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"More Brains, Less Brawn: Why The Future of Unmanned Systems Depends on Making Them Smarter"

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Abstract for
More Brains, Less Brawn: Why The Future Of Unmanned Systems Depends On Making Them Smarter

No arena is richer in possibilities than unmanned systems used by national and multinational organizations. These systems have been used extensively in today's conflicts and are already creating strategic, operational, and tactical possibilities that did not exist a decade ago.

Unmanned systems have created substantial "buzz" in policy, military, industry and academic circles, and have even spawned best-selling books such as P.W. Singer's *Wired for War*. In addition, they have generated innumerable articles in professional journals and magazines, as well as in "popular science and literature" publications such as *Wired Magazine*.

But for these unmanned systems to reach their full potential, important C4ISR considerations *must* be addressed. Currently, there is far too much discussion of "brawn" and not enough "brains," that is, an almost exclusive focus on platforms and little discussion or focus on the C4ISR systems that will enable these impressive platforms to reach their full potential.

Absent this focus, these systems will be severely sub-optimized in their ability to provide information and knowledge to the warfighter. We will present examples of ground-breaking work going on in the DoD laboratory community with systems such as the Multi-Robot Operator Control Unit (MOCU) System that are paving the way for a completely new paradigm – multiple unmanned systems controlled by one operator.

More Brains, Less Brawn: Why The Future Of Unmanned Systems Depends On Making Them Smarter

Perspective

"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 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 last ten years alone, the military's use of unmanned aerial vehicles (UAVs) has increased from only a handful to over 5,000, while the use of unmanned ground vehicles (UGVs) exploded from zero to over 12,000.[2] 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 rapid pace of technological research and development taking place within industry, academia, and DoD laboratories.

But for these unmanned systems to reach their full potential, important Command, Control Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) 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 "intelligence" – that is, 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-

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

synchronization, thereby allowing these systems to become truly autonomous[3] and eventually to become warfighters' partners rather than simply tools.

The Challenge of *Revolutionary* Change

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[4] has garnered support from both the federal government and the Department of Defense.[5] In 2009, the Department published its second *Unmanned Systems Roadmap*, which explicitly established 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.

At the U.S. Navy's level, 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.[6] 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.[7] This link

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[3] There are multiple, competing definitions for the terms "automation," "autonomous," and "full autonomy." For the purposes of this paper, we will adopt the usage proposed by the 28th Strategic Studies Group (SSG) in their 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."

[4] 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.

[5] 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).

[6] 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.

[7] The Brookings Institution, "Proceedings,The Future of Unmanned Naval Technologies: A Discussion with Admiral Gary Roughead, Chief of Naval Operations," Nov 2, 2009, Washington, D.C. Accessed online 25 Jan 2010

between increased autonomy and decreased TOC has made the revolutionary, rather than simply evolutionary, development of unmanned vehicles absolutely imperative.

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 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.

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.

In last generation's Navy with ships with robust manning, there was some flexibility to somehow make this all work. But with today's – and especially tomorrow's – optimally manned ships like LCS, DDG-1000 and Future Surface Combatant, the manpower challenge is especially acute. And against this backdrop is the indisputable fact that the biggest – and most rapidly rising – cost of ships and systems is manpower, which makes up close to 70% of the

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<http://www.brookings.edu/~/media/Files/events/2009/1102_unmanned_naval_technologies/20091102_unmanned_technologies.pdf>.

Total Ownership Cost (TOC) of ships. This massive, manpower-induced, portion of TOC has the full attention of the highest levels of the Navy's leadership.[8]

Publication of the *Total Ownership Cost Guidebook* highlights importance of TOC reduction at the highest echelons of the Department of the Navy. Released by Deputy Chief of Naval Operations (Fleet Readiness and Logistics) (OPNAV N4), this guidebook is intended to assist all Naval organizations engaged in requirements generation, acquisition, and life-cycle sustainment to understand and apply TOC-related requirements. Specifically, it provides program managers an aid to meet the minimum TOC requirements and critical system characteristics of acquisition programs.[9] Along with the release of the *DoD Human Systems Integration Managament Plan*[10] the previous year, these efforts portend an increasing focus on total life-cycle cost reductions.

Nor can manning reductions come at the cost of mission performance. Recently, the Navy abandoned its "optimal manning" efforts as the negative impact on crews and ships resulted in lowered states of readiness and operation, exemplified by the grounding of the *USS Port Royal* off Hawaii. Admiral Roughead, Chief of Naval Operations, expressed that these reductions need to take place with attendant insertions of technology.[11] Clearly, systems in development must fold in human systems integration/human factors engineering concepts as KPPs in order to enable both optimal manning and performance.

The introduction of the Fire Scout UAV to the Fleet is instructive.[12] Although it was developed in its own Navy/contractor "envelope," when Fire Scout deploys to the Fleet aboard LCS, that "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

[8] See, for example, CNO Guidance For 2011, *Executing The Maritime Strategy*, which notes that one of Admiral Roughead's goals is to "pursue unmanned systems as an integrated part of our force, ensuring that the move to "unmanned" truly reduces personnel requirements." 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.

[9] Department of the Navy,*Total Ownership Cost Guidebook*, February 16, 2010. Accessed at https://acc.dau.mil/adl/en-US/349509/file/49055/TOC_Guidebook_20100128_v1.pdf

[10] FY09 Department of Defense Human Systems Integration Management Plan, Version 1.0. 2009. Washington, DC: ODUSD(A&T), ODUSD(S&T) Director of Biological Systems. This document "establish formal responsibility, authority, and accountability for [HSI] within the DoD." The Deputy Under Secretary of Defense for Acquisition and Technology (DUSD (A&T)) was designated as the senior lead responsible for coordination and management of HSI in acquisition programs. On science and technology matters, the Deputy Under Secretary of Defense for Science and Technology, Director of Biological Systems, has been assigned as the co-lead.

[11] Ewing, Philip, "Lean manning saps morale, puts sailors at risk," *Defense News*, October 19, 2009. By way of background, cruisers (CGs) and destroyers (DDGs) were, on average, manned with 17% fewer sailors as compared to their original design specifications.

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

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.

Compounding the Total Ownership Cost issue, the data overload problem 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.[13] General James E. Cartwright, Vice Chairman of the Joint Chiefs of Staff, was recently quoted characterizing the current situation. He stated, "Today an analyst sits there and stares at Detah TV for hours on end, trying to find the single target or see something move. It's just a waste of manpower."[14]

Instead, 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. According to a recent newsletter posted by the DON Chief Information Officer, "Some type of autonomous analysis needs to take place on the vehicle if we hope to sever the constant link between platform and operator."[15] Indeed, increasing unmanned systems' capability to conduct autonomous analysis may be the only sustainable way ahead, as demands for real-time ISR in three dimensions continue to increase exponentially.

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 command, control, communications, and computers (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 *Unmanned Systems Roadmap* indicates that the DoD's goal of fielding transformational capabilities will require that the Department "achieve greater interoperability among systems controls, communications, data products, data links, and payloads/mission equipment packages on unmanned systems including tasking, processing, exploitation, and dissemination."[16] This transformation also requires significant increases in the autonomy of "autonomous" systems.

[13] For example, see Kate Brannen, "U.S. Intel Chiefs Need Better Data Tools," *Defense News*, October 18, 2010.
[14] Ellen Nakashima and Craig Whitlock, "Air Force's New Tool: 'We Can See Everything,'" *Washington Post*, January 2, 2011.
[15] 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>
[16] *FY 2009-2034 Unmanned Systems Integrated Roadmap*, p. 35.

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."[17]

The Way Ahead

"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."[18]

President Franklin D. Roosevelt

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. At a recent industry forum, Rear Admiral Michael Broadway, the Navy's Deputy Director, Concepts and Strategies for Information Dominance, 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."[19]

In one vision for the future of increasingly autonomous unmanned vehicles they are capable of operating in a swarm. This concept is exemplified by the Navy's Unmanned Combat Air System-Demonstrator (UCAS-D), which is currently conceived of as operating in swarms utilizing state based control. In this model, such a swarm would be collectively tasked with a mission objective and a set of broad instructions, and the individual vehicles would then communicate amongst themselves to formulate an optimum mission plan. The human operator would communicate with the swarm only as a whole in order to select and prioritize its assignments.[20] However, there remain several technological hurdles to overcome before this vision becomes a reality.[21]

The Navy laboratory community is embarked on leading-edge research to address this challenge. One initiative responding to the challenge of manning requirements discussed above is the "UV-Sentry" project, a joint developmental effort between the Office of Naval Research

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[17] When asked what single event was most helpful in developing the theory of relativity, Albert Einstein is reported to have answered, 'Figuring out how to think about the problem." Wilber Shramm and William Porter, Men, *Women, Messages and Media: Understanding Human Communication* (New York, Harper and Rowe, 1982).
[18] Attributed to President Franklin Delano Roosevelt.
[19] 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.
[20] 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.
[21] See, for example, Inside Defense, "Former Navy UAV Chief Sees Unmanned Future For Aircraft Carriers," December 20, 2010 and Inside Defense, "NSWC Carderock: Navy Faces Obstacles In Using UAV Swarms On Ships," December 31, 2010.

and the Marine Corps Warfighting Laboratory.[22] This program enables autonomous command and control and cooperative autonomy of autonomous systems, allowing for automated data fusion into a common operational picture. Thus, rather than having many operators provide constant input and direction to large numbers of autonomous vehicles, a constellation of unmanned systems with increased intelligence and the ability to adaptively collect and process sensor data into actionable information provides this capability to the operator with minimum human intervention.[23]

Another initiative underway at the Space and Naval Warfare (SPAWAR) Systems Center Pacific is the Multi-Robot Operator Control Unit (MOCU), a groundbreaking unmanned project that directly addresses the CNO's directive to allow one operator to control multiple systems in order to reduce manning costs. MOCU is a graphical operator-control software package that allows simultaneous control of multiple heterogeneous unmanned systems from a single console. It is designed to address interoperability, standardization, and customization issues by using a modular, scalable, and flexible architecture. This software is being beta-tested in a number of platforms, including the LCS. A third-generation product, based upon a publish/subscribe architecture, is currently under development.[24] This update completely uncouples the human interface from the core management software, thus allowing even more flexibility in user customization of the product.

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.[25] 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.

While the future for autonomous vehicles is virtually unlimited, and their ability to deliver revolutionary change to the Navy-after-Next is real, this process is not without challenges. This

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[22] 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.

[23] 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.

[24] The Air Force Research Laboratory's Information Directorate is working with SPAWAR to develop these Publish-Subscribe-Query-Broker technologies.

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

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 Department of Defense *Unmanned Systems Roadmap* to "expedite the transition of unmanned technologies from research and development activities into the hands of the Warfighter."[26] Getting a "pretty good" autonomous maritime system into the Fleet today is infinitely better than getting a near-perfect UMV into a Sailor's hands five years from now.

There is no more propitious time to do this. The Secretary of Defense 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.[27] If the Navy follows this 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 right, 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*."[28] 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.

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

[27] 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 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>.

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