Soldiers with 254th Regiment (Combat Arms), New Jersey Army National Guard, fly RQ-11B Raven small unmanned aircraft system at Joint Base McGuire-Dix-Lakehurst, New Jersey, July 11, 2016 (U.S. Air National Guard/Mark C. Olsen)

Moore's Law and the Challenge of Counter-sUAS Doctrine

By Mark D. Newell

As I reflect back on four decades of service in uniform, it is clear that the pace of change has accelerated significantly.

—General Joseph F. Dunford, Jr.

In 1965, Gordon Moore, co-founder of the Intel Corporation, made his now famous prediction that the "number of transistors incorporated in a chip will approximately double every 24 months."[1] More than 50 years later, his prediction has not only held true, but also the implications of what is now called Moore's Law define the combat environment for the joint force.

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The continual miniaturization, mass production, proliferation, and improvement of integrated circuits and microprocessors have introduced powerful computing technology into every aspect of modern life.

One of the many modern applications of the integrated circuit is in controlling small unmanned aircraft systems (sUAS). Commonly referred to by the name *drones*, commercially available sUAS have increasingly become a weapon of choice for nonstate actors with limited resources. Their rapid evolution and innovative application have created several challenges for a joint force tasked to establish a defense against them. Not least among these challenges has been the development and dissemination of useful counter-sUAS (C-sUAS) doctrine.

History and Context

At first glance, Moore's Law appears to describe the potential growth of a single technology through miniaturization. What is unique about the exponential miniaturization of transistors, though, is their foundation. Transistors form the basic building blocks of integrated circuits and microprocessors, which in turn act as the computational core of almost every piece of electronic technology. For each reduction in transistor size over the last five decades, computing capability has increased, while production costs have decreased. The increased affordability for consumers has resulted in broad market penetration. Today, transistor and microprocessor technology are ubiquitous; they touch every aspect of modern life including the weapons systems of the joint force and its adversaries. Although it is doubtful he understood it at the time, Moore predicted the dawn of a technological age no less significant than the industrial revolution in the 18th century.

Despite the fact that weapons technology in every sector has transformed rapidly over the last 50 years, the evolutionary pace of sUAS has been particularly startling. These systems seem to have burst onto the battlefield with remarkable and fully developed capabilities. In truth, this perception is not entirely accurate, as the capabilities of today's sUAS were nurtured in what amounts to a global cottage research and development program. While the weight of military effort was focused on replicating manned aircraft capabilities in larger UAS, anything under 50 pounds had been essentially relegated to the realm of hobbyists.

Quietly in garages and basements around the world, remote control aircraft enthusiasts incorporated each advancement in miniaturization and processing capacity into their hobby. Smaller radios allowed greater range with less weight. Miniaturized cameras were incorporated that could transmit real-time data to operators wearing virtual reality headsets. Powerful microprocessors and Global Positioning System receivers created aerodynamic stability and allowed complex propulsion configurations and the capability to preprogram routing beyond radio range. These advances, along with ever-decreasing entry-level costs, greatly expanded the global remote-control (RC) aircraft market.

In December 2015, the Federal Aviation Administration (FAA) designated RC aircraft between 0.55 and 55 pounds as "sUAS" and began regulating their activities in an effort to manage the growing numbers operating in the United States. As one indication of the scale and pace of UAS growth, this year's *FAA Aerospace Forecast* predicts as many as 4.4 million sUAS will be registered in the United States by 2021.[2] If accurate, this would amount to a 400 percent increase over the next 5 years.[3]

Terrorism and Budget

With the steady rise of international terrorism over the last two decades, bad actors around the globe have actively sought low-cost, readily available technology that can be weaponized for their purposes. Predictably, they have found and embraced the sUAS as an economical tool in their arsenal. The decade-long pursuit and evolution of terrorist organizations' use of sUAS is detailed in a 2017 report by the Middle East Media Research Institute.[4] What began in 2004 with a 20-minute sUAS reconnaissance over Israel by Hizballah[5] has evolved to a point where so-called Islamic State fighters routinely use sUAS to drop grenades on U.S. special operations forces in Iraq and Syria.[6]

Concerns for the future, however, lie much closer to home as the Department of Homeland Security has advised American citizens that terrorist groups are actively pursuing "new technologies and tactics, such as unmanned aerial systems and chemical agents that could be used outside the conflict zones."[7] While the technology and tactics to defend against larger UAS have existed in the form of antiaircraft capability since the dawn of aviation, sUAS pose a new and unique threat. Small and maneuverable enough to elude most surveillance and early warning radar systems, they are also quiet and therefore difficult to detect. In the United States, aside from FAA registration, there are no restrictions on the purchase of military-grade sUAS. People interested in acquiring a capability via the Internet will find that they can purchase a quadcopter with its own camera system, capable of 12-minute flights, controlled with a cell phone, and delivered to their home for under $180.[8] On the high end of the spectrum, 20 hours of endurance, cruising speeds of 50 mph, and a 22-pound payload can be purchased for just $17,000.[9] Given the availability and capability of these systems, the joint force, along with the entire U.S. defense apparatus, has significantly increased its focus on countering their capability at home and abroad.

Change and Challenge

In keeping with Moore's Law, the evolution of sUAS technology continues to accelerate. An examination of new, marketable ideas in the field makes one of the better illustrations of this point. A 2014 report showed a total of five new UAS patents were published in 2001.[10] The same report showed 12 new patents published in 2003, 22 in 2005, and a near perfect exponential increase every 24 months through the end of the reported period, where it indicated that 372 new patents were published in 2014.[11] Even if each of these patents only represents a small but measurable increase in capability, the rate of sUAS evolution is daunting.

The effort to establish and deploy C-sUAS capability within the joint force has been remarkably expeditious. Even a casual Internet search for "C-UAS" reveals a significant uptick in government outreach to industry in 2016. Phrases such as *Joint Urgent Operational Need*[12] and government-sponsored C-UAS competitions focused on *evaluating "Hard Kill" technologies*[13] are prevalent in the results. The same search also reveals an outpouring of industry response. Dozens of new technologies and adaptations of existing ones have been rapidly developed, and just as rapidly fielded for evaluation on the battlefield.

With the support of innovative industry partners, U.S. Central Command is meeting the C-sUAS challenge with deliberate action. In response to the immediate nature of the sUAS threat, the command has deployed over 100 different experimental C-sUAS systems throughout the theater.[14] Ranging from man-portable to large fixed-base systems, all are undergoing operational evaluation by the joint force in the combat

Marine with Company Bravo, 1st Battalion, 6th Marine Regiment, prepares to fly Mark-2 Instant Eye during Infantry Platoon Battle course as part of Deployment for Training on Fort Pickett, Virginia, August 15, 2017 (U.S. Marine Corps/Michaela R. Gregory)

environment.[15] Once sufficient data have been collected, the field will be narrowed and a subset chosen for larger scale production and deployment. Were it not for the evolutionary rate of sUAS, this process would be relatively straightforward.

Unfortunately, as the current experimental C-sUAS systems are being evaluated in the field, teams of designers and engineers are already working on the next generation. A thumb through the science and technology periodicals at any bookstore yields articles about artificial intelligence, autonomous systems, swarm tactics, and more. Given the current rate of evolutionary change, it is entirely possible that the next generation of sUAS technology will be deployed on the battlefield before evaluation of the current C-sUAS systems has completed. This moving target, which is increasingly harder to hit, is the challenge implied by Moore's Law. If there is one aspect of the C-sUAS effort more difficult than keeping pace with sUAS evolution, it might be producing useful C-sUAS doctrine.

Doctrine and Adaptation

The concept of military doctrine bears brief discussion because it often means different things to different people. There are essentially three levels of military doctrine: Service, multi-Service, and joint. Where multi-Service doctrine may be specific to two or more Services, joint doctrine is published by the Chairman of the Joint Chiefs of Staff for use by all the Services. Generally speaking, doctrine should be both aspirational and instructional. It should capture the best ideas and practices from across the formation, boil them down to their essences, clearly articulate them, and present them back to the formation as achievable goals and standard procedures. This description is in line with the Chairman's Memorandum 5120.01A, *Joint Doctrine Development Process*, which requires joint doctrine to reflect "extant practice" and capture "lessons learned."[16] It also illustrates how the efforts of the joint force are synchronized through common understanding and expectation.

One prerequisite to capturing, documenting, and disseminating extant practice is the establishment of the extant practice itself. In other words, it is difficult to describe how things are normally done when they are not done in any particular way. The same can be said for the durability of the extant practice. If the way things are done changes at an interval shorter than the doctrine development timeline, any doctrine produced will be of limited value. This is particularly challenging regarding joint doctrine, where new submissions are thoroughly vetted by a joint doctrine development community of 264 representatives from combatant commands, Services, and other stakeholders. Over the past 20 years, joint doctrine development timelines have been streamlined from 21 months in 1996, to 17 months, and again this summer to 12 months with the implementation of the Adaptive Doctrine initiative.[17] Even with these significant improvements, capturing rapidly evolving C-sUAS practices in joint doctrine remains a challenge.

The approach the C-sUAS doctrine community has taken is to balance specificity and accuracy while favoring timeliness. That is to say they have purposely provided an intellectual framework that allows efficient communication of ideas in the short term, while avoiding some of the specificity that might become inaccurate by the time it is published. Within the joint force, the Army gets full credit for the groundwork that it laid in C-sUAS doctrine. In October 2016, as the first experimental C-sUAS systems were being deployed, the Army released an unclassified C-UAS strategy that had as its stated purpose "to integrate and synchronize C-UAS efforts across the Army, and to inform joint, inter-organizational, and multinational partners."[18]

This was not the first C-sUAS discussion, but it was the first broadly disseminated and authoritative document to outline a course forward. Not only did it establish baseline terminology in its 13 pages, but it also laid out short- and long-term priorities in the development of C-sUAS capability. The value of the standard military terms and their definitions cannot be overstated as they establish the foundation of doctrine. Even before the first joint publication (JP) was printed, the Department of Defense Dictionary was created in 1948 to allow "the joint force to organize, plan, train, and execute operations with a common language that is clearly articulated and universally understood."[19]

Armed with the baseline terminology and concepts from the Army C-UAS strategy, deployed forces established local procedures from which generic tactics, techniques, and procedures were written. These and other tactically oriented planning considerations were initially captured in Army Tactical Publication 3-01.81, *Counter–Unmanned Aircraft System Techniques*, and ultimately consolidated into the *Multi-Service Tactics, Techniques, and Procedures (MTTP) Manual for Air and Missile Defense*. Because joint publications are focused on operational- and strategic-level doctrine, the April 2017 revision of JP 3-01, *Countering Air and Missile Threats*, provides a brief C-sUAS discussion, but ultimately refers the reader to the MTTP where the majority of C-sUAS doctrine resides, pending the further development of higher level practice.

The end result of this effort is a framework of concepts, terminology, definitions, considerations, and generic procedures specific enough to be useful, yet vague enough to remain relevant as C-sUAS technology evolves. Although it is addressed at the joint, multi-Service, and Service levels, C-sUAS doctrine rarely refers to a *specific* C-sUAS technology. By maintaining a conceptual approach, this framework is presented with the expectation that combatant commands and deployed forces will adapt it to their specific circumstances and experimental systems.

Conclusions

Just as the sUAS is likely to remain on the battlefield for quite some time, so will the changes they have illuminated in the doctrine development process. If Moore's Law continues to hold true, new technologies will increasingly be fielded in response to emerging threats with only the roughest outline of employment doctrine in place. Therefore, despite a continued and concerted effort to simplify doctrine development, the burden of adapting general guidance to new battlefield situations will remain heavy on the shoulders of the men and women engaged in the fight.

Effective C-sUAS doctrine is in the hands of deployed personnel today because doctrine developers did not wait for the environment to match their expectations; they adapted their expectations and the doctrine development process to the new environment. On the modern battlefield where the technology is evolving almost faster than it can be documented, matching that speed with non-technology based processes is not always an option. Going forward, flexibility and adaptation will be the joint force's key to avoid being outpaced by its own technology or that of its adversaries. **JFQ**

Notes

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14 *Combined Joint Task Force–Operation Inherent Resolve Leaders C-UAS Handbook* (MacDill Air Force Base, FL: U.S. Central Command, August 12, 2017), 3.

15 Ibid.

16 Chairman of the Joint Chiefs of Staff Memorandum 5120.01A, *Joint Doctrine Development Process* (Washington, DC: The Joint Staff, 2014), B1.

17 Gregory E. Browder and Marcus J. Lewis, "Adaptive Doctrine: Infusing the Changing Character of Warfare into Doctrine," *Joint Force Quarterly* 86 (3rd Quarter 2017), 120–121, available at <ndupress.ndu.edu/JFQ/Joint-Force-Quarterly-86/Article/1223847/adaptive-doctrine-infusing-the-changing-character-of-warfare-into-doctrine/>.

18 *Counter–Unmanned Air Craft System (C-UAS) Strategy Extract* (Washington, DC: Headquarters Department of the Army, October 5, 2016), available at <www.arcic.army.mil/App_Documents/Army-CUAS-Strategy.pdf>.

19 Joint Publication 1-02, *Department of Defense Dictionary of Military and Associated Terms* (Washington, DC: The Joint Staff, August 2017).