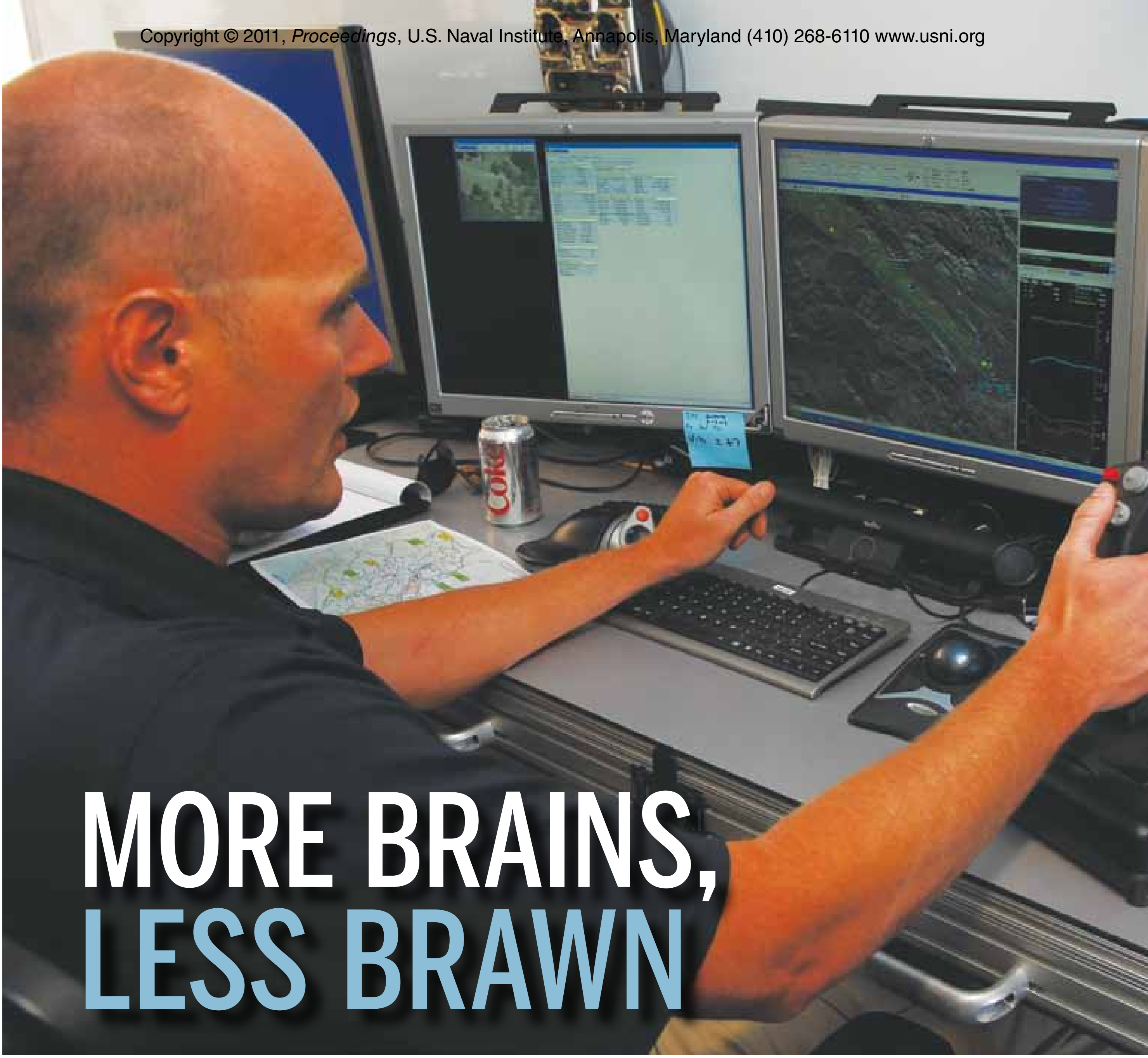


MORE BRAINS, LESS BRAWN

By Captain George Galdorisi, U.S. Navy (Retired), Steve Koepenick, Rachel Volner, and Major Charles Weko, U.S. Army Reserve

Why the future of unmanned systems depends on making them smarter.

In his November 2010 *Proceedings* article "How To Fight An Unmanned War," Navy Lieutenant James Drennan explored many of the important tactical, decision-making, and political considerations warfighters will need to address as unmanned systems become more autonomous. However, that article also addressed manpower considerations when it noted that "some believe that unmanned vehicles could reduce manpower requirements. On the contrary, the military is learning that robotic warfare only displaces the manpower requirements."

Two members of the Navy's Strategic Studies Group who helped produce the "Integration of Unmanned Systems Into Navy Force Structure" study and two naval analysts suggest this manning challenge is vastly worse than Lieutenant Drennan suggests, and that without enlightened change by Navy leadership, manning issues may be the "fatal flaw" that dooms the Navy to substantially sub-optimize its enormous investment in unmanned systems.

In his book *War Made New: Technology, Warfare, and the Course of History, 1500 to Today* (Gotham Books,

U.S. AIR FORCE (D. R. ALLEN)

Adam Stock, lead pilot for unmanned aerial systems out of Twentynine Palms, California, maneuvers a ScanEagle at Fort Hunter Liggett on 19 May as part of joint exercise Global Medic 2011 (field training for aero-medical evacuation) and tactical exercise Warrior 91 11-01 (response training to simulated enemy attacks). Manning issues, the authors say, may doom the Navy's "enormous investment in unmanned systems."

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."

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.[1]

Ten Years Ago, the Possibilities Didn't Exist

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) 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-synchronization, thereby allowing the systems to become truly autonomous and eventually to become warfighters' partners rather than simply tools.[2]

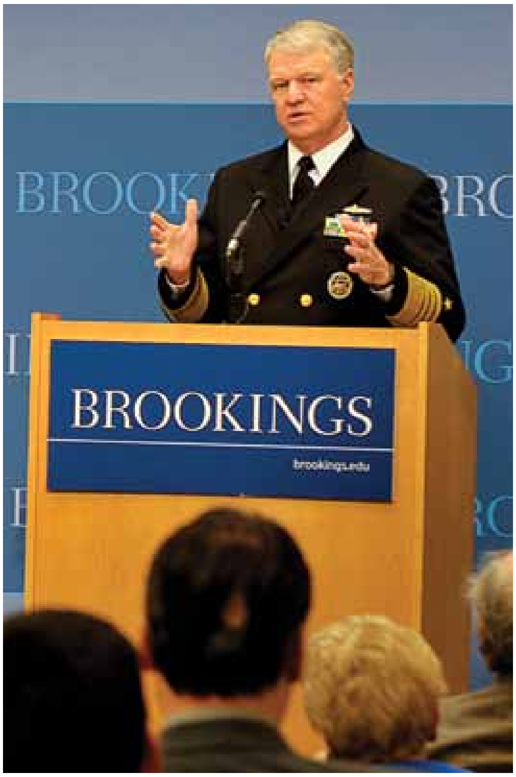
The Challenge of Revolutionary Change

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 has garnered support from DOD and other parts of the federal government. 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 those systems' degree of autonomy.

At the U.S. Navy's level, Admiral Gary Roughead, then Chief of Naval Operations (CNO), demonstrated his commitment to developing a long-term vision for unmanned systems in 2008, when he directed the 28th CNO Strategic Studies Group (SSG) to spend one year examining this issue.[3] Reflecting the SSG's work, Admiral Roughead spoke 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

(TOC).[4] Given the Navy's plans to replace the canceled EP-3 patrol aircraft with a "family" of unmanned systems in today's fiscally constrained environment, current CNO Admiral Jonathan Greenert is likely to continue Admiral Roughead's focus in this area.[5] This link between increased autonomy and decreased TOC has made the revolutionary, rather than simply evolutionary, development of unmanned vehicles imperative.

One of the most significant ways 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.



U.S. NAVY (T. JONES VANDERWYST)

Admiral Gary Roughead, then Chief of Naval Operations, answers questions during a November 2009 Brookings Institution discussion titled "Unmanning the Helm: The Future of Unmanned Naval Technologies." There, he emphasized "the need to enhance C2 capabilities to allow one sailor to control multiple systems in an attempt to lower total ownership costs," a focus that "current CNO Admiral Jonathan Greenert is likely to continue," the authors predict.

'A Pernicious Cycle'

Unfortunately, this technical and operational "tail" typically persists even after the system is in the field, as commanders are just as loath to have the system fail as its developers were. There is little evidence that reducing manpower 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 concept of operations (CONOPS) for autonomous aerial and maritime systems deployed from Navy ships or submarines. Currently, every operator and technician must be embarked in 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

We Don't Call Them Horseless Carriages Anymore

By Major Charles Weko, U.S. Army Reserve

In the past decade, unmanned systems (UxS) have more than proven their combat effectiveness. They have cemented their presence on the battlefield. Now, as the associated article here points out, unmanned systems must prove themselves to be cost effective. But there is a third achievement that UxS will need as they mature and integrate with existing systems; unmanned systems will have to find their true names.

It is a common trait of emerging technology that it begins with names that describe what it is not rather than describing what it is. Virtually every life-altering technology has experienced this shift. Early automobiles were called "horseless carriages." Early radios were called "wireless sets."

We can see this same pattern with unmanned systems. The vocabulary that has emerged around UxS struggles to describe what this revolutionary technology really is. The two words that typify this situation are the adjectives most frequently applied: unmanned and autonomous.

Clearly, calling an unmanned system unmanned is a misnomer. Even in their most idealized state, UxS have significant human controls. No naval captain will ever stand on the bridge of his ship and say, "I wonder why those UAVs just launched?" Human judgment will always play a central 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.[6]

Lessons from Fire Scout

The introduction of the Fire Scout UAV to the Fleet is instructive.[7] Although it was developed in its own Navy/contractor "envelope," when the Fire Scout deploys to the Fleet on board the Littoral Combat Ship (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 developmental efforts, each tether will need to be broken, and Fleet operators already part of the Ship's Manning Document will need to be cross-trained to operate and maintain 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 KPPs 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 in 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, many doubt that hiring additional analysts will help to ease the burden of sifting through thousands of hours of video.[8] General James Cartwright, the retired Vice Chairman of the Joint Chiefs of Staff, recently characterized the current situation: "Today an analyst sits

U.S. NAVY (K. SCHINDLER)

An MQ-8B Fire Scout UAV completes the first unmanned biofuel flight at Webster Field, Naval Air Station Patuxent River, Maryland, on 30 September. "The introduction of the Fire Scout UAV to the Fleet is instructive," the authors contend. Developed by a Navy/contractor team, when the aircraft deploys in the Littoral Combat Ship, an MH-60 helicopter detachment will take over the reins, "with no increase in manning."

role in the application of lethal force. It is not unrealistic to expect that UxS will enhance our ability to use force in a more discriminatory and proportional manner.

In a similar way, calling a system autonomous fails to express what really makes it different from other systems. Unfortunately, the range of technologies that might be implied by the word autonomous is virtually all-encompassing. Many efforts have been made to define autonomy, but often those definitions are merely tailored to the developmental milestones of the system to which they are applied.

Further, both "unmanned" and "autonomous" act as barriers to the discussion of UxS. Pilots naturally resist the implication that unmanned systems do not need the specialized skills of professional aviators. "Autonomy" is a double-edged source of confusion and resistance. Use of the word conjures images of rogue machines turned against humanity for the Luddites at the same time it overpromises to the Early Adopters.

The sheer breadth of UxS technology suggests that it may be a long time before effective collective terms develop. It would be vain to suggest what terms we should be using; however, when we finally begin to use the true name of UxS, technology will leap ahead because the change in vocabulary will signal the end of resistance.

In the meantime, we need to do two things. First, we have to recognize that our current vocabulary is inadequate for the real potential of UxS. While it is sufficient for well-informed professionals to have technical discussions, it falls short of what is needed for the general population. Second, we should not be concerned when the taxpayers give UxS a name of their own choosing. Rather than viewing this as a misunderstanding that needs to be corrected, we should recognize it as an acceptance of this important technology into American life.

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."[9]

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 office of the Department of the Navy 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."[10] 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.


U.S. NAVY (P. MIGLIACCIO)

Rear Admiral Michael Broadway hands out a souvenir ball cap at the University of New Mexico Children's Hospital during Albuquerque Navy Week in October. At a National Defense Industrial Association symposium a year earlier, the Navy's deputy director, Concepts and Strategies for Information Dominance, declared that the Navy and industry should "give the C4 architecture the priority, it is critical." The authors say, "from the CNO down, this aspiration is palpable."

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 enables 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 to decrease their associated manpower costs.[11] 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."

Beyond the Horizon

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 could 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 then-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."[12]

In one prominent 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, which is currently conceived of as operating in swarms using 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 among themselves to formulate an optimum mission plan. The human operator would communicate with the swarm only as a whole to select and prioritize its assignments.[13] Clearly, technological hurdles remain before this vision becomes a reality.[14]

Addressing the Manning-Requirements Challenge

The Navy laboratory community is embarked on leading-edge research to address this challenge. One initiative responding to the manning requirements discussed previously is the "UV-Sentry" project, a joint developmental effort between the Office of Naval Research and the Marine Corps Warfighting Laboratory.[15] This program allows for autonomous command-and-control as well as cooperative autonomy of these systems, and the data thus obtained can be fused into a common operational picture. Hence, rather than having many operators provide constant input and direction to large numbers of autonomous vehicles, a large array of unmanned systems with increased intelligence and the ability to adaptively collect and process sensor data into actionable information provides that capability to the operator with minimum human intervention.[16]

Another initiative under way 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 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 on a publish/subscribe architecture, is currently under development.[17] This update completely uncouples the human interface from the core management software, thus allowing even more flexibility in user customization of the product.

'Constellations' and 'Swarms'

These efforts, and others like them that 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.[18] 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. The vision must be supported by a commitment from the top levels of naval leadership and also from leadership and stewardship at the programmatic level—from acquisition professionals, to requirements officers, to scientists and engineers in the Navy and industry who are 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."[19] 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.

The time to do this is no more propitious than now. Former Secretary of Defense Robert Gates was widely quoted as being adamantly opposed to seeking the 99-percent solution that takes years to develop and instead getting the 80-percent solution into warfighters' hands today.[20] If

The Future of Manned-Unmanned Integration

By Rachel Volner

As the companion article here notes, 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."[1]

There is 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."[2] 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.[3]

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."[4] 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 the Navy follows this mandate, sailors, chiefs, and officers will begin to imagine what a Navy 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 and the operational concepts of tomorrow's, and will usher in a strategic shift for the Navy-after-next. In the words of Air Force Lieutenant General David Deptula, "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*."[21] 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 of the future is the greatest one that ever sailed.

U.S. NAVY

A Tiger Shark UAV—the product of a rapid-deployment effort by the Naval Air Systems Command special surveillance program—returns in June from a mission supporting Central Command forces in theater. The Tiger Shark's delivery in only seven months is a good illustration of former Secretary of Defense Robert Gates' opposition "to seeking the 99-percent solution that takes years to develop and instead getting the 80-percent solution into warfighters' hands today."

1. P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the 21st Century* (New York: The Penguin Press, 2009).
2. For the purposes of this article, we adopted the usage proposed by the 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."
3. See the 28th SSG's "Integration of Unmanned Systems into Navy Force Structure," in which the group was tasked with developing concepts for autonomous systems' development and operations between 2020 and 2028.
4. The Brookings Institution, "Proceedings: The Future of Unmanned Naval Technologies: A Discussion with Admiral Gary Roughead, Chief of Naval Operations," 2 November 2009, Washington, DC. www.brookings.edu/~/media/Files/events/2009/1102_unmanned_naval_technologies/20091102_unmanned_technologies.pdf>.
5. See, for example, "Advance Questions for Admiral Jonathan W. Greenert, USN," Senate Armed Services Committee, 28 July 2011, http://armed-services.senate.gov/statement/2011/07%20July/Greenert%2007-28-11.pdf>
6. 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*, 19 October 2010, and "Chief Concerns: Interview with CNO Mullen," *Government Executive*, May 2006.
7. See "MQ-8B Fire Scout," *GlobalSecurity.org*, www.globalsecurity.org/military/systems/aircraft/mq-8b.htm.
8. For example, see Kate Brannen, "U.S. Intel Chiefs Need Better Data Tools," *Defense News*, 18 October 2010.
9. Ellen Nakashima and Craig Whitlock, "Air Force's New Tool: 'We Can See Everything,'" *The Washington Post*, 2 January 2011. See also, Walter Pincus, "Military Services Should Consider Common Cause in Chase for Updated Unmanned Aircraft," *The Washington Post*, 11 January 2011, and W. J. Hennigan, "Drones Become Speedier, Deadlier," *Los Angeles Times*, 11 January 2011.
10. Tom Kidd, Mikel Ryan, and Antonio Siordia, "Unmanning Unmanned Systems," *Department of the Navy Chief Information Officer News*, 19 May 2010, www.doncio.navy.mil/ContentView.aspx?ID=1756>
11. *FY 2011–2036 Unmanned Systems Integrated Roadmap* (Washington, DC: Department of Defense), p. 35.
12. Remarks by RADM Michael Broadway, Deputy Director, Concepts and Strategies for Information Dominance (N2/N6F) at the National Defense Industrial Association Information Dominance Symposium, San Diego, 5 October 2010.

standoff ranges, as it allows for "enhanced Situational Awareness, greater lethality, improved survivability, and perhaps in the future, [providing] sustainment."[5] Even more impressive, the Block III upgrade of the AH-64 (scheduled for 2012) will increase the Level of Interoperability, 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.[6]

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 tactics, techniques and procedures (TTP) that improve the teaming of unmanned systems with the manned force."[7] 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.

1. *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035* (Fort Rucker AL: U.S. Army UAS Center of Excellence, April 2010), p. 15.
2. 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.
3. 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>
4. 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.
5. *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035* (Fort Rucker AL: U.S. Army UAS Center of Excellence, April 2010), p. 15.
6. 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 *FY 2011-2036 Unmanned Systems Integrated Roadmap* (Washington, DC: Department of Defense). See also U.S. Army Aviation Center of Excellence, "Manned-Unmanned Operations (MUM-O)," 22 March 2010.
7. *FY 2011-2036 Unmanned Systems Integrated Roadmap* (Washington, DC: Department of Defense).

13. Norman Friedman, *Unmanned Combat Air Systems: A New Kind of Carrier Aviation* (Annapolis, MD: Naval Institute Press, 2010). See also Norman Friedman, "UCAVs: Considering the Next Step," *The Year in Defense: 2009 In Review* (Tampa, FL: Faircount Media, 2010). See also, Meinhaj Hussain, "UCAVs: The Future of Air Warfare," Strategy Paper, The Grand Strategy Group of Malaysia, 26 December 2010, www.grand-strategy.com for one indication of how the strategic, operational, and tactical possibilities of UCAVs are recognized in other militaries.

14. See, for example, *Inside Defense*, "Former Navy UAV Chief Sees Unmanned Future for Aircraft Carriers," 20 December 2010, and *Inside Defense*, "NSWC Carderock: Navy Faces Obstacles in Using UAV Swarms on Ships," 31 December 2010.

15. 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, 6-9 August 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, CA, 7–10 May 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, 2006.

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

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

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

19., *FY 2009-2034 Unmanned Systems Integrated Roadmap,* p. 34.

20. See Department of Defense News Transcript, "Remarks By Secretary of Defense Robert Gates at the Army War College, Carlisle, PA," 16 April 2009, www.defense.gov/transcripts/transcript.aspx?transcriptid=4404>.

21. LTGEN David Deptula, USAF, Remarks at the C4ISR Journal Symposium, 13 October 2010.

Captain Galdorisi is director, Corporate Strategy Group, at the Space and Naval Warfare (SPAWAR) Systems Center Pacific. His most recent book is Leave No Man Behind: The Saga of Combat Search and Rescue (Zenith Press, 2009).

Mr. Koepenick is deputy for Program Development, Autonomous Systems ISR/IO Competency, at SPAWAR Systems Center Pacific. In 2008-09 he served as an associate fellow with the CNO Strategic Studies Group XXVIII. His brief to the CNO was titled "The Unmanned Imperative."

Ms. Volner is a strategic analyst in the Corporate Strategy Group, SPAWAR Systems Center Pacific. She holds a masters degreee in Pacific International Affairs from the University of California, San Diego.

Major Weko serves on the staff of the Office of the Chief, U.S. Army Reserve, and holds a masters degree in Operations Research from the Naval Postgraduate School.