being conducted in the DoD laboratory community, highlighting systems such as the Intelligence Carry On Program (ICOP) that are paving the way for a completely new paradigm – multiple unmanned systems controlled by one operator.

Taking the Next Step: From "Unmanned" to True Autonomy

Perspective (Thesis)

"My view is that technology sets the parameters of the possible; it creates the potential for a military revolution."[1]

Max Boot
War Made New

In his book, *War Made New: Technology, Warfare, and the Course of History 1500 to Today* (Gotham Books, 2006), military historian Max Boot supports the following thesis with historical examples: "My view is that technology sets the parameters of the possible; it creates the potential for a military revolution."[2]

In keeping with the historical trend, over the past quarter-century the U.S. military has embraced a wave of technological change that has constituted a true revolution in military affairs. Unquestionably, one of the most rapidly growing areas of technology adoption involves unmanned systems. In the past ten years alone, the military's use of unmanned aerial vehicles (UAVs) has increased from only a handful to more than 5,000, while the use of unmanned ground vehicles (UGVs) exploded from zero to more than 12,000.[3] The rising use of armed, unmanned systems is not only changing the face of modern warfare, but is also altering the process of decision-making as our nation launches combat operations. Indeed, it's been argued that the rise in drone warfare is changing the way we conceive of and define "warfare."[4]

The urgent demands of Operations Enduring Freedom and Iraqi Freedom have spurred the development and employment of these systems to the point that they are already creating strategic, operational, and tactical possibilities that did not exist a decade ago. This remarkably rapid rise has been supported by the equally fast pace of technological research and development taking place within industry, academia, and Department of Defense laboratories.

But for unmanned systems to reach their full potential, important command, control communications, computers, intelligence, surveillance and reconnaissance (C4ISR)

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[1] Max Boot, *War Made New: Technology, Warfare, and the Course of History 1500 to Today* (New York, Gotham Books, 2006). Boot uses historical examples to show how technological-driven "Revolutions in Military Affairs" such as the Gunpowder Revolution, the Industrial Revolution, the Second Industrial Revolution, and the Information Revolution have transformed warfare and altered the course of history.

[2] Max Boot, *War Made New: Technology, Warfare, and the Course of History 1500 to Today* (New York, Gotham Books, 2006).

[3] P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the 21st Century* (New York, The Penguin Press, 2009).

[4] P.W. Singer, "Do Drones Undermine Democracy?," *New York Times*, January 21, 2012.

considerations must be addressed. The science of building unmanned air, ground, surface, and underwater vehicles is well advanced. But the costs of military manpower mandate that we move beyond the "one-man, one-joystick, one-vehicle" paradigm that has existed during the past decades of unmanned systems development.

If the vision of unmanned systems is to be fully realized, the focus must be on their perception capabilities and intelligence—and more broadly, on their C4ISR capabilities—rather than on the platforms themselves. This will usher in a new paradigm whereby multiple unmanned systems are controlled by one operator. The way ahead for future unmanned systems is for them to ultimately provide their own command and control and self-synchronization, thereby allowing the systems to become truly autonomous[5] and eventually to become warfighters' partners rather than simply tools.

The Past is Prologue: Coming Full Circle

One only has to read a few lines of defense media reports of autonomous systems development or industry advertisements regarding a particular air, ground, surface or subsurface UxS to come away with the impression that autonomous systems represent completely new technology, an artifact of the 21st Century, or perhaps the late 20th Century. But in fact, autonomous systems have been around for over a century.

As with the use of autonomous systems today in Iraq and Afghanistan, unmanned aerial systems (UAS) have led the way over most of the past century of UxS development and the exigencies of wartime have spurred rapid development of these systems. A large part of the motivation is clear; these UAS (often called drones) can go where it might be too hazardous to risk a pilot in a manned platform.

The earliest recorded use of an unmanned aerial vehicle for warfighting occurred on August 22, 1849, when the Austrians attacked the Italian city of Venice with unmanned balloons loaded with explosives. The first pilotless aircraft were built shortly after World War I. The U.S. Army led the way, commissioning a project to build an "aerial torpedo," resulting in the "Kettering Bug" which was developed for wartime use, but which was not deployed in time to be used in World War I.

All the Services continued to develop various types of UxS during the inter-war years, much of it focused on UAS, such as actor Reginald Denny's RP-1 target drone, adapted directly from his

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[5] For the purposes of this paper, we adopted the usage proposed by the U.S. Navy's 28th Strategic Studies Group (SSG) in its report "The Integration of Unmanned Systems into Navy Force Structure." The SSG found that "a level of autonomy is more correctly addressed as a combination of a degree of human interaction with a degree of machine automation . . . [therefore], autonomy is not a level or a linear function."

radio-controlled model aircraft. Development of, primarily, UAS, continued through World War II and into the second half of the last century.

Compared to today's technologies used to control autonomous systems, the technology of the 50s, 60s and even the 70s was primitive at best. In many cases, what was being attempted with drones was, literally, a bridge too far. In fact, the failure of UAS in those early days confirmed for many that UAS were just a bad idea, truncated UAS development, and spawned the development of entire communities of *manned* airborne systems.

Nowhere is this truer than for the U.S. Navy. Perhaps the classic case is the QH-50 DASH (Drone Anti-Submarine Helicopter) Program. Briefly: in April 1958 the Navy awarded Gyrodyne Company a contract to modify its RON-1 *Rotorcycle* small two coaxial rotors helicopter to explore its use as a remote-controlled drone capable of operating from small decks. The Navy bought nine QH-50A and three QH-50B drone helicopters. By 1963 the Navy approved large-scale production of the QH-60C, with the ultimate goal of putting three DASH units on all its 240 FRAM-I and FRAM-II destroyers. In January 1965 the Navy began to use the QH-50D as a reconnaissance and surveillance vehicle in Vietnam. Equipped with a real-time TV camera, a film camera, a transponder for better radar tracking, and a telemetry feedback link to inform the remote control operator of drone responses to his commands, the QH-50D began to fly "SNOOPY" missions from destroyers off the Vietnamese coast. These missions had the purpose of providing over-the-horizon target data to the destroyer's five-inch batteries. Additionally, DASH was outfitted with ASW torpedoes to deal with the rapidly growing Soviet submarine menace, the idea being that DASH would attack the submarine with Mk-44 homing torpedoes or Mk-57 nuclear depth charges at a distance that exceeded the range of submarine's torpedoes.

But by 1970, DASH operations ceased fleet-wide. Although DASH was a sound *concept*, the Achilles heel of the system was the electronic remote control system. The lack of feedback loop from the drone to the controller, and its low radar signature and lack of transponder, accounted for 80% of all drone losses. While apocryphal to the point to being a bit of an urban legend, it was often said the most common call on the Navy Fleet's 1MC general announcing systems during the DASH-era was, "DASH Officer, Bridge," when the unfortunate officer controlling the DASH was called to account for why "his" system had failed to return to the ship and crashed into the water.

Without putting too fine a point on it, the abject failure of DASH led directly to the Navy's LAMPS (Light Airborne Multi-Purpose System), first the LAMPS Mk I system embodied in the SH-2F aircraft, later the LAMPS Mk III and CV-helo programs embodied in the SH-60B and SH-60F aircraft respectively, and today in the MH-60R and MH-60S aircraft. Collectively, these programs represent tens of billions of dollars invested in manned aircraft, with three to four operators per aircraft.

While it would be too much of a stretch to say none of these communities would have come to exist if DASH had been successful, it is fair to speculate that at least some this investment in manned aircraft would have been steered to DASH and its successor UAS programs a half-

century ago had DASH made more of a splash (other than the "splash" of accidentally dropping into the ocean). Put another way, by the early 1970s the "market space" for single or multi-mission rotary wing systems flying from small decks on U.S. Navy ships was completely filled by *manned* helicopters.

But today, due to rapid advances in various technologies, we have come full circle as the MQ-8B *Fire Scout* UAS is a new autonomous system to be deployed on Navy ships such as the LCS to complement and supplement the MH-60R and MH-60S aircraft embarked. While DASH was a technological bridge too far, the mature UAS technology of the 21st Century has already made *Fire Scout* a star.

The Plan

DoD's Plan

Of course, the imperative to invest in making unmanned systems "smarter" rather than simply "stronger" has been noted before. Unmanned systems have been discussed and studied by high-level groups for more than two decades, and their potential[6] has garnered support from both the federal government and the Department of Defense.[7] In 2009, and again in 2011, DOD published its *Unmanned Systems Roadmap*, which explicitly establishes the goal of enabling constellations of unmanned systems to provide their own C4, thereby throwing down the gauntlet for the research-and-development community to increase these systems' degree of autonomy.

The 2011 *Unmanned Systems Roadmap* outlines a common DoD vision for unmanned systems, stating that:

> The Department of Defense's vision for unmanned systems is the seamless integration of diverse unmanned capabilities that provide flexible options for Joint Warfighters while exploiting the inherent advantages of unmanned technologies, including persistence, size, speed, maneuverability, and reduced risk to human

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[6] According to the March 2003 Naval Research Advisory Committee (NRAC) report, *Roles of Unmanned Vehicles*, "The combat potential of UVs (unmanned vehicles) is virtually unlimited … There is no question that the Fleet/Forces of the future will be heavily dependent upon UVs" (accessed at: www.onr.navy.mil/nrac). This 2003 NRAC report recognized the importance of unmanned systems in conflicts eight years ago, noting: "Increasing demands upon operating forces in terms of tempo, increased threat capabilities, rules of engagement parameters and risk management are leading Naval Forces, as well as other services, to the development and reliance on such systems." See also, Naval Studies Board, N.R.C., *Autonomous Vehicles in Support of Naval Operations*, The National Academies Press, Washington, D.C., 2005.

[7] The Fiscal Year 2011 Obama Administration budget announcement instantiated changes directed by Congress in the Fiscal Year 2007 National Defense Authorization Act, which called for the Department of Defense to "establish a policy that gives the DoD guidance on unmanned systems, a key point of which included identifying a preference for unmanned systems in the acquisition of new systems" (*FY 2009-2034 Unmanned Systems Integrated Roadmap* [Washington, D.C., Department of Defense, 2009], p. 4).

life. DoD envisions unmanned systems seamlessly operating with manned systems while gradually reducing the degree of human control and decision making required for the unmanned portion of the force structure.

It also describes the current state of unmanned systems in the DoD, and outlines a strategy for addressing the challenges common to unmanned systems employed in all military Services. These challenges include the need to enhance interoperability, autonomy, airspace integration, communications, training, propulsion and power and manned-unmanned teaming.

The Navy's Plan

The Navy has been tackling similar issues for several years. At the U.S. Navy's level, former Chief of Naval Operations, Admiral Gary Roughead, demonstrated his commitment to developing a long-term vision for unmanned systems in 2008, when he directed the 28th Chief of Naval Operations (CNO) Strategic Studies Group (SSG) to spend one year examining this issue.[8] Leveraging the SSG's work, Admiral Roughead has spoken extensively regarding the challenges the Navy will need to address as it integrates unmanned vehicles into its force structure, emphasizing in particular the need to enhance C2 capabilities to allow one sailor to control multiple systems in an attempt to lower Total Ownership Costs.[9] This link between increased autonomy and decreased TOC has made the revolutionary, rather than simply evolutionary, development of unmanned vehicles absolutely imperative.

Since becoming Chief of Naval Operations, Admiral Greenert has reinforced Admiral Roughead's imperatives regarding unmanned systems. In his article "Navy 2025: Forward Warfighters" he argues that payloads, including unmanned systems, will increasingly become more important than platforms themselves.[10] He also notes that unmanned systems will be vital assets as they're fully integrated into an undersea network that also incorporates unattended sensors and traditional platforms in order to "create a more complete and persistent common operational picture of the underwater environment when and where we need it."

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[8] The SSG reports directly to the Chief of Naval Operations. Its work typically involves year-long projects during which the group "generates revolutionary naval warfare concepts … that appear to have great potential, but Navy organizations are currently not pursuing" (Chief of Naval Operations Strategic Studies Group, Overview, accessed at: < http://www.usnwc.edu/About/Chief-Naval-Operations-Strategic-Studies-Group.aspx>). The 28th SSG's theme was officially titled "Integration of Unmanned Systems Into Navy Force Structure," and the group was tasked with developing concepts for autonomous systems' development and operations in the 2020 to 2028 timeframe.

[9] The Brookings Institution, "Proceedings, The Future of Unmanned Naval Technologies: A Discussion with Admiral Gary Roughead, Chief of Naval Operations," November 2, 2009, Washington, D.C. Accessed online January 25, 2010
<http://www.brookings.edu/~/media/Files/events/2009/1102_unmanned_naval_technologies/20091102_unmanned_technologies.pdf>.

[10] Chief of Naval Operations Admiral Jonathan Greenert, "Navy 2025: Forward Warfighters," *U.S. Naval Institute Proceedings*, December 2011. Accessed at: < http://www.usni.org/magazines/proceedings/2011-12/navy-2025-forward-warfighters>.

Moreover, following the cancellation of the EP-X program, the Navy has taken an approach to unmanned systems termed the "Intelligence, Surveillance and Reconnaissance and Targeting Family of Systems." This construct was discussed at the Information Dominance Industry Day in April 2011,[11] and has also been referenced by Chief of Naval Operations Admiral Greenert.[12] It's heavily reliant on unmanned systems, including the Broad Area Maritime Surveillance (BAMS), Medium-Range Unmanned Aerial System (MRUAS), Unmanned Carrier Launched Airborne Surveillance and Strike (UCLASS) and FireScout systems. As Admiral Dorsett, then-Deputy Chief of Naval Operations for Information Dominance, explained, these platforms are envisioned to fully leverage enhanced C4ISR capabilities and related developments, such as cloud computing, to "enable an individual operator to utilize sensors regardless of their location … [increasing] our operational and tactical effectiveness while delivering a worldwide-capable processing, exploitation and dissemination [PED] architecture."[13]

The Office of Naval Research has aligned its priorities with the DoD's and Navy's guidance. In the latest Naval Science and Technology Strategic Plan, autonomy and unmanned systems are called out as one of nine focus areas.[14] It includes four specific objectives: human and unmanned systems collaboration; perception and intelligent decision-making; scalable and robust distributed collaboration; and intelligence enablers and architectures. According to the report, ONR would like to "achieve an integrated hybrid force of manned and unmanned systems with the ability to sense, comprehend, predict, communicate, plan, make decision and take appropriate actions to achieve its goals."[15]

The Challenge

Manning Is Increasing TOC to Unacceptably High Levels

One of the most significant ways that unmanned systems can usher in revolutionary change in tomorrow's Navy, as well as for the Navy-after-Next, is in the area of manpower reductions in the Fleet. In fact, this represents the single biggest challenge facing the development and

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[11] Armed Forces Communications and Electronics Association, "Information Dominance Industry Day Questions and Answers," April 2011, Washington, D.C. Accessed at: http://www.afcea.org/mission/intel/documents/MasterAnswerDocument05APR11.pdf.
[12] Senate Armed Services Committee, "Advance Questions for Admiral Jonathan W. Greenert, USN: Nominee for the Position of Chief of Naval Operations," July 28, 2011. Accessed at: http://armed-services.senate.gov/statemnt/2011/07%20July/Greenert%2007-28-11.pdf.
[13] Admiral David Dorsett, "Information Dominance Industry Day Questions and Answers," April 2011. Accessed at: <https://www.afcea.org/mission/intel/documents/MasterAnswerDocument05APR11.pdf>
[14] Office of Naval Research, "2011 Naval Science & Technology Strategic Plan," accessed at: <http://www.onr.navy.mil/en/About-ONR/~/media/Files/About%20ONR/Naval-Strategic-Plan.ashx>
[15] Office of Naval Research, "2011 Naval Science & Technology Strategic Plan," pg. 15, accessed at: <http://www.onr.navy.mil/en/About-ONR/~/media/Files/About%20ONR/Naval-Strategic-Plan.ashx>

integration of unmanned systems today. Lessons learned throughout the development process of most unmanned systems – especially unmanned aerial systems – demonstrate that unmanned systems can actually *increase* manning requirements, as legions of technicians and operators work with the system to ensure it works properly and is a welcome addition to whatever warfighting capability and community it is trying to satisfy.[16]

Unfortunately, this technical and operational "tail" typically persists even after the system is in the field; as commanders are just as loathe to have the system fail as its developers were. There is little evidence that reducing manpower as the systems enter service is a vital part of the Key Performance Parameters (KPP) for any of these autonomous systems. This, in turn, introduces a pernicious cycle – as the unmanned systems enter service, they can require more operators, more technicians, and more "tail" than the manned systems they supplanted.

While this is a less-than-desirable outcome for air and ground autonomous systems, the burden is often masked in the aerial or terrestrial domains. Whether it takes two or four or six or some higher multiple of people to support one autonomous aerial system, in the case of UAVs flying in Iraq that are operated from a base in Nevada, the "tail" is obscured to most. When an operator or technician finishes his or her shift, they return to their home and the support they require is provided there.

Unfortunately, this is not true in the case of the present CONOPS for autonomous aerial and maritime systems deployed from Navy ships or submarines. Currently, every operator and technician must be embarked on the ship. Each person has a bunk, must be fed, generates administrative and overhead requirements and has quality of life needs that must be met. This, in turn, generates its own manpower needs and adds weight and space to these ships. This situation is exacerbated by the indisputable fact that the biggest—and most rapidly rising—cost of ships and systems is manpower, which makes up close to 70 percent of the total ownership cost of ships. This massive, manpower-induced portion of TOC has the full attention at the highest levels of the Navy's leadership.[17]

The introduction of the Fire Scout UAV to the Fleet is instructive.[18] Although it was developed in its own Navy/contractor "envelope," when Fire Scout deploys to the Fleet aboard LCS, that

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[16] For example, a recent Economist article notes that the remotely-piloted MQ-9 Reaper requires more than 180 people to keep it flying. See The Economist, "Flight of the Drones: Why the Future of Air Power Belongs to Unmanned Systems," October 08, 2011. See also Captain George Galdorisi et al, "More Brains, Less Brawn," *U.S. Naval Institute Proceedings*, December 2011.

[17] See, for example, CNO Guidance For 2011, *Executing the Maritime Strategy*. See also "Navy's Top Officer: 2011 To Be Year of Watching Costs," *San Diego Union Tribune*, October 19, 2010, and "Chief Concerns: Interview with CNO Mullen," *Government Executive*, May 2006.

[18] The MQ-8B Fire Scout is the Navy's vertical take-off and landing tactical unmanned air vehicle (VTUAV). Designed to autonomously take off from and land on any aviation-capable ship or confined land area, the Fire Scout provides the U.S. Navy and U.S. Marine Corps with reconnaissance, situational awareness and precision targeting

"tether" will be severed and the MH-60 helicopter detachment will operate and maintain this UAV with the net result being no increase in manning. This is precisely the path UMVs and UAVs deployed from naval ships *must* follow. But with a wide array of autonomous system developmental efforts, each developmental "tether" will need to be broken and Fleet operators already part of the Ship's Manning Document (SMD) will need to be cross-trained to operate and maintain these autonomous vehicles. While daunting, none of this is impossible, *if* this commitment to making unmanned systems deployed from naval ships is part of the solution – not part of the problem – in reducing manpower on Navy ships and is instantiated in the KPP of every autonomous system. In the future, this may even lead to a new CONOPS for unmanned systems deployed from Navy ships, in which the operators are not located on the ship at all.

However, beyond these manpower-reduction efforts, the full potential to have autonomous aerial and maritime systems *reduce* overall TOC for Navy ships will not be realized without the concurrent development of the C4 technology that enable these unmanned systems to communicate with, and be tasked by, their operators as well as communicate and self-synchronize with each other. The Department of Defense *FY2011 - FY2036 Unmanned Systems Integrated Roadmap* explicitly states that DoD's goal of fielding transformational capabilities will require that the department increase the autonomy of "autonomous" systems in order to decrease their associated manpower costs.[19]

Data Overload

Compounding the Total Ownership Cost issue, the data overload challenge generated by the proliferation of unmanned aircraft and their sensors has created its own set of manning challenges. In fact, the situation has escalated so quickly that many doubt that hiring additional analysts will help to ease the burden of sifting through thousands of hours of video.[20] General James E. Cartwright, former Vice Chairman of the Joint Chiefs of Staff, complained that a single Air Force Predator can collect enough video in one day to occupy 19 analysts.[21] He stated, "Today an analyst sits there and stares at Death TV for hours on end, trying to find the single target or see something move. It's just a waste of manpower."[22]

The data overload challenge is so serious that it's widely estimated that the Navy will face a "tipping point" in the 2016 timeframe, after which the Navy will no longer be able to process the

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support. For more, see "MQ-8B Fire Scout," *GlobalSecurity.org*, at: < http://www.globalsecurity.org/military/systems/aircraft/mq-8b.htm >

[19] *FY 2011-2036 Unmanned Systems Integrated Roadmap* (Washington, D.C., Department of Defense), pg. 35.

[20] For example, see Kate Brannen, "U.S. Intel Chiefs Need Better Data Tools," *Defense News*, October 18, 2010.

[21] William Matthews, "Keeping Pace," *Seapower Magazine*, December 2011.

[22] Ellen Nakashima and Craig Whitlock, "Air Force's New Tool: 'We Can See Everything,'" *Washington Post*, January 2, 2011.

amount of data that it's compiling.[23] In order to combat this problem, the Navy's Information Dominance Directorate has established a Tasking, Collection, Processing, Exploitation and Dissemination (TCPED) Working Group. According to Admiral Dorsett, former Deputy Chief of Naval Operations for Information Dominance, it is "actively studying Navy TCPED operations to discover a process for separating the wheat from the chaff, which should keep data transfer to a realistic level."[24] However, the ultimate success of the TCPED mission will be heavily dependent on the development of supporting C4ISR capabilities.

A recent newsletter posted by the DON Chief Information Officer proposes a possible way ahead, arguing that "some type of autonomous analysis needs to take place on the vehicle if we hope to sever the constant link between platform and operator."[25] Rear Admiral William Leigher, the Navy's Director of Program Integration for Information Dominance, goes a step further, noting that the future of intelligence is "automated systems that can analyze and fuse enough intelligence information from multiple sources to begin to predict events."[26] Indeed, increasing unmanned systems' capability to conduct autonomous analysis may be the only sustainable way forward, as demands for real-time ISR in three dimensions continue to increase exponentially.

Dependence on SATCOMs

A serious vulnerability of unmanned systems' is their current level of dependence on satellites for communications and command and control (C2). Satellites are increasingly vulnerable to interference from adversaries, and the DoD must bolster its ability to operate in a denied environment. This challenge is particularly acute for the Navy, which must maintain the capability to operate forward in anti-access/area denied (A2/AD) regions. Of course, satellite communications links can also go down without any help from adversaries.

In the case of remotely-piloted UAV such as the MQ-1 Predator and MQ-9 Reaper, if the satellite link is broken the pilot would lose direct control of the aircraft, leaving it to rely on pre-

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[23] The ISR "tipping point" has been noted in a TCPED study from the Office of the Chief of Naval Operations and PMW 120 (Battlespace Awareness and Information Operations), an independent Navy Cyber Forces study, and the NRAC study from summer 2010. See Admiral David Dorsett, "Information Dominance Industry Day Questions and Answers," April 2011. Accessed at:
<https://www.afcea.org/mission/intel/documents/MasterAnswerDocument05APR11.pdf>. See also CHIPS, "Interview With J. Terry Simpson, PEO C4I Principal Deputy for Intelligence," April – June 2011. Accessed at: < http://www.doncio.navy.mil/uploads/0623ATL15115.pdf>.
[24] Admiral David Dorsett, "Information Dominance Industry Day Questions and Answers," April 2011. Accessed at: <https://www.afcea.org/mission/intel/documents/MasterAnswerDocument05APR11.pdf>.
[25] Tom Kidd, Mikel Ryan, and Antonio Siordia, "Unmanning Unmanned Systems," *Department of the Navy Chief Information Officer News*, May 19, 2010, accessed at: < http://www.doncio.navy.mil/ContentView.aspx?ID=1756>
[26] William Matthews, "Keeping Pace," *Seapower Magazine*, December 2011.

loaded software and GPS guidance. While that might be acceptable for routine missions, it presents a serious vulnerability for those missions requiring constant oversight.

Even if the datalinks were sufficiently robust and reliable, the current level of bandwidth demanded by UxV – especially the remotely-piloted Predator and Reaper – is quickly outpacing the DoD's supply. The shortfall is often made up through reliance on commercial satellite communications, which makes up nearly 80 percent of the U.S. government's satellite communications capacity.[27] However, commercial satellite communications aren't as secure as their government counterparts, and they are also extraordinarily expensive. This problem is expected to grow more severe as UxV demand for bandwidth continues to exceed the DoD's ability to field its own satellite systems.

Given satellite communications' persistent vulnerabilities and the projected imbalance between supply and demand, the only sustainable way forward is to cut the satellite "tether" that UxV currently rely on. If these systems' autonomy and interoperability were enhanced so that they were tasked with a mission but could "decide" themselves how best to accomplish it, operators could rely on the UxV onboard systems carrying out the mission rather than having to maintain direct control of the craft.

What each of these three challenges has in common is that there is a growing realization (albeit without concomitant funding) that increasing investment in C4ISR for unmanned systems to make them *truly* autonomous may hold the answer. However, this is undeniably easier said than done—in Albert Einstein's words, it requires a new way of "figuring out how to think about the problem."

Airspace Deconfliction & Manned-Unmanned Teaming

The employment of unmanned aircraft systems (UAS) has increased exponentially in the past 15 years. Despite some initial cultural roadblocks, UASs have become indispensable to our nation's warfighters. However, the true test of their value lies in how effectively they are able to integrate with their manned counterparts. At a minimum, this requires deconflicting the airspace to prevent mishaps. However, a stronger model of integration mandates that manned and unmanned platforms work together, combining their strengths to "produce synergy not seen in single platforms."[28]

The employment of unmanned aircraft systems (UAS) has increased exponentially in the past 15 years. Despite some initial cultural roadblocks, UASs have become indispensable to our nation's warfighters, as they conduct ISR, serve as communications relays, carry cargo, and there is

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[27] Grace V. Jean, "Remotely Piloted Aircraft Fuel Demand for Satellite Bandwidth, *National Defense Magazine*, July 2011.
[28] *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035* (Fort Rucker AL, U.S. Army UAS Center of Excellence, April 2010), p. 15.

currently no routine integration of manned and unmanned aircraft in civil airspace; instead, UAS access to the U.S. National Airspace System (NAS) has been granted on a case-by-case basis. The Pentagon's ultimate goal is "to have appropriately equipped UAS gain routine access to the NAS in order to conduct domestic operations, exercises, training, and testing."[29] However, there are several barriers to overcome before this goal is realized. First and foremost, a sound "sense and avoid" capability must be developed to mitigate UAS' lack of an on-board capability to see and avoid other aircraft, as is currently required by the U.S. Code of Federal Regulations. In addition, coping mechanisms must be developed to address vulnerabilities of the UAS command-and-control link.[30]

However, a more significant challenge for such integration is that posed by "Manned-Unmanned (MUM) Teaming." The concept of MUM Teaming has been spearheaded by the U.S. Army, which defines it as "the use of both an Unmanned Aircraft System (UAS) and an armed (manned) helicopter in one engagement."[31] Using the VUIT-2 system on AH-64 Apache helicopters, U.S. Army pilots can currently receive video feeds and other sensor information from a host of different Army UAS. This provides an unprecedented capability for increased standoff ranges, as it allows for "enhanced Situational Awareness, greater lethality, improved survivability, and perhaps in the future, [providing] sustainment."[32] Even more impressive, the Block III upgrade of the AH-64 (scheduled for 2012) will increase the Level of Interoperability,[33] so that AH-64 pilots will be able to receive UAS feeds, control UAS Electro-Optical (EO)/Infrared (IR) payloads, and dynamically re-task UASs.[34]

According to DoD's *FY 2011-2036 Unmanned Systems Integrated Roadmap*, "To achieve the full potential of unmanned systems, DoD must continue to implement technologies and evolve

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[29] Department of Defense Report to Congress on Addressing Challenges for Unmanned Aircraft Systems, Under Secretary of Defense Acquisition, Technology, and Logistics, September 2010 at <http://www.acq.osd.mil/psa/docs/2010-uas-annual-report.pdf>. *Inside Defense*, "DOD: UAS Flights In National Airspace To Boom In Next Five Years," 18 November 2010.

[30] Andrew Lacher et. al., "Airspace Integration Alternatives for Unmanned Aircraft," Presented at AUVSI Unmanned Asia-Pacific 2010, 1 February 2010 at:
<http://www.mitre.org/work/tech_papers/2010/10_0090/10_0090.pdf>

[31] U.S. Army Aviation Center of Excellence, "Manned-Unmanned Operations (MUM-O)," 22 March 2010 at : <http://www.rucker.army.mil/docs/usaace_info/USAACE%20Info%20Paper%20UAS%20COE%20MUM-O%2022%20Mar%2010.pdf>. See also *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035* (Fort Rucker AL, U.S. Army UAS Center of Excellence, April 2010), pp. 15-16.

[32] *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035* (Fort Rucker AL, U.S. Army UAS Center of Excellence, April 2010), p. 15.

[33] As defined by NATO's Standardization Agreement 4586, the five Levels of Interoperability are:
Level 1: Transfer of filtered UAV data to a third party
Level 2: Direct transfer of live UAV data via a ground station to a remote command system
Level 3: Control of the onboard systems by commanders in the command system
Level 4: In-flight control by the command system
Level 5: Full flight control by the command system, including take-off and landing

[34] *FY 2011-2036 Unmanned Systems Integrated Roadmap* (Washington, D.C., Department of Defense). See also U.S. Army Aviation Center of Excellence, "Manned-Unmanned Operations (MUM-O)," 22 March 2010.

tactics, techniques and procedures (TTP) that improve the teaming of unmanned systems with the manned force."[35] The Army's model provides one glimpse into the capabilities that these technologies and TTPs might ultimately deliver. The Navy would be well-advised to follow suit in developing its own model, as the future utility of UASs will depend on successfully achieving MUM integration.

There is Hope

President Franklin Roosevelt purportedly once said: "To change anything in the Navy is like punching a feather bed. You punch it with your right and you punch it with your left until you are finally exhausted, and then you find the damn bed just as it was before you started punching." Now, the Navy is confronted with its own potential feather bed.

Unmanned systems have the potential to create strategic, operational, and tactical possibilities that did not exist a decade ago – but this promise will not be realized without substantial improvements in the C4ISR systems that will allow them to achieve true autonomy. At the highest levels of the Navy, from the CNO down, this aspiration is palpable. Rear Admiral Michael Broadway, the Navy's Deputy Director, Concepts and Strategies for Information Dominance, has challenged industry by declaring himself "absolutely not interested in platforms," and instead charging the Navy and industry to "give the C4 architecture the priority, it is critical."[36] The Navy laboratory community is embarked on leading-edge research to address this challenge. Some of the most cutting-edge work in this area includes:

- *UV-Sentry*: The "UV-Sentry" project is a joint developmental effort between the Office of Naval Research and the Marine Corps Warfighting Laboratory.[37] This program enables cooperative autonomy and autonomous command and control of UxS. This, in turn, allows for automated data fusion into a common operational picture. Thus, a constellation of unmanned systems with increased intelligence and the ability to adaptively collect and process sensor data into actionable information operate in a self-

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[35] *FY 2011-2036 Unmanned Systems Integrated Roadmap* (Washington, D.C., Department of Defense).
[36] Remarks by Rear Admiral Michael Broadway, Deputy Director, Concepts and Strategies for Information Dominance (N2/N6F) at the National Defense Industrial Association Information Dominance Symposium, San Diego, California, October 5, 2010.
[37] See, for example, Michael Fetsch, Chris Mailey, and Sara Wallace, "UV Sentry," paper presented at the *Association for Unmanned Vehicle Systems International, 34th Annual Symposium and Exhibition*, Washington, DC, August 6-9, 2007; Ryan Kilgore et al, "Mission Planning and Monitoring for Heterogeneous Unmanned Vehicle Teams: A Human Centered Perspective," paper presented at the *American Institute of Aeronautics and Astronautics Conference*, Rohnert, California, May 7-10, 2007; C.E. Nehme et al, "Generating Requirements for Futuristic Heterogeneous Unmanned Systems," *Proceedings of the 50th Annual Meeting of the Human Factors and Ergonomics Society*, San Francisco, California, 2006.

synchronized manner without having many operators provide constant input and direction to large numbers of autonomous vehicles. [38]

- *JUDIE*: The Joint Unmanned Aircraft Systems Digital Information Exchange (JUDIE) is a project designed to enable UAS information-exchange as an initial step in enabling UAS to self-synchronize and ultimately work as swarms. It is an inter-Service project involving all the military Services and is using the MQ-1 Predator and RQ-7 Shadow UAS as test platforms. Testing began at four locations in 2011 and will continue throughout 2012.

- *MOCU*: The Multi-Robot Operator Control Unit (MOCU) is an autonomous systems project that allows one operator to control multiple systems in order to reduce manning costs. Under the stewardship of scientists and engineers at the Space and Naval Warfare (SPAWAR) Systems Center Pacific, MOCU is a graphical operator-control software package that allows simultaneous control of multiple unmanned systems from a single console. Given the severely proscribed manning profile for Navy ships like the DDG-1000 and the LCS, MOCU is envisioned to be a strong enabler aboard these – as well as future – Navy surface combatants.

- *UCAS-D*: UCAS-D (Unmanned Combat Air System-Demonstrator) takes advantage of emerging technology to enable autonomous unmanned vehicles to operate in a swarm. Under the evolving UCAS-D CONOPS, this swarm of UCAS-Ds would be tasked *as one unit* with a mission objective and once the human operator selected a mission and communicated that to the swarm as a *unit*, the individual vehicles would then communicate and self-synchronize amongst themselves to formulate and carry out a mission plan. The human operator would communicate with the swarm only as a whole in order to select and prioritize its assignments.[39]

- *ICOP*: ICOP (Intelligence Carry On Program) leverages the Distributed Common Ground System – Navy (DCGS-N) in providing workstations onboard U.S. Navy surface combatants to exploit data and video from multiple UAS simultaneously. Using a triple-screen workstation adopted from the successful Multi-Modal Watch Station introduced to the Fleet at the beginning of the last decade, engineers from SPAWAR Systems Center Pacific are experimenting with this system in exercises such as Trident Warrior 2011 to enable one operator to view and exploit video from several UAVs such as Scan Eagle and Predator (as well as F/A-18 FLIR video), freeing the UAV launching platform from the one operator, one joystick, one UAV paradigm.

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[38] Thomas McKenna, (Office of Naval Research) "Future Capabilities: Perception, Understanding and Intelligent Decision Making," briefing presented at the Unmanned systems Innovation Summit, Arlington, Virginia, November 17-18, 2008.

[39] Norman Friedman, *Unmanned Combat Air Systems: A New Kind of Carrier Aviation* (Annapolis, Naval Institute Press, 2010). See also Norman Friedman, "UCAVs: Considering The Next Step," *The Year In Defense: 2009 In Review*, 2010.

These efforts and others like them – which support the goals of the DoD *Unmanned Systems Roadmap* of enabling constellations of unmanned systems to provide their own C4 – *must* be applied to autonomous aerial and maritime vehicles deployed from naval ships. This is vital to reducing the extent of human operators' engagement in direct, manual control of autonomous vehicles.[40] If this C4 breakthrough is achieved, it may well exceed improvement in UAV, UGV, USV and UUV propulsion, payload, stealth and other attributes and unleash the revolutionary changes these unmanned systems can deliver to tomorrow's Navy and especially to the Navy-after-Next.

Way Ahead

The future for autonomous vehicles is virtually unlimited. Indeed, concepts for new missions, such as using autonomous aerial vehicles to detect approaching ballistic missiles are being generated by visionaries who have seized on the enormous potential of these systems.[41]   But while their ability to deliver revolutionary change to the Navy-after-Next is real, this process is not without challenges. This vision must be supported by both a commitment of the top levels of naval leadership and also by leadership and stewardship at the programmatic level – from acquisition professionals, to requirements officers, to scientists and engineers in the Navy and industry imagining, designing, developing, modeling, testing, and fielding these systems.

Evolutionary change is good and, in many ways, easy. Revolutionary change, however, will not occur without big bets and a thoughtful degree of risk-taking on the part of professionals embedded in a thoroughly risk-averse culture. One sure way to spur this revolutionary change is to operationalize the mandate of the *FY2009 – FY2034 Unmanned Systems Roadmap* to "expedite the transition of unmanned technologies from research and development activities into the hands of the Warfighter."[42] Getting a "pretty good" autonomous system into the Fleet today is infinitely better than getting a near-perfect UxV into a sailor's hands five years from now.

There is no more propitious time to do this. Former Secretary of Defense Robert Gates has been widely-quoted as adamantly opposed to seeking the 99% solution that takes years to develop and instead getting the 80% solution into warfighter's hands today.[43]   If the Navy follows this

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[40] Ryan Kilgore et al, "Mission Planning and Monitoring for Heterogeneous Unmanned Vehicle Teams: A Human Centered Perspective, pp. 1-2."

[41] Amy Butler, "Reaping the Benefits," Aviation Week and Space Technology, August 15, 2011, pp. 48-51.

[42] *FY 2009-2034 Unmanned Systems Integrated Roadmap,* p. 34.

[43] Secretary of Defense Robert Gates has made this point repeatedly in speeches and interviews. One of the most widely quoted speeches on this subject was his remarks at the Army War College on April 16, 2009 when he noted, "Finally, I concluded we needed to shift away from the 99% exquisite service-centric platforms that are so costly and so complex they take forever to build and only then in very limited quantities. With the pace of technological and geopolitical change and the range of possible contingencies, we must look more to the 80-percent solution, the multi-service solution that can be produced on time, on budget and in significant numbers. As Stalin once said, 'Quantity has a quality all of its own.'" Department of Defense News Transcript, "Remarks By Secretary of

mandate, Sailors, Chiefs, and Officers will begin to imagine what a Navy robustly manned with a wide array of autonomous vehicles could accomplish. *That* is where the future vision of autonomous maritime systems will be developed and nurtured.

If the Navy does this well, autonomous vehicles will continue to change the tactics of today's Navy, the operational concepts of tomorrow's Navy, and will usher in a strategic shift for the Navy-after-Next. In the words of Lieutenant General David Deptula, USAF, "The challenge before us is to transform *today* to dominate an operational environment that *has yet to evolve*, and to counter adversaries who *have yet to materialize*."[44] For these reasons, autonomous vehicle development deserves ongoing enlightened leadership and stewardship and the additional consideration, focus, and funding necessary to ensure that the Navy-after-Next is the greatest navy that ever sailed.

Defense Robert Gates at the Army War College, Carlisle, PA," April 16, 2009. Accessed online 20 Dec. 2010 at: <http://www.defense.gov/transcripts/transcript.aspx?transcriptid=4404>.

[44] Lieutenant General David Deptula, USAF, Remarks at the C4ISR Journal Symposium, October 13, 2010.

Taking the Next Step:
From "Unmanned" to True Autonomy

Topic 7:
Architectures, Technologies, and Tools

Mr. George Galdorisi
Mr. Robin Laird
Ms. Rachel Volner

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

Max Boot
War Made New

23

Outline

▼The Plan

▼The Challenge

▼ C4ISR Innovation As the Answer

▼Into the Future

"Creation of substantive autonomous systems/platforms within each domain will create resourcing and leadership challenges … Trust of unmanned systems is still in its infancy in ground and maritime systems … Unmanned systems are still a relatively new concept … As a result, there is a fear of new and unproven technology."
FY 2009-2034 Unmanned Systems Integrated Roadmap

"The combat potential of UV's (unmanned vehicles) is virtually unlimited … There is no question that the DoD envisions the continued expansion of unmanned systems in the future force structure … expanding into new mission areas …" *Naval Research Advisory Committee (NRAC) defines a path … Roles of Unmanned Vehicles, March 2003*

"… challenges is apparent that cuts across all military Services, budgets, and all three domains."
FY 2011-2036 Unmanned Systems Integrated Roadmap

"The National Defense Authorization Act for FY 2007 … called for the DoD to establish a policy … on unmanned systems, some key points of which included identifying a preference for unmanned systems in acquisitions of new systems."
FY 2009-2034 Unmanned Systems Integrated Roadmap
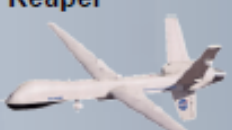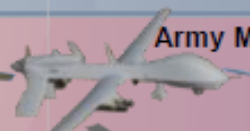
The Plan

"The Department of Defense's vision for unmanned systems is the seamless integration of diverse unmanned capabilities … DoD envisions unmanned systems seamlessly operating with manned systems while gradually reducing the degree of human control and decision making required."

FY 2011-2036 Unmanned Systems Integrated Roadmap

Unmanned Aircraft Systems

Mission Areas

2011 — Increasing Reach, C2, Autonomy, & Complexity — 2035+

Increasing Performance, Payload, & Vehicle Size

ISR / Data Relay Platforms — Strike Capable

Long Endurance
Group 5
- > 1320 lbs
- > FL180

Air Force MQ-9 Reaper
Air Force RQ-4 Global Hawk
Navy MQ-4 BAMS
Air Force MQ-La/b
Air Force MQ-X
Air Force MQ-Lc

Persistent
Group 4
- > 1320 lbs
- < FL180

Army MQ-5 Hunter
Air Force MQ-1 Predator
Army MQ-1C Gray Eagle
Navy MQ-8 Fire Scout
Army / Navy / USMC VTOL
Navy UCAS-D
Navy UCLASS
Navy MRMUAS
Navy UCAS FAA-XX

Tactical
Group 3
- < 1320 lbs
- < FL180
- < 250 kts

Army / USMC / SOCOM RQ-7 Shadow
SOCOM EUAS (VTOL)
SOCOM EUAS (FW)
Navy /USMC RQ-21A STUAS

Black: Programs of Record
Red: Future concepts

Small Tactical
Group 2
- 21-55 lbs
- < 3500 AGL
- < 250 kts

Navy / USMC/ Air Force / SOCOM ScanEagle

Micro/Mini Tactical
Group 1
- 0-20 lbs
- < 1200 AGL
- < 100 kts

Army / Navy / USMC/ SOCOM RQ-11 Raven
Navy / Air Force / SOCOM Wasp
SOCOM Puma
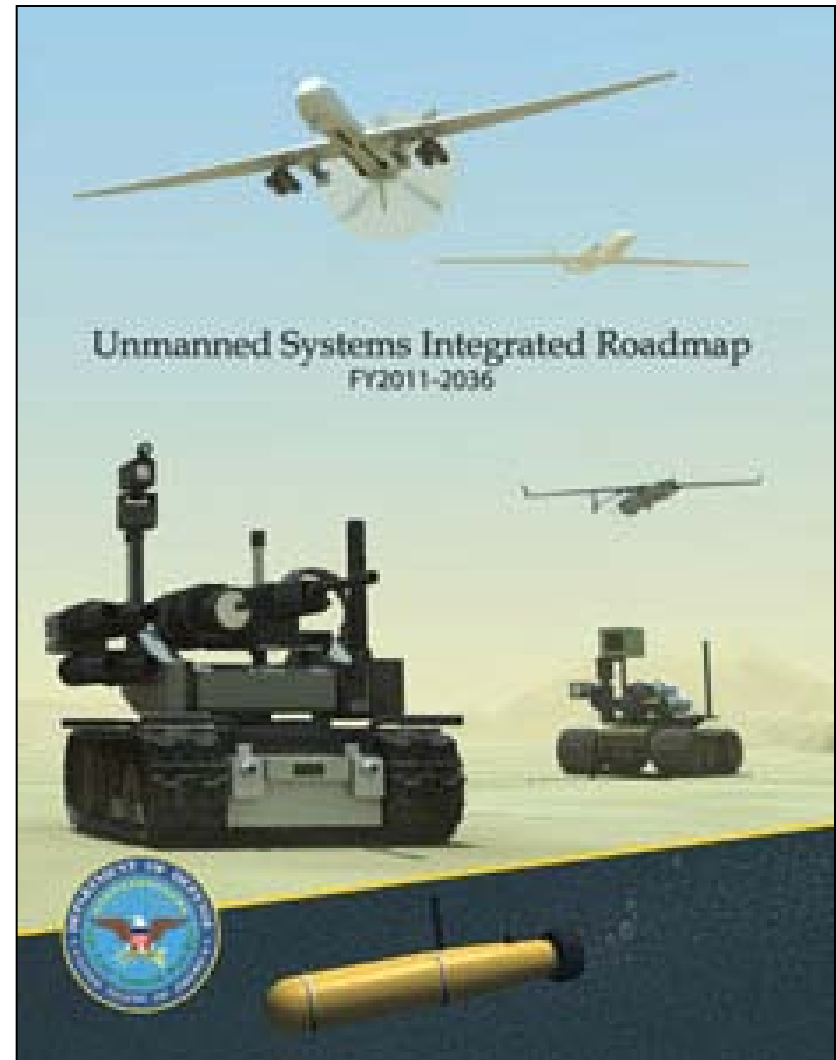Army gMAV Navy T-Hawk
Small Family of Systems
Nano UAS

4

DoD Guidance

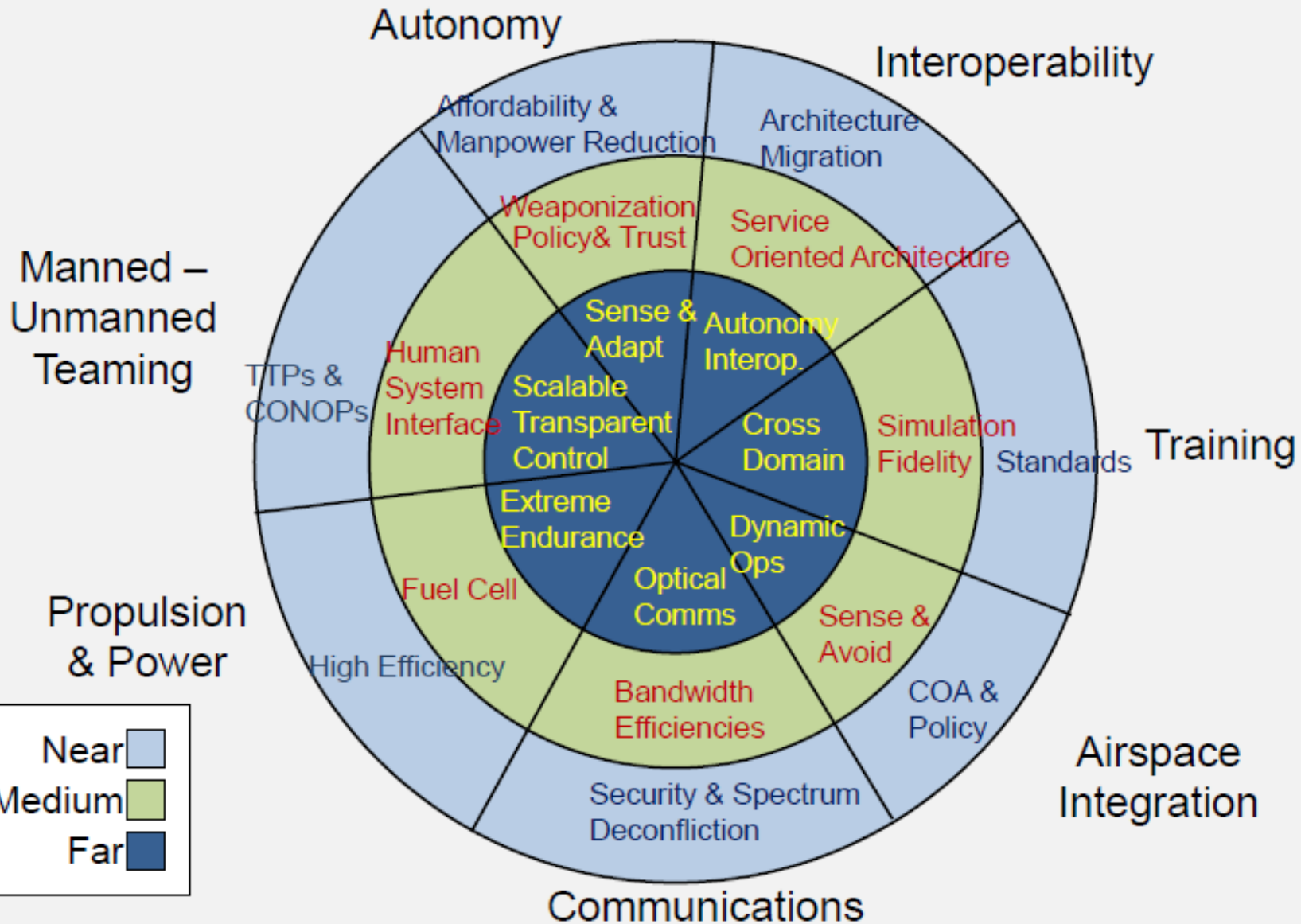## Key Challenges

▼ Interoperability

▼ Autonomy

▼ Airspace Integration

▼ Communications

▼ Training

▼ Propulsion and Power

▼ Manned-Unmanned Teaming

Unmanned Systems Integrated Roadmap
FY2011-2036

Meeting the Challenges
Unmanned System Roadmap

Navy's AISR&T "Family of Systems"

▼ **Broad Area Maritime Surveillance (BAMS)**
- Long-endurance remotely operated signals intelligence
- Airborne support for MDA and battlespace preparation

▼ **Unmanned Carrier Launched Airborne Surveillance and Strike (UCLASS)**
- Carrier-based intelligence and precision strike

▼ **MQ-8B FireScout**
- Real-time ISR, battle management and target classification

▼ **P-8A Poseidon**
- Maritime patrol ASW, ASUW and armed ISR capability

▼ **H-60 Helicopter**
- Will be equipped with additional sensors

▼ **E-2D Advanced Hawkeye**
- Carrier-based Airborne Early Warning and Battle Management Command & Control

The Challenge

"Today's unmanned systems require significant human interaction to operate. As these systems continue to demonstrate their military utility and are fielded in greater numbers, the manpower burden will continue to grow … [this] is occurring at a time when constrained budgets are limiting growth in Service manpower authorizations."

FY 2011-2036 Unmanned Systems Integrated Roadmap

The Total Ownership Cost Challenge

▼ The irony of "unmanned" systems

▼ TOC issue intensified by increasing manpower costs, ongoing budget crisis

▼ Data overload exacerbates the challenge

▼ C4 technological innovation a prerequisite for success

Manpower Costs Have Reached An All-Time High

Military Personnel Expenditures
(in billions of current dollars)

$159 billion

$74 billion
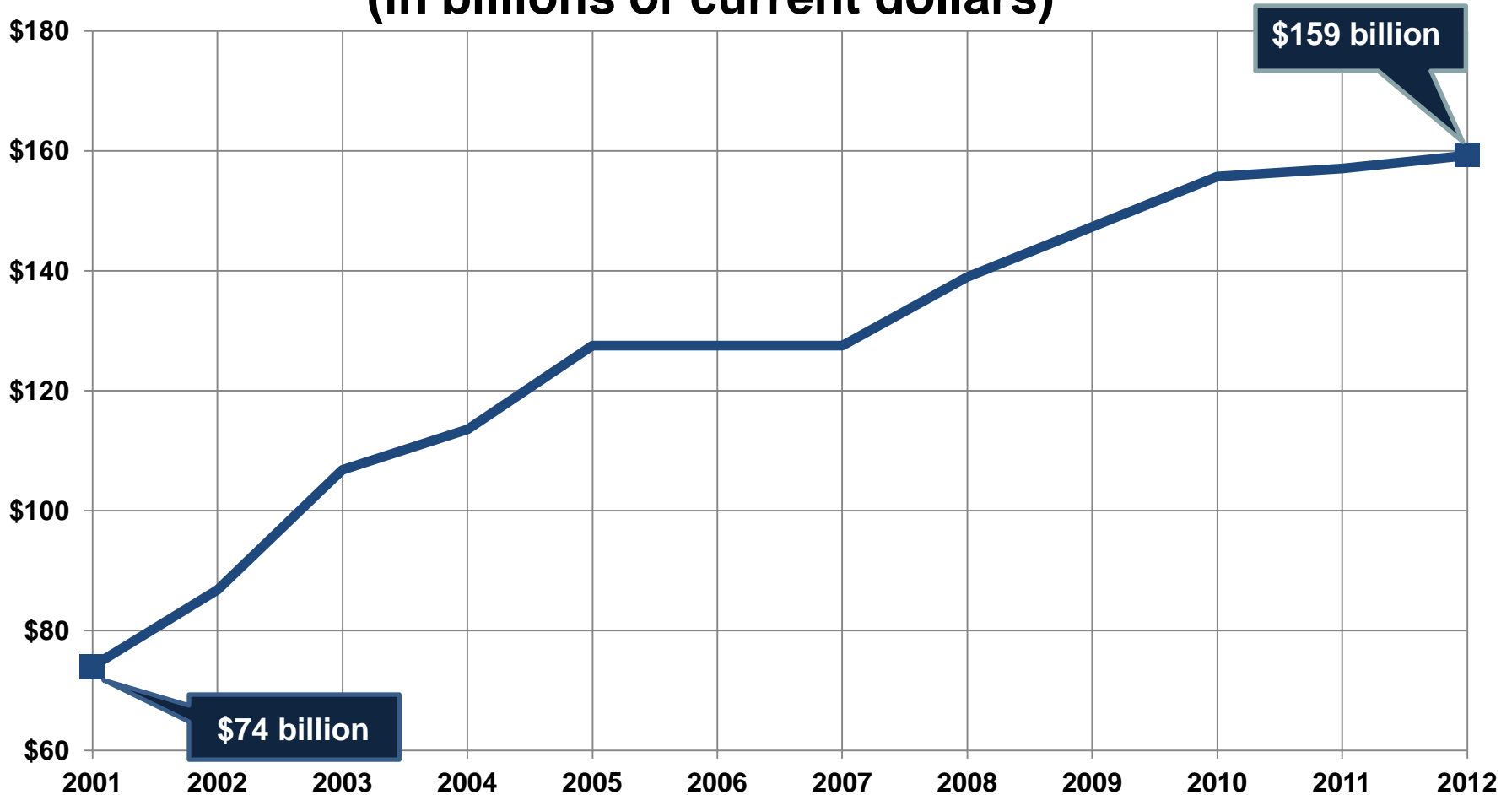
Data from: Office of Management and Budget, *Budget of the U.S. Government, FY 2012, Historical Tables*

C4ISR Innovation As the Answer

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

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

Making UxV Smarter

▼ Automated TCPED processes

▼ Ability to sense and adapt to the environment

▼ Autonomous collaboration

▼ One operator, multiple UxV

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

Intel Carry-On Program

Live FMV: • Process • Exploit • Dissemination
Integrated 3-D picture of battlespace
• CIP/COP • ELINT/COMINT Ext. • Ship tracking

ICOP prototype workstation.
Photo courtesy of BAE Systems.

▼ A portable, robust suite of ISR PED capabilities for unit-level platforms

▼ Allows operators to exploit data & video from multiple UAS simultaneously

▼ Demonstrated in exercises such as Trident Warrior 2011

23

UCAS-D

▼ Conceived as operating in swarms, using state-based control

▼ Operators would collectively task and communicate with the swarm

▼ Autonomy and manning challenges must still be overcome

Into the Future

"To change anything in the Navy is like punching a feather bed. You punch it with your right and you punch it with your left until you are finally exhausted, and then you find the damn bed just as it was before you started punching."

President Franklin Delano Roosevelt

Into The Future

▼ UxVs' ability to deliver revolutionary change is real …

▼ … but to be realized, this vision <u>must</u> be supported by commitment at the top levels of naval leadership, and by leadership and stewardship at the programmatic level

▼ A way ahead: operationalize the mandate of the Department of Defense *Unmanned Systems Integrated Roadmap* to "expedite the transition of unmanned technologies from research and development activities into the hands of the Warfighter."

THE NEW FACE OF WAR

★ ★ ★ ★ ★

How War Will Be Fought in the 21st Century

BRUCE BERKOWITZ

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 Americans 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

Questions?