

NOT THE DRONES YOU'RE LOOKING FOR:
CIVIL DRONES INVADING STABILITY OPERATIONS

BY

MAJOR DAVID M. HALL

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APPROVAL

The undersigned certify that this thesis meets master's-level standards of research, argumentation, and expression.

DR. MARK J. CONVERSINO (Date)

DR. STEPHEN D. CHIABOTTI (Date)



DISCLAIMER

The conclusions and opinions expressed in this document are those of the author. They do not reflect the official position of the US Government, Department of Defense, the United States Air Force, or Air University.



ABOUT THE AUTHOR

Major David M. Hall received his commission in 2003 through the Air Force Officer Training School at Maxwell AFB, AL following his graduation from Virginia Tech with a degree in Aerospace Engineering. He also received a Master of Science degree in Aeronautical Engineering from the Air Force Institute of Technology in 2008 and a Master of Arts degree in National Security and Strategic Studies from the US Naval War College in 2015. His career as a developmental engineer and acquisition officer has included assignments at the Air Force Research Laboratory's Directed Energy Directorate, the National Air and Space Intelligence Center, the 577 Expeditionary Prime BEEF Squadron in Afghanistan, and Headquarters Air Combat Command. Upon graduation from SAASS, Major Hall will serve on the staff of the Assistance Secretary of the Air Force for Acquisition at the Pentagon in Washington D.C.



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ABSTRACT

This study examines the implications to military operations of the proliferation of small unmanned aircraft systems (UAS) into civil applications. It argues that, by maintaining separate discussions on the topics of civil UAS expansion and military efforts to counter state-based UASs, military planners fail to recognize a changing military operating environment brought about by the proliferation of civil UASs and are therefore unprepared for its emergence. The author begins by assessing the likelihood of the continued proliferation of small UASs to civil sectors and delves into the current use of civil UASs and projections of their future utility and diffusion to numerous applications within the public, commercial, and private sectors. Next, the study evaluates the severity of the threat to military forces by reviewing the utility of UASs for nefarious purposes and their implications within an emerging civil UAS environment. In that context, this study introduces the concept of the “aerial littoral” as the emerging seam between the air and land domains comprised of a low-altitude layer of highly dense civil air. By overlaying this emerging environment onto a historical case study, the author demonstrates the extreme utility of civil UASs to both non-governmental organizations and nefarious actors in stability-operations scenarios and the likely issues which military forces will face in this new environment. Ultimately, this study suggests that the proliferation of small civil UASs will usher in a new and highly dynamic operating environment, particularly in stability-operations scenarios. The US military is not adequately prepared to address this phenomenon; therefore, this study ends by providing recommendations on how to begin closing that gap.

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Chapter 1

Introduction

The woman's frantic cries pierced the clear winter air. "Sam? Sam! Help! Help! My husband's having a heart attack!" A passer-by quickly grabs his phone and dials the number for the local emergency service. Normally, the simple five-word response of "Help is on the way" from the dispatcher would provide some comfort, but not today. Today, snow covers New York's roads and the plows struggle to dig out from last night's storm. Today, traffic is stacked up as far as the eye can see. Today, this woman will likely lose her husband because the ambulance simply will not make it in time. Then again, today, there are other ways to save this man's life.

A siren echoes out across the plaza before the Good Samaritan can even comprehend what he just heard. *A drone? They're sending a drone? A puny, insignificant drone?* By now, the little yellow aircraft is descending slowly from above them as the gathered crowd parts to give it room to land. The emergency dispatcher tells him to point the drone's camera at the victim and then standby for instructions as she transfers all communications through the drone's intercom system. *It's a defibrillator*, the Good Samaritan thinks to himself. *They sent a defibrillator!* The ambulance is still nowhere in sight, but this woman might not be a widow at the end of the day after all.

In another town, thousands of miles away, the same scenario plays out. The closest emergency drone is perched in its docking station on the side of a local hotel. Within seconds of processing the words "heart attack" over the emergency phone system, the drone is already airborne and racing between buildings along the shortest route to the victim's coordinates. Only, this time, there is a problem. The drone's erratic flight path takes it directly over a group of soldiers out on their daily patrol as they attempt to provide security and stability for a country recovering from recent political turmoil. This is a group of soldiers who, just last week, lost a teammate to an attack from a bomb-laden drone. They are not about to repeat that mistake.

The newly installed counter-drone laser system on their patrol vehicle reacts almost instantly and burns a small hole through the drone's fuselage and into its internal power and control systems causing it to narrowly miss a group of children as it plummets

to the earth. The squad is safe again and can continue their efforts to safeguard the lives of the local population. It is clearly a tactical success.

Four blocks away a woman and her children slowly realize that help is not going to make it in time. That night on the local news, a reporter mourns the death of a prominent local businessman. A death which was preventable. A death which the reporter blames on the trigger-happy American soldiers. A tactical success quickly gives way to a strategic failure.

The Case of Civil Drones

While these vignettes are purely fictional, efforts are currently underway to make their components near-term realities. Alec Momont, a graduate student at the Delft University of Technology in the Netherlands, recently built and demonstrated an unmanned-aircraft-based defibrillator aimed at drastically decreasing the average response time to cardiovascular emergencies.¹ Over the next few years, Momont envisions a distributed fleet of these “ambulance drones” aiding the European Union’s 800,000 cases of cardiac arrest each year, potentially increasing survival rates from 8 percent to 80 percent. On the counter-unmanned aircraft side, militaries around the globe are racing to develop new technologies to counter the threat to military operations created by small unmanned aircraft. At formal events such as the Joint Integrated Air and Missile Defense Organization’s annual Black Dart exercises, defense contractors have already demonstrated the ability to neutralize small-unmanned aircraft with lasers, communications jammers, and a host of other engagement systems.²

On one hand, civil societies across the globe are embracing the development of small, affordable unmanned aircraft and attempting to harness a newfound degree of access to the air domain in novel ways. Efforts promoting the proliferation of civil unmanned aircraft systems (UAS) face technological hurdles in overcoming performance limitations and social hurdles in addressing safety and privacy concerns as governments decide how, and to what extent, to integrate civil UASs into their national airspace. All

¹ TU Delft, “TU Delft’s ambulance drone drastically increased chances of survival of cardiac arrest patients,” TU Delft, 27 October 2014, <http://www.tudelft.nl/en/current/latest-news/article/detail/ambulance-drone-tu-delft-vergroot-overlevingskans-bij-hartstilstand-drastisch/>.

² Tadjeh, “Inside Black Dart”.; Richard Whittle, “Marine Sniper In Helicopter Kills a Drone! Black Dart Results,” *Breaking Defense*, 27 August 2015, <http://breakingdefense.com/2015/08/marine-sniper-in-helicopter-kills-a-drone-black-dart-results/>.

the while, public, commercial, and private entities continue to aggressively pursue the use of small UASs for a growing range of innovative, and sometimes illicit, applications.

On the other hand, militaries have already integrated small UASs into their offensive operations and are now recognizing the threat of those same systems being used against them in conventional battlefield scenarios. Defeating or otherwise neutralizing UAS threats before they can injure friendly forces, interdict supply lines, or simply spy on covert troop movements are slowly becoming priorities within many military circles. These concerns have resulted in a plethora of so-called counter-UAS capabilities as defensive-minded military and civil organizations alike search for solutions to the mounting nefarious UAS issue.

Up to this point, these discussions have occurred in relatively distinct stovepipes. Civil actors concern themselves with the proliferation of civil UASs and, outside of home station nuisance issues, military actors largely concern themselves with the proliferation of small UASs on the battlefield. However, dismantling these stovepipes and combining the civil and military discussions on the proliferation of small UASs, as this study argues is necessary, results in a third and potentially more important set of problems. In a combined discussion one can begin to recognize the broader implications of a changing military operating environment as societies across the globe begin to embrace and come to depend upon the use of civil UASs for essential services, public safety, and a variety of other civil applications.

For over a hundred years, states, large corporations, and a select group of private citizens have enjoyed a relative monopoly on the use of the air domain. The proliferation of small civil UASs is poised to upend that paradigm and create a low-altitude layer of highly dense air traffic more akin to terrestrial roadways than the wide-open airways at 30,000 feet. For the first time in history, this emerging seam between the air and land domains, this “aerial littoral,” will bring civil and military defense forces alike in contact with the aerial equivalents of ambulances, utility vehicles, postal delivery trucks, and private bicycles, the disruption of which could have significant effects on host-societies.

This study assesses this emerging environment and the US military’s preparedness for that future development. To that end, following a brief overview of unmanned aircraft in Chapter 2 to provide an analytical foundation, this paper will

progress through three steps in assessing the risk to military operations from the proliferation of small UASs. The effort in Chapter 3 investigates the likelihood of the continued proliferation of small UASs to civil sectors and delves into the current use of civil UASs and projections of their future utility and diffusion to numerous applications. Subsequently, Chapter 4 assesses the severity of the threat to military operations inherent in the proliferation of civil drones from both a technical-capabilities perspective and that of a changing operating environment. These risk components of likelihood and severity come together in Chapter 5 to holistically assess the risk to military operations in a notional stability-operations scenario. Ultimately, this study suggests that the proliferation of small civil UASs will usher in a new and highly dynamic operating environment, particularly in stability-operations scenarios, which the US military is not currently adequately prepared to address.

Necessary Caveats

Militaries, policy makers, and academics have studied the use of the air domain for state and commercial activities for well over a hundred years and fully understand the impacts of air power on the tactical, operational, and strategic levels of war. This study focuses instead on the emerging access to the air domain for lower-level entities throughout civil society, to include nefarious actors, and its potential to alter the military operating environment. Civil usage of small UASs is not new, but it is still relatively immature in comparison to state or large-scale commercial use of the air domain. Similarly, non-state actors have begun using UASs in criminal and battlefield applications, but those cases are still very limited. This study is therefore decidedly speculative, but intentionally so, in order to help start the discussion on how the proliferation of civil drones will affect military operations. Only by understanding and assessing these trends, before they reach a critical inflection point, can the US military address any necessary changes in policy, organization, force structure, or training.

Furthermore, the relative immaturity of the broader civil UAS discussion creates a highly dynamic situation which presents new and exciting revelations on a daily basis and subsequently challenges efforts to develop trends and forecasts. Although small UAS manufacturer Parrot introduced the first consumer-grade UAS back in 2010, the subject of civil UAS proliferation has only recently emerged from the shadows of niche-

developer forums and backroom-lobbyist proposals to enter the collective social conscious.³ The vast majority of the references cited in this study arose within the last few years, the more academically rigorous of which mostly appear within the last six to nine months and still allude to, but fail to disclose, internal or proprietary information. Consequently, both the real-world application of civil UASs and the corresponding academic and policy debates are highly dynamic subjects which must be viewed with a healthy level of skepticism. However, using that as an excuse to delay meaningful debate is shortsighted. Military planners who fail to account for the enduring reality of civil UASs do so at their own peril.

Finally, although the intent of this study is to start the conversation, it is by no means all encompassing and will not cover all aspects of civil UAS interaction with military operations. This effort focuses on the threat to ground forces in stability operations as a useful lens to merge the stovepiped civil and military discussions about UASs. Stability operations present scenarios that include the necessary components to illustrate the changing military operating environment. Similarly, this study refers to, but does not directly address, the military's use of UASs or the broader debate on legal and moral implications of those applications.

All told, the following chapters present a detailed investigation into an immature and highly dynamic subject and an initial foray into its longer-term implications to military operations. As the bibliography at the end of this study suggests, there is no shortage of information on the subject of civil UASs; however, academically rigorous pieces are relatively scarce. It is the author's sincere hope that this piece positively alters that balance.

³ Dan Gettinger and Arthur Holland Michel, *Drone Sightings and Close Encounters: An Analysis* (Washington, DC: Center for the Study of the Drone at Bard College, 11 December 2015), 1.

Chapter 2

Unmanned Aircraft

Just over fourteen years after Orville and Wilbur Wright introduced manned aircraft to the world, Lawrence Sperry, a pioneer in early aviation, removed man from the picture. The successful flight of Sperry's Aerial Torpedo heralded the birth of unmanned aircraft on 6 March 1918.¹ After nearly one hundred years of unmanned flight, the world is only just beginning to awaken to the concept of unmanned aviation and still views it as a relatively new phenomenon. As noted by Michael Kreuzer in his doctoral dissertation, the contemporary media frenzy surrounding this awakening has created a broad misunderstanding of the nature and capabilities of unmanned aircraft. Without understanding the nuanced discussions taking place between experts in the field, the general public and political leaders alike have begun to conflate highly capable, but extremely expensive, systems with extremely cheap, but relatively incapable, systems. Within society's collective mind, this misunderstanding created an image of highly capable and extremely cheap systems proliferating to all corners of the world. Before embarking on a study to assess the future impact of a subset of unmanned aircraft on future military operations, this chapter attempts to demystify Kreuzer's "mythical 'super RPA'" and place the civil drone discussion within the broader context of unmanned aircraft.²

Terminology

A truly meaningful discussion cannot begin without a shared understanding of key concepts and terminology; however, despite a century of experience, discussions surrounding unmanned aviation have not even settled on a term for the unmanned aircraft itself. This oversight both perpetuates and exacerbates the misunderstanding which plagues common discussion and study of unmanned aircraft. The list of terms alternatively used by various organizations to refer to unmanned aircraft includes at least eight distinct terms: Unmanned Aircraft (UA), Unmanned Aerial Vehicle (UAV),

¹ Laurence R. Newcome, *Unmanned Aviation: A Brief History of Unmanned Aerial Vehicles* (Reston, VA: American Institute of Aeronautics and Astronautics (AIAA), 2004), 20.

² Michael P. Kreuzer, "Remotely Piloted Aircraft: Evolution, Diffusion, and the Future of Air Warfare" (PhD diss., Princeton University, September 2014), 292.

Unmanned Aircraft System (UAS), Remotely Piloted Vehicle (RPV), Remotely Piloted Aircraft (RPA), Remote Controlled (R/C) Aircraft, Remotely Operated Aircraft (ROA), Remotely Piloted Aircraft Systems (RPAS), and more generically, drones. When used interchangeably, each of these terms, at their most basic level, refers to an aircraft capable of airborne operations without the onboard presence of human operators.³ Delving more deeply into each specific term reveals an implied set of subtle differences, which drive misunderstanding and confusion between different groups of operators as well as the broader public.

The general differences between these terms revolve around the scope and emphasis of the definition. Both military and commercial organizations prefer to use the term UAS, for example, in reference to both a UAV and the broader system of equipment and personnel necessary to control that aircraft.⁴ Similarly, the US Air Force uses the terms RPV and RPA to highlight the integral role of human pilots, regardless of their off-aircraft location.⁵ The term drone, from a military perspective, emerged in the early 1930s and generally refers to unmanned aircraft used for target practice for surface-to-air or air-to-air engagements.⁶ More broadly, however, the term drone is now commonly accepted slang within the general public to refer to all unmanned aircraft.

After the prolific use of US Predator and Global Hawk systems in Afghanistan and Iraq, the term drone took on an intensely negative connotation within the public vernacular and evoked images of armed aircraft, devoid of human control, raining indiscriminate death from above in so-called “drone strikes”.⁷ This negative connotation drove both military and commercial organizations alike to shun the use of the term drone in all official communications.⁸ However, the media and broader public latched onto the term and would not let go. Today the term drone can refer to any unmanned aircraft ranging from small toys to full-scale aircraft such as the US Air Force’s RQ-4 Global

³ Joint Publication (JP) 1-02, *Department of Defense Dictionary of Military and Associated Terms*, 15 February 2016, 252.

⁴ Department of Defense, *Unmanned Systems Integrated Roadmap FY2013-2038* (Washington, DC: Office of the Secretary of Defense, 2013), 4.

⁵ Department of Defense, *Integrated Roadmap*, 105.

⁶ Newcome, *Unmanned Aviation*, 57.

⁷ Richard Whittle, “Don’t Say ‘Drones,’ Beg Drone Makes,” *Breaking Defense*, 14 August 2013. <http://breakingdefense.com/2013/08/dont-say-drones-beg-drone-makers/2/>

⁸ Whittle, “Don’t Say ‘Drones’.”

Hawk and can simultaneously present a decidedly neutral or explicitly derogatory connotation, depending on the context and audience.

As manufacturers and retailers began to inundate the commercial and private markets with commercially available unmanned aircraft, the preponderance of advertising and media coverage referred to the new systems as drones.⁹ An Australian study in 2014 demonstrated the contemporary evolution of these terms and found no correlation between the term used and the public's perception of a system's relative safety or utility.¹⁰ Despite the distaste for the term within the defense and commercial sectors, the term drone now represents the most efficient means of conveying the concept of an unmanned aircraft to a wide and diverse audience. As such, this study will use the term UAS to refer to unmanned aircraft systems in general and the term drone to specifically refer to the civil UASs which represent the focus of the remaining effort.

Despite the use of a single term, UASs come in a vast array of shapes and sizes and possess an equally wide range of capabilities. Academia, industry, and government organizations use several different frameworks to categorize these UASs in order to avoid conflating the capabilities and characteristics of fundamentally different types of aircraft. One of the most common methods, and the scheme favored by the US military and the Federal Aviation Administration (FAA), divides UASs into five categories based on their size, weight, maximum operating altitudes and maximum speed. As summarized in Table 1, increasing group numbers correspond to increases in size and performance of the UAS. Within this categorization defense and industry experts often refer to the aggregation of Groups 1 and 2 as Small Unmanned Aircraft Systems (sUAS).¹¹

In his doctoral work, Kreuzer clarifies a common, though largely uncoded, categorization scheme by dividing UASs into two categories: tactical and strategic. Within this vernacular, tactical UASs are generally smaller aircraft with limited payloads, speeds, and operating ranges and are relatively cheap to procure and operate. Strategic systems, on the other hand, are significantly more technologically advanced aircraft with

⁹ Jack Nicas, "Why Some Drone Makers Hate the Word 'Drone' and Want to Change It," *The Wall Street Journal*, 9 October 2014. <http://www.wsj.com/articles/why-some-drone-makers-hate-the-word-drone-and-want-to-change-it-1412821801>.

¹⁰ Reece A. Clothier et al., "Risk Perception and the Public Acceptance of Drones," *Risk Analysis* 35, no. 6 (June 2015): 13.

¹¹ Department of Defense, *Integrated Roadmap*, 6.

enhanced payloads, speeds, and operating ranges and more closely resemble manned aircraft in terms of procurement and operating costs.¹² This characterization, although less refined and more subjective than the typical five-group scheme, does help to highlight the technical and economic requirements which typically limit the use of strategic UAS systems to states and large corporations. For this reason and the general trends within the proliferation of civil drones, this study will focus on UASs that fall within the tactical and sUAS categories.

Table 1: Unmanned Aircraft System Group Categorization

Group	Name	Weight (lbs)	Altitude (ft)	Speed (knots)	Example UAS
5	Penetrating	> 1,320	> 18,000	> 250	RQ-4B Global Hawk
4	Persistent	> 1,320	< 18,000	> 250	MQ-1B Predator
3	Tactical	< 1,320	< 18,000	< 250	RQ-7 Shadow
2	Small Tactical	21 – 55	< 3,500	< 250	ScanEagle
1	Micro / Mini Tactical	0 – 20	< 1,200	< 100	RQ-11 Raven

Source: Adapted from Department of Defense, Unmanned Systems Integrated Roadmap FY2013-2038 (Washington, DC: Office of the Secretary of Defense, 2013), 6.

A Brief History of Unmanned Aircraft

With nearly a hundred years of active development and use, UASs are not new and actually possess a rich and ever-expanding history of key milestones and operational employments. As previously mentioned, the first real flights of feasible UAS prototypes occurred in 1918 with the demonstrations of Sperry’s “Aerial Torpedo” and Charles Kettering’s “Bug,” both of which operated autonomously based on preset timers and inertial guidance systems.¹³ As World War I came to a close, however, interest in those efforts largely died out and the military’s UAS focus shifted to developing reliable methods to remotely control a UAS in flight. Those efforts resulted in the production of several target-drone systems for naval and army anti-aircraft gunnery training.¹⁴ World

¹² Kreuzer, “Remotely Piloted Aircraft”, 224, 325-326.

¹³ Newcome, *Unmanned Aviation*, 20, 28, 30.

¹⁴ Newcome, *Unmanned Aviation*, 31,47, 58.

War II brought a renewed increase in UAS research and witnessed several successful operational employments of UASs such as Germany's V-1 "buzz bomb" attacks on the United Kingdom and the United States' Operation Option strikes against Japanese forces in the Pacific.¹⁵ By the Vietnam War, the US military was using UASs daily for reconnaissance missions.¹⁶

Although this history, and the majority of the identified milestones, highlighted UAS development and operation within United States (US) military circles, the US did not possess a monopoly on postwar UAS development. Israel, for example, began an extensive UAS industry in the early 1970s and supplied several of the US military's initial tactical UASs in the 1980s. Key examples of this include the Marine Corps' Scout UAS and the Army's Hunter UAS, which collectively saw service in the early 1990s in Iraq, Bosnia and Kosovo.¹⁷

The contemporary awareness of UASs largely began with the now notorious "drone strikes" as part of the war on terror in the early 2000s. Since the first use in 2001, drone strikes have simultaneously become both a commonplace occurrence in the nightly news and a lightning rod for the debate over the legal and moral implications of remote warfare.¹⁸ Today, militaries in 79 nations operate tactical UASs and at least 14 of those nations operate strategic UASs.¹⁹ As of July 2013, the US inventory alone contained over 11,000 UASs ranging in wingspan from the Marine Corps' 28 inch RQ-12 Wasp to the Air Force's 131 foot RQ-4 Global Hawk.²⁰ Of those 11,000 systems, over 9,700 of them are Group 1 tactical systems. Similarly, although recent US estimates of China's future UAS procurement predict acquisition of nearly 42,000 systems between 2014 and 2023, over 90% of those will likely be tactical systems.²¹ No matter how one approaches the issue, both strategically and tactically, UASs are taking on integral roles in support of air, land and sea operations for most of the world's militaries.

¹⁵ Newcome, *Unmanned Aviation*, 51, 68.

¹⁶ Newcome, *Unmanned Aviation*, 83.

¹⁷ Newcome, *Unmanned Aviation*, 93-97.

¹⁸ Kreuzer, "Remotely Piloted Aircraft", 68.; James DeShaw Rae, *Analyzing the Drone Debates: Targeted Killings, Remote Warfare, and Military Technology* (New York: Palgrave Macmillan, 2014), 2-7.

¹⁹ Kreuzer, "Remotely Piloted Aircraft", 327, 385-386.

²⁰ Department of Defense, *Integrated Roadmap*, 5.; Rae, *Drone Debates*, 11-12.

²¹ Kreuzer, "Remotely Piloted Aircraft", 328.; U.S. Department of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015* (Washington, DC: Office of the Secretary of Defense, 7 April 2015), 36.

Despite the contemporary narrative that civil unmanned aviation is a relatively new phenomenon, civil UASs entered the scene as their military counterparts expanded the development of radio-control systems in the early 1930s. These early forays into radio-controlled aircraft spawned the 1936 formation of the Academy of Model Aeronautics, a hobbyist organization still in existence today.²² Unlike the military side of UAS development, however, civil usage did not proliferate as quickly. As late as 1996, Israel's largest UAS manufacturer Malat unsuccessfully lobbied the US Forest Service to procure Malat's FireBird tactical UAS to aid in spotting forest fires. Although Malat successfully demonstrated the FireBird's utility in the field, the UAS did not provide enough of a cost-benefit over the existing manned systems to warrant its acquisition.²³

There were, however, isolated areas of more rapid civil UAS expansion. In 1990 Japanese farmers began to adopt the use of remote-controlled helicopters for crop-dusting as a way to overcome limitations caused by a small, highly dispersed farming industry located in mountainous regions.²⁴ Starting with a fleet of 106 helicopters in 1990, the industry expanded rapidly and sported a fleet of 1,420 registered helicopters by 2000.²⁵ Beyond a few such isolated cases, however, civil drone use expanded slowly. For example, although military UASs had participated in civil disaster response efforts for years, the first use of a civil UAS in a disaster scenario did not occur until the 2005 response to Hurricane Katrina where a small UAS provided aerial surveillance capabilities in search of stranded victims.²⁶

The real break in the stagnant civil UAS industry occurred in 2010 when Parrot, an early developer of small civil drones, released the Parrot AR.Drone, the first of what would become an expansive consumer UAS market. As the smartphone industry drove down the cost, size, and weight of electronics, accelerometers, gyroscopes, high definition cameras, and other sensors, the budding civil drone industry capitalized on

²² Dan Gettinger and Arthur Holland Michel, *Drone Sightings and Close Encounters: An Analysis* (Washington, DC: Center for the Study of the Drone at Bard College, 11 December 2015), 1.

²³ Newcome, *Unmanned Aviation*, 99.

²⁴ David Szondy, "UC Davis Investigates using helicopter drones for crop dusting," *gizmag*, 23 June 2013. <http://www.gizmag.com/uav-crop-dusting/27974/>.

²⁵ Association for Unmanned Vehicle Systems International, *The Economic Impact of Unmanned Aircraft Systems Integration in the United States* (Arlington, VA: Association for Unmanned Vehicle Systems International, March 2013), 21.

²⁶ Robin R. Murphy, *Disaster Robotics* (Cambridge, MA: MIT Press, 2014), 29.

those savings to create consumer-grade UASs with autonomous and semi-autonomous flight capabilities, UASs now known simply as drones.²⁷

Drone Capabilities

As Kreuzer alluded to with his “mythical ‘super RPA’,” the hype around drones continues to drive misunderstanding concerning what drones can and cannot actually accomplish in the air. Investigating how the proliferation of small civil drones might impact military operations requires a baseline understanding of these systems’ performance capabilities and their current technical limitations.

Physical Characteristics

While civil drones come in a wide variety of shapes and sizes, there are some general trends which can help guide the conversation. First, drones usually conform to one of two basic configurations: fixed-wing or rotorcraft. Fixed-wing drones resemble and fly like conventional aircraft whereas rotorcraft, also known as multicopters, consist of three or more vertically oriented propellers arranged around the body of the aircraft and fly in a manner similar to standard helicopters. At this point in time, the most common drone configuration is a four-bladed multicopter design, also known as a quadcopter. This configuration provides significant platform stability and permits both low-speed flight and high-precision maneuvering. While larger examples of civil drones such as the Yamaha RMax helicopter or the Urban Aeronautics AirMule can exhibit length and wingspan dimensions of several meters and weights over several hundred pounds, the vast majority of commercially available drones have wingspans of a few feet or less and fall under the 55-pound limit which defines the upper bounds of the small-drone category for both the US military and the FAA.²⁸ These sizes are mostly driven by cost-versus-utility decisions and could easily trend upwards in the future if civil users embrace drone applications that require heavier systems.

²⁷ Gettinger, *Drone Sightings*, 1.

²⁸ Szondy, “UC Davis.”; Michael Rundle, “AirMule ‘drone ambulance’ makes first untethered flight,” *wired.co.uk*, 12 January 2016, <http://www.wired.co.uk/news/archive/2016-01/12/air-mule-drone-ambulance>.; Department of Defense, *Integrated Roadmap*, 6.; The Remote Control Project and Open Briefing, *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets* (London, United Kingdom: The Remote Control Project and Open Briefing, January 2016), 4-5.

Performance

As with conventional aircraft, one typically assesses a drone's performance capabilities based on five standard parameters: speed, range, endurance, operating altitude, and payload capacity. When developing a new drone, a designer must carefully balance high performance in any of these parameters against increased weight and cost of the system. Together, these performance parameters will define which applications a specific drone platform can or cannot accomplish. For example, the 800-foot range and 12-minute endurance, or maximum flight time, of the popular Parrot Bebop drone significantly limits its utility in comparison with other drones which often double or triple those parameters. Most consumer grade multicopters can only fly for up to 30 minutes at speeds of 30 – 40 miles per hour and out to ranges up to 3,000 feet, all while carrying less than five pounds of payload. Commercial grade multicopters, on the other hand, often reach ranges out to several miles with flight times approaching or exceeding an hour and payloads in excess of 15 pounds.²⁹ In terms of operating altitudes, although the FAA restricts civil drone use to operations below 500 feet, many consumer and commercial grade systems are technically capable of reaching altitudes in excess of 10,000 feet.³⁰

Alternatively, fixed-wing drones trade slow speeds, hovering, and precision maneuver capabilities for increased range and endurance. In one notable instance in 2003, for example, a drone designer flew an 11-pound drone with a six-foot wingspan over 1,900 miles across the Atlantic Ocean from Newfoundland to Ireland in a record-breaking 38-hour flight.³¹ While most fixed-wing civil drones exhibit more modest performance parameters, it is important to understand the art of the possible when considering future implications. The disparity between fixed-wing and rotorcraft endurance figures is driven by the inherently inefficient use of rotors to generate both lift and forward momentum on rotorcraft and their reliance on batteries for power generation.

²⁹ Remote Control Project, *Hostile Drones*, 5.; Association for Unmanned Vehicle Systems International, *The First 1,000 Commercial UAS Exemptions* (Arlington, VA: Association for Unmanned Vehicle Systems International, 2015), 6.

³⁰ Association for Unmanned Vehicle Systems International, *First 1,000*, 6.

³¹ Frank Wicks, "Maynard Hill: Legend Pilots a Radio-Controlled Model Airplane across the Atlantic Ocean," *Progressive Engineer*, accessed 10 April 2016, <http://www.progressiveengineer.com/profiles/maynardHill.htm>.

Fixed-wing aircraft, on the other hand, can harness small internal combustion engines and highly efficient wing designs to achieve significantly longer flight durations.

Payload Types

As with any aircraft, the drone's payload converts an otherwise entertaining airplane into a functional piece of equipment. The key enabling payload for drones is the miniaturized camera that emerged from the smartphone industry. Compact high-definition cameras are so integral to drone operations that specifications lists rarely identify them as actual payloads. However, for many applications, such as aerial photography, a camera is not only a tool for controlling the drone, but often the entire reason for flying the drone in the first place. Available cameras range from little more than smartphone-style digital cameras integrated into the drone's fuselage, as in the Parrot Bebop Drone, to gimbal-mounted and inertially-stabilized cameras for Hollywood-quality filmography, as in the DJI Spreading Wings S1000.³²

Beyond integrated and externally mounted cameras, drones can carry almost any imaginable payload as long as it falls within their available carrying capacity. Depending on the drone, available payload weights for most commercial off-the-shelf (COTS) systems vary from zero excess capacity to approximately 15 pounds on the high end. Operators have used this capacity to expand payloads with capabilities such as infrared thermal-imaging cameras, cargo holds for goods delivery, crop-dusting sprayers, a wide variety of multi-spectral sensors, and even weapons.³³

Control and Functionality Programming

Along with the smartphone industry's advancement in electronics and sensor miniaturization came concurrent advancements in software applications, which similarly aided the budding drone industry. In 2010, operators of the original Parrot AR.Drone controlled the drone directly through applications installed on their smartphones.³⁴

³² Parrot, "Parrot Bebop Drone," accessed 10 April 2016, <http://www.parrot.com/products/bebop-drone/>; DJI Inc., "Spreading Wings S1000+," accessed 10 April 2016, <http://www.dji.com/product/spreading-wings-s1000-plus>.

³³ Remote Control Project, *Hostile Drones*, 5.; DJI Inc., "Agras MG-1," accessed 10 April 2016, <http://www.dji.com/product/mg-1>; Parrot, "Sequoia," accessed 10 April 2016, <http://www.parrot.com/usa/companies/sequoia/>; Ryan J. Wallace and Jon M. Loffi, "Examining Unmanned Aerial System Threats & Defenses: A Conceptual Analysis," *International Journal of Aviation, Aeronautics, and Aerospace* 2, no. 4 (October 2015), 11.

³⁴ "Parrot AR.Drone: Your reality becomes a video game," news release, Parrot, 15 June 2010, <http://www.parrotcorp.com/en/pressrelease/2010publications/parrotunveilsar.droneate3expo>.

Although some drones still rely solely on direct control via tablet or smartphone, today's COTS drones often augment those devices with advanced-control and antenna suites or utilize dedicated control systems. These systems now provide payload controls and data-recording features in addition to relatively advanced functionality such as automatic-flight control modes, GPS-waypoint following, and options that allow the drones to autonomously return home in case of a lost control signal.³⁵ Some drones also incorporate dual-control schemes where one operator flies the drone while another controls the payload through a separate dedicated controller.³⁶ Emerging capabilities just hitting the market include capabilities for beyond line-of-sight operations, sense-and-avoid technologies that enable drones to detect obstacles and automatically reroute their flight to avoid them, and swarming technologies that allow multiple drones to operate in close proximity to one another in cooperative execution of a mission.³⁷ This combination of control and functionality results in drone systems which are extremely easy to operate right out of the box with little to no training, and systems which are constantly evolving as developers push software-based capability upgrades.

Procurement and Operating Costs

The costs to acquire, learn to operate, fly, and maintain an aircraft are not generally considered performance parameters; however, those combined costs generally represent the most significant barrier to entry into the air domain. Individuals, small companies, and even modest-sized municipalities simply can't afford a manned aircraft, much less a fleet of them. For example, although one can find a used Cessna 172, lauded as the "undisputed king of light aircraft," for less than \$35,000, that price does not account for fuel, maintenance, training, airfield access, and other operating costs.³⁸

One of the most important aspects of civil drones is that they drop this initial price point by up to two orders of magnitude and require very little in the way of operating

³⁵ DJI Inc., "Phantom 3 Professional," accessed 10 April 2016, <http://www.dji.com/product/phantom-3-pro>.

³⁶ DJI Inc., "Inspire 1," accessed 10 April 2016, <http://www.dji.com/product/inspire-1>.

³⁷ DJI Inc., "Phantom 4," accessed 10 April 2016, <http://www.dji.com/product/phantom-4>.; Tracy Staedter, "100 Drones Swarm in Formation, Set World Record," *Dscovrd*, 14 January 2016, <http://www.discovery.com/dscovrd/tech/100-drones-swarm-in-formation-set-world-record/>.

³⁸ Robert Goyer, "Cessna 172: Still Relevant," *Flying*, 19 January 2012, <http://www.flyingmag.com/aircraft/pistons/cessna-172-still-relevant>.; Controller, "Cessna 172 For Sale," accessed 10 April 2016, <http://www.controller.com/listings/aircraft/for-sale/list/category/6/piston-single-aircraft?Manu=CESSNA&MDLGrp=172>.

expenses. The world's leading line of COTS multicopters, manufactured by China's DJI Inc., present price points of \$500 for the third-generation Phantom 3 and \$1,400 for the newly released Phantom 4, both of which provide all of the necessary capabilities for 25 minutes of dynamic aerial photography.³⁹ Upgrading to commercial-grade systems increases the cost to prices ranging from \$4,500 for DJI's Spreading Wings S100 to upwards of \$42,000 for more robust systems such as MircoDrone's MD4-100, again with minimal additional operating costs.⁴⁰

The important point here is not to equate a drone's capabilities to that of a conventional aircraft, but to highlight the never-before-available options provided by these accessible price points. A DJI Phantom 4 cannot compete with even an outdated \$35,000 Cessna 172 in parameters such as speed, range, or endurance, but at \$500 it opens a world of limited-capability applications within the air domain to the average citizen.

Availability

The civil drone industry has expanded significantly since Parrot kick-started the market in 2010. Ranging from typical leaders such as the US and China to smaller countries like Latvia and Slovenia, at least 18 different nations now boast civil drone manufacturers. Within the US alone, companies in 22 states have entered the burgeoning civil drone market.⁴¹ Drones are now available from most electronics retailers or directly from the manufacturer. Furthermore, the open-architecture and plug-and-play designs for many drone systems allow users an almost endless ability to customize their drones with aftermarket components.⁴² Taking this to an extreme, public forums such as DIY Drones provide collaborative environments where private citizens design, build, and learn skills necessary to modify complex drone components such as autopilot systems.⁴³ Combining these capabilities with emerging private manufacturing trends such as 3D printing now allows individuals to fully customize their drones on short notice in order to meet their

³⁹ DJI Inc., "Phantom 3 Professional."; DJI Inc., "Phantom 4."

⁴⁰ DJI Inc., "Spreading Wings S1000+."; Remote Control Project, *Hostile Drones*, 5.

⁴¹ Association for Unmanned Vehicle Systems International, *First 1,000*, 10.

⁴² Larry Friese, N.R. Jenzen-Jones and Michael Smallwood, *Emerging Unmanned Threats: The use of commercially-available UAVs by armed non-state actors*, special report (Perth, Australia: Armament Research Services (ARES), February 2016), 21.

⁴³ Chris Anderson, "A newbie's guide to UAVs," *DIYDrones* (blog), 28 March 2009, <http://diydrones.com/profiles/blogs/a-newbies-guide-to-uavs>.

specific requirements.⁴⁴ Whether prospective drone operators aspire to design and build their own platform or simply purchase one from an electronics retailer, drones are readily available.

Limitations

To avoid abetting the perpetuation of Kreuzer's concept of the "mythical 'super [drone]'," it is important to understand the current limitations of drone technologies. First and foremost, they simply cannot compete with conventional airplanes or helicopters in terms of basic capabilities such as range, endurance, and payloads. With the state-of-the-art in civil drones limited to less than 30 minutes of flight time, less than 15-pound payloads, and less than a mile of operating range, their capabilities are severely limited in comparison to conventional aircraft. Key issues include size-drive constraints such as onboard battery capacity which continues to plague multirotor systems and drives their limited endurance.⁴⁵ Similarly, unlike military-grade systems, civil drones typically cannot operate in adverse weather conditions and those that do provide the necessary levels of flight control and weather hardening, such as MicroDrone's MD4-100, carry price tags on the order of \$42,000.⁴⁶

None of these limitations are insurmountable, however, and developers continue to work towards expanding all areas of drone-performance parameters. Under endurance alone, ongoing efforts include networks of ground- or building-based recharging stations, miniaturized hydrogen fuel cells, and even systems that recharge drones in flight via laser power transmission.⁴⁷ Whereas overhyping existing drone capabilities can easily overplay the significance of the emerging drone proliferation, fixating on their current limitations hinders one's ability to realistically project their future implications. This

⁴⁴ Jordan Golson, "A military-grade drone that can be printed anywhere," *Wired*, 26 September 2014, <http://www.wired.com/2014/09/military-grade-drone-can-printed-anywhere/>.

⁴⁵ Association for Unmanned Vehicle Systems International, *First 1,000*, 15.

⁴⁶ Remote Control Project, *Hostile Drones*, 5.

⁴⁷ Colin Jeffrey, "Nesting platform takes smart drone capabilities to new heights," *gizmag*, 17 February 2016, <http://www.gizmag.com/dronebox-remote-uav-nesting-platform/41850/>; Ben Popper, "Hydrogen fuel cells promise to keep drones flying for hours," *The Verge*, 15 December 2015, <http://www.theverge.com/2015/12/15/10220456/intelligent-energy-hydrogen-fuel-cell-drone>; Mark Brown, "Lockheed uses ground-based laser to recharge drone mid-flight," *Wired*, 12 July 2012, <http://www.wired.co.uk/news/archive/2012-07/12/lockheed-lasers>.

study attempts to maintain a reasonable balance between these two extremes while embarking on a decidedly speculative endeavor.

Conclusion

While it is important to recognize the relative limitations of commercial-off-the-shelf drone systems, it is equally important to recognize that currently available systems do provide a modest capability and that developers are continuously improving the state-of-the-art in drone technologies. Even a 25-minute flight time with only a camera payload provides the average citizen with unprecedented capabilities. Drones represent a relatively small and limited step into the air domain, but a potentially significant step as they open the benefits of the air domain to wider participation. The next chapter begins the study of civil drones and their effect on military operations in earnest by exploring how societies are harnessing drone capabilities in new and imaginative ways and how that will evolve in the future.



Chapter 3

Drones Outside of the Military

Long before it was technically feasible, the dream of flight permeated man's thoughts and dreams. Perpetually frustrated since at least the days of Leonardo da Vinci, reality continue to reinforce man's earthbound existence until the first manned hot air balloon ascended into the French sky on November 21, 1783. Unfortunately, this miraculous event resulted in a paradigm shift for only a small portion of society. Although a deep and widespread enthusiasm for flight erupted across Europe in 1783, only a select few of the moneyed and influential citizens succeeded in experiencing the new phenomenon.¹

History repeated itself on December 17, 1903 when Orville Wright took to the sky over Kitty Hawk, North Carolina, and achieved the world's first sustained and controlled flight of a manned aircraft. Aviation enthusiasts and entrepreneurs across the globe rejoiced as their efforts shifted from challenging the old paradigm of lighter-than-air flight to building upon the "new and improved" heavier-than-air approach.² Once again, however, the paradigm only shifted for a small subset of society. Yes, man could fly, but only after overcoming numerous obstacles such as relatively exorbitant costs, extensive training requirements, and cumbersome governmental regulations.

For the majority of the population, flight remained an unachievable dream outside of a passenger seat aboard a commercial airliner. As late as 2014, only 440,000 people within the United States, a mere one tenth of one percent of the US population, held active pilot's licenses, and the FAA expects that number to increase by only 8,000 through 2035. The number of commercial aircraft in the US inventory reached 6,676 in 2014, with an expected fleet of 8,131 by 2035.³ The proliferation of small UASs throughout society is shattering the barriers-to-entry which held those numbers so low for so long. Within the first month of requiring private citizens to register their drones for

¹ Walter J. Boyne, *The Influence of Air Power upon History*, (Gretna, LA: Pelican Publishing, 2003), 372.

² Boyne, *Influence of Air Power*, 31.

³ Federal Aviation Administration, *FAA Aerospace Forecast: Fiscal Years 2015 – 2035* (Washington, DC: Federal Aviation Administration, 2014), 63, 58.

recreational uses, the FAA received 300,000 submissions from these new aviators.⁴ Further, current estimates place the total civil drone fleet within the US alone at nearly two million aircraft.⁵ Across the globe, all sectors of civil society are embracing their newfound access to the air domain. Understanding the current status of drones in civil society and the likely trajectory of the drone revolution is now critical to understanding the global air domain and, by extension, any future military operating environment.

Drones in Current Society

Estimates vary, but industry experts routinely note that midsize military and commercial UASs, once the luxury of a select few, now operate within at least 87 countries.⁶ Producing a similar estimate for the proliferation of small UASs presents a significantly larger challenge. China's DJI Inc., the world's leading manufacturer of small drones for civil use, currently ships their products directly to 44 countries with the notable exceptions of Africa and the regions of the Middle East and South Asia; however, a simple internet search reveals examples of DJI equipment operating throughout those areas as well.⁷ At this point, given the expansive e-commerce market and other retail outlets, one can safely assume that small civil drones operate in nearly every country in the world. However, unlike the case of military UASs, gauging the proliferation of civil drones in the same binary approach and viewing the world horizontally with each country represented as a unitary actor presents little insight into their actual proliferation. Instead, a vertical view of the world, which categorizes the use of drones across the various sectors of society, provides a better opportunity to understand both the breadth and depth of drone proliferation throughout modern society.

Categorizing Drone Applications

When assessing the components of a society, various disciplines favor different frameworks when disaggregating the whole into complementary sectors. For the purpose of analyzing drone uses, consider a framework of three primary sectors: public,

⁴ "Nearly 300,000 recreational drone owners in U.S. database – FAA," *Reuters*, 22 January 2016, <http://www.reuters.com/article/us-usa-drones-registration-idUSKCN0V02FI>.

⁵ Grant Begley (Strategic planning committee permanent member, Association for Unmanned Vehicle Systems International), e-mail message to author, 17 January, 2016.

⁶ Kelley Saylor, *A World of Proliferated Drones: A Technology Primer* (Washington, DC: Center for New American Security, 2015), 17.

⁷ DJI Inc, "Shipping & Delivery," accessed 26 January 2016, <https://store.dji.com/help/shipping/faq>.

commercial and private. Public-sector applications encompass those that support the broad public good through official efforts, be they federal, state, local, or non-governmental organizations. These types of applications include sub-categories such as public administration, environmental management, infrastructure management, public safety, and utilities. Applications grouped into the commercial sector represent those drones used in support of corporations or individuals engaged in profitmaking endeavors such as agriculture, entertainment, or the sale and distribution of goods. Private applications, on the other hand, represent those applications solely used by individuals for non-profit purposes such as recreation.

Although these three broad categories adequately cover the breadth of current and projected civil drone applications, assessing the threat inherent within a civil drone paradigm requires the further delineation of a criminal sector. Criminal sector applications which utilize drones for nefarious purposes represent a subcategory within each of the public, commercial, and private categories. This crosscutting category covers uses such as smuggling, illicit surveillance and physical attacks using drones. Through this framework of four broad application categories, one can begin to assess the current and future proliferation of drones within civil society.

Civil Drones in Operations Today

The miniaturization of electronics, sensors, and components over the last decade brought drones out of the pages of science-fiction novels and into skies across the globe. Individuals, groups and governments alike now actively employ drones on a daily, albeit limited, basis. The applications currently used in operations today form the starting point for projecting the future civil-drone environment that military operations will encounter.

Public-Sector Applications. Although the military sector pioneered the contemporary push for unmanned flight, it, by no means, represents the only aspect of the public sector embracing this drone revolution. Within the US alone, the FAA has already granted UAS Certificates of Waiver or Authorization (COA) to organizations across all aspects of the public sector including county sheriff departments, state forestry departments, federal agencies, universities, and numerous others in between.⁸ Under the

⁸ Federal Aviation Administration, “Freedom of Information Act Responses,” accessed 26 January 2016, https://www.faa.gov/uas/public_operations/foia_responses/.

FAA's current restrictions on commercial and public drone operations, the COA process represents the only means of legally operating a non-hobbyist drone within the US. By 2013, at least 24 local and state-level law enforcement agencies across the US had filed for FAA drone licenses, and others were actively enlisting the larger platforms within the U.S. Customs and Border Protection's UAS fleet for support in local missions.⁹ Even this top-level survey illustrates how organizations across the public sector are embracing their newfound access to the air domain.

Considering the fundamental responsibility of governments at all levels to protect their citizens and provide them with basic services, it is not surprising that the most rapid growth in public drone use falls into the realm of public safety. As previously mentioned, disaster-response operations provided one of the earliest uses of civil drones under the guise of public safety. In the aftermath of Hurricane Katrina in 2005, a Florida State Emergency Response Team employed a small drone for the first time to search for stranded victims in support of disaster-relief operations and actually deployed their system before any federal UASs reached the area. Since then, civil authorities have used drones to respond to disasters in at least nine countries, notably beginning the use of systems that were commercially available to average consumers in 2011.¹⁰

Since these early uses, drone use for public safety has expanded significantly. Drones now augment lifeguard operations with surveillance and airdropped life preservers in Brazil, and police departments across the US have embraced the flexible reconnaissance capabilities of small drones in their daily operations.¹¹ Some of the most impactful public safety uses, however, fall outside of the typical urban environment. In remote countries such as Haiti, Bhutan, Dominican Republic and Papua New Guinea, small drones are enabling civil authorities to bypass degraded road networks and provide medical diagnostics and care to otherwise isolated populations.¹² In 2014, Doctors Without Borders enlisted Matternet Inc., a California-based small-drone company, in an

⁹ "Law Enforcement Agencies Using Drones List, Map," *Governing*, 2013, <http://www.governing.com/gov-data/safety-justice/drones-state-local-law-enforcement-agencies-license-list.html>.

¹⁰ Robin R. Murphy, *Disaster Robotics* (Cambridge, MA: MIT Press, 2014), 29, 36, 52.

¹¹ "Rio lifeguards now using drones with life preservers to prevent drowning," *Fox News Latino*, 30 December 2015, <http://latino.foxnews.com/latino/lifestyle/2015/12/30/brazilian-lifeguards-operate-drones-for-quicker-safer-rescues/>.

¹² Clay Dillow, "Meet Matternet, the drone delivery startup that's actually delivering," *Fortune*, 1 May 2015, <http://fortune.com/2015/05/01/matternet-drone-delivery/>.

effort to combat a rising tuberculosis (TB) epidemic in Papua New Guinea. In what one doctor described as “the biggest swamp in the world,” where 87% of the population lives in rural settings often days away from medical care, Papua New Guinea loses one person to TB every two hours. Matternet drones demonstrated the ability to rapidly transport diagnostic tests from remote locations to centralized medical facilities and then returned carrying medicine and other critical supplies.¹³ Although only one specific account, scenarios like that in Papua New Guinea are routinely playing out around the world.

Beyond the critical, but limited, subcategory of safety, public officials have begun using drones in numerous other areas as well. Operational examples in the environmental-management field include wildfire management support in Colorado, counter-poaching operations in South Africa, and even volcano monitoring in the South Pacific.¹⁴ In the public-services and utilities realm, universities around the globe have used drones as teaching aids and research platforms for over twenty years. Embracing their utility for the “dull, dirty, and dangerous” jobs, local governments are even using drones in tasks as mundane as inspecting local bridges and conducting aerial surveys for planning and land management.¹⁵ Table A.1 in Appendix A provide a broader, but necessarily incomplete, sample of current operational drone applications within the public sector. Relatively early adopters of drones, public sector organizations now routinely employ small-drone capabilities across a wide variety of applications, a list that continues to grow on a daily basis.

Commercial-Sector Applications. While the public sector embraced the use of small drones earlier, the commercial sector now more aggressively pursues the innovation small drones represent. After initially banning the use of drones for commercial operations within the US, the FAA began accepting exemption requests in

¹³ Scott Mitchell, “Drones are Being Tested in the Fight Against a Tuberculosis Epidemic in Papua New Guinea,” *Vice News*, 3 December 2014, <https://news.vice.com/article/drones-are-being-tested-in-the-fight-against-a-tuberculosis-epidemic-in-papua-new-guinea>.

¹⁴ “Drones and Volcanoes,” *Drones for Good*, 16 July 2014, <https://www.dronesforgood.ae/media/drones-and-volcanoes>.; “Cranes and Drones: Strange Airfellows,” United States Geological Survey, accessed 26 January 2016, <https://www.fort.usgs.gov/science-feature/127>.; Kim Helfrich, “South Africa’s UAVs – Crime Fighters and Job Creators,” *defenceWeb*, 9 September 2015, http://www.defenceweb.co.za/index.php?option=com_content&task=view&id=40639&catid=35&Itemid=107.

¹⁵ Federal Aviation Administration, “Authorizations Granted Via Section 333 Exemptions,” accessed 26 January 2016, https://www.faa.gov/uas/legislative_programs/section_333/333_authorizations.; Marc Goodman, *Future Crimes* (New York, NY: Doubleday, 2015), 292.

May 2014 and approved the first set of authorized commercial operations in September 2014.¹⁶ In an effort to gain insight into the first data available on US commercial drone usage, the Association for Unmanned Vehicle Systems International (AUVSI) conducted a detailed analysis on the first 1,000 approved exemption requests. Although the FAA required applicants to possess an FAA-approved pilot's license before applying to operate a civil UAS and still restricted approved operations to limited areas and simple flight profiles, the first thousand exception approvals spanned 25 major industries across 49 states. The five most common approved applications were in aerial photography, real estate, aerial survey, aerial inspection, and agriculture.¹⁷ By mid-January 2016, the FAA had granted over 3,100 exemption requests for commercial drone operations.¹⁸ Despite a slow start, commercial drone operations are alive, well, and growing within the US.

Compared with the lackluster growth within the US, the global story presents a much brighter image of the current state of commercial-drone operations. In early 2015, industry experts predicted that the then-700,000-strong global commercial-drone fleet would surpass the one million aircraft mark by the end of 2015.¹⁹ This seemingly massive force includes examples such as Japan's 2,600 aircraft fleet of crop-dusting drones. Part of a broader application known as *precision agriculture*, Japan's agricultural industry introduced the use of 106 remotely controlled helicopters for crop dusting in 1990 and subsequently expanded to a fleet of over 2,600 aircraft which now accounts for over 90% of Japan's crop dusting activity.²⁰ Fledgling drone-delivery services have similarly benefited from more amenable regulatory environments abroad. Shipping giant DHL began the world's first operational drone-delivery service in 2014 by establishing limited, but regular, drone flights to the remote German island of Juist, and Switzerland

¹⁶ Association for Unmanned Vehicle Systems International, *The First 1,000 Commercial UAS Exemptions* (Arlington, VA: Association for Unmanned Vehicle Systems International, 2015), 2.

¹⁷ Association for Unmanned Vehicle Systems International, *First 1,000*, 2.

¹⁸ Federal Aviation Administration, "Authorizations Granted Via Section 333 Exemptions," accessed 26 January 2016, https://www.faa.gov/uas/legislative_programs/section_333/333_authorizations/.

¹⁹ Bill Canis, *Unmanned Aircraft Systems (UAS): Commercial Outlook for a New Industry*, CRS Report R44192 (Washington, DC: Congressional Research Service, 9 September 2015), 6.

²⁰ Association for Unmanned Vehicle Systems International, *The Economic Impact of Unmanned Aircraft Systems Integration in the United States* (Arlington, VA: Association for Unmanned Vehicle Systems International, March 2013), 21.; Charles Spence, "Other nations ahead of U.S. in use of drones," *General Aviation News*, 16 January 2014, <http://generalaviationnews.com/2014/01/16/other-nations-ahead-of-u-s-in-use-of-drones/>.

teamed with Matternet to demonstrate postal service via drone delivery to remote locations in 2015.²¹ Including broader uses such as filming sporting events at the 2014 Winter Olympics in Sochi, Russia, and as “flying waiters” at restaurants in the UK, Table A.2 in Appendix A provides an expanded sample of current operational commercial-drone applications.²² With an estimated fleet size over one million aircraft and operational applications ranging from sushi deliveries to Olympic sportscasting, drones are now an integral and growing part of global commercial-sector operations.

Private-Sector Applications. When compared with the public and commercial sectors, the list of currently operational drone applications within the private sector, summarized in Table A.3 in Appendix A, appears somewhat repetitive. Manufacturers have paid relatively little attention to identifying and promoting specific applications for personal use, preferring instead to push as much capability as possible into those drones and leave the applications to the imagination of the personal user. Whereas organizations within the public and commercial sectors have had access to the air domain for some time and therefore have an initial framework of applications to work from, until the advent of drones, the average citizen’s access was limited to passively riding on commercial airliners or flying relatively cumbersome remote-control aircraft. The array of capabilities at their disposal now rivals those available to the commercial sector. It is simply a matter of when, where, and how individuals choose to employ those capabilities.

First, and foremost, one cannot discount the entertainment aspect of personal-drone use. People enjoy flying them and seeing what they can accomplish. In addition to established model-aircraft organizations, many college campuses now feature drone clubs dedicated to promoting the utility and enjoyment of drone use.²³ Some individuals

²¹ “On demand delivery could mark new future for retail,” *Drones for Good*, 14 June 2015, <https://www.dronesforgood.ae/media/demand-delivery-could-mark-new-future-retail>.; John Biggs, “Matternet to Test the First Real Drone Delivery System in Switzerland,” *Tech Crunch*, 23 April 2015, <http://techcrunch.com/2015/04/23/matternet-to-test-the-first-real-drone-delivery-system-in-switzerland/#.fqwot9cXptS>.

²² Angela Charlton, “Sochi drone shooting Olympic TV, not terrorists,” *AP*, 10 February 2014, <http://wintergames.ap.org/lebanonenterprise/article/sochi-drone-shooting-olympic-tv-not-terrorists>.; Jonathan Fincher, “Yo Sushi’s “flying waiter” serves your meal via quadcopter,” *Gizmag.com*, 13 June 2013, <http://www.gizmag.com/yo-sushi-itray-quadcopter/27910/>.

²³ Jessica Hill, “Ohio University students start the first drone club on campus,” *The Post*, 26 January 2016, http://www.thepostathens.com/culture/ohio-university-students-start-the-first-drone-club-on-campus/article_ca0a712a-c470-11e5-84ed-4fe5f9318024.html.

choose to express this newfound three-dimensional freedom through culturally significant mediums such as painting with drones, and others successfully use them for tasks as mundane as catching fish.²⁴ The list of potential personal applications need not make sense or seem useful to anyone other than the individual using it at the time. On the other hand, some uses do appeal to larger audiences. First-person-view (FPV) drone racing, for example, materialized seemingly overnight in 2015 and now draws significant interest across the globe from the fairground-based Drone Nationals in Sacramento, California to the million-dollar prize World Drone Prix in Dubai, United Arab Emirates.²⁵

For more practical uses, almost any application available to the public sector is a viable private application on a smaller scale. As homemaking mogul Martha Stewart immediately recognized after flying her first drone, the infrastructure-inspection and project-planning applications in the public and commercial sectors directly translate into useful capabilities for any home or property owners looking to maintain or improve their assets.²⁶ Those more inclined to embrace security-oriented applications can use a drone's automatic waypoint-following features to regularly patrol their property. The increasingly common capability for drones to automatically follow a moving person allows individuals to film their latest snowboarding run down a mountain or follow their kids as they bike around the neighborhood.²⁷ Other users have demonstrated the ability to deliver small items to remote friends and family such as house keys to a relative locked out of their house.²⁸

²⁴ "The Art of Drone Painting," *Center for the Study of the Drone at Bard College*, <http://dronecenter.bard.edu/art-of-drone-painting/>; Avianne Tan, "Kansas Farmer Catches Fish Using Flying Drone," *abc News*, 3 September 2015, <http://abcnews.go.com/US/kansas-farmer-catches-fish-flying-drone/story?id=33509187>.

²⁵ Chad Kapper, "First-person-view drone racing: Five essential tips for beginning pilots," *PCWorld*, 27 October 2015, <http://www.pcworld.com/article/2997557/consumer-electronics/first-person-view-drone-racing-five-essential-tips-for-beginning-pilots.html>; Ben Guarino, "The Million-Dollar Dubai Drone Grand Prix Legitimizes Quadcopter Racing," *Inverse*, 14 December 2015, <https://www.inverse.com/article/9163-the-million-dollar-dubai-drone-grand-prix-legitimizes-quadcopter-racing>.

²⁶ Reed Tucker, "5 surprising uses for your highflying drone," *New York Post*, 19 August 2014, <http://nypost.com/2014/08/19/5-surprising-uses-for-your-high-flying-drone/>.

²⁷ Julie Bort, "Very soon, robotic drones will automatically follow you (or your kids) around," *Business Insider*, 13 July 2015, <http://www.businessinsider.com/drones-will-soon-automatically-follow-you-2015-7>.

²⁸ Rhiannon Williams, "Drone on your doorstep: UK start-up trials delivery service," *The Telegraph*, 5 November 2014, <http://www.telegraph.co.uk/technology/news/11210026/Drone-on-your-doorstep-UK-start-up-trials-delivery-service.html>.

Contrary to standard operating procedures within a governmental bureaucracy or a well-regulated commercial environment, individuals do not necessarily ask permission or discuss new ideas before employing their drones in new and imaginative ways. Playing off this newfound freedom, the personal-drone market has exploded since Parrot introduced the first commercially available system in 2010.²⁹ When the FAA introduced mandatory registration for recreational drones in December 2015, the industry expected worldwide holiday sales that year to reach upwards of one million systems.³⁰ Within the first month of open registration, the FAA processed over 300,000 applications.³¹ Regardless of the perceived utility, the combined fleet of personal drones in use around the globe presents a substantial addition to the increasingly congested air domain.

Criminal-Sector Applications. As with any innovation, the applications for civil drones are not limited to those that aid society as a whole. Criminals within all sectors of society can, just as easily, utilize civil drones for nefarious and malicious purposes. Although average citizens can, and do, inadvertently operate their aircraft in an illegal manner, the focus of this section is on the deliberate use of drones for criminal purposes. Similar to the use of drones in the private sector, most public and commercial applications also have analogs within the criminal sector. The goods-delivery application, for example, has already manifested itself in the smuggling of drugs into the US and contraband into US prisons.³² Hackers have demonstrated the ability to use a drone to provide an airborne communications relay by simulating a cellular tower and, in turn, using it to hack into mobile phones.³³ In Japan, the Yakuza crime syndicate has begun using drones so often that Japanese police departments have begun creating specific anti-drone units to counter the threat, particularly after one drone delivered a

²⁹ Dan Gettinger and Arthur Holland Michel, *Drone Sightings and Close Encounters: An Analysis* (Washington, DC: Center for the Study of the Drone at Bard College, 11 December 2015), 1.

³⁰ Michal Addady, "The number of drones expected to sell during the holidays is scaring the government," *Fortune*, 29 September 2015, <http://fortune.com/2015/09/29/drones-holiday-sales/>.

³¹ *Reuters*, "Nearly 300,000".

³² Nick Valencia and Michael Martinez, "Drone carrying drugs crashes south of U.S. border," *CNN*, 22 January 2015, <http://www.cnn.com/2015/01/22/world/drug-drone-crashes-us-mexico-border/>; "2 arrested in plot to fly contraband into prison with drone," *USA Today*, 24 August 2015, <http://www.usatoday.com/story/news/nation/2015/08/24/2-arrested-plot-fly-contraband-into-prison-drone/32306943/>.

³³ Marc Goodman, "Attack of the drones – The dangers of remote-controlled aircraft," *Janes Intelligence Review*, 16 December 2011, 2.

small, yet detectable, amount of radioactive material to the roof of the Prime Minister's office in 2015.³⁴ The next chapter will examine the threat, particularly the threat to military forces, inherent within the criminal sector in more detail, but, at this point, the mere existence of a set of operational applications within the criminal sector provides an important caveat to the otherwise beneficial list of civil drone uses.

Social Acceptance of Drones

The systems approach to technological innovation, introduced into the field by historian Thomas Hughes, holds that the introduction of a new technology into society produces mutual interactions between the two that simultaneously reshape both the technology and society itself.³⁵ This interaction is already playing out in several ways in the proliferation of drones throughout society. From a technology-shaping perspective, social concern over privacy issues and safety concerns have already influenced drone manufacturers to include geofencing technology in their systems that enables drones to automatically avoid publically established "no drone zones".³⁶ In the reverse, despite significant media attention to the perceived safety and privacy concerns associated with small drones, most nations have generally not created outright bans on their use; and the concerns of those that have are now left behind as the broader global society continues to embrace the technology.

Recent public polling presents a picture of broad public acceptance of, but also a decidedly ambivalent opinion of, the proliferation of civil drones. A 2014 survey conducted in Australia found that its respondents did not generally fear the risks inherent in wider civil-drone usage, but neither did they enthusiastically embrace its potential benefits. However, respondents did tend to view the innovation from a holistic

³⁴ David Kravets, "Man lands drone carrying radioactive sand on Japanese prime minister's office," *ars technical*, 25 April 2015, <http://arstechnica.com/tech-policy/2015/04/man-arrested-for-flying-drone-carrying-radioactive-sand-in-tokyo/>; Jake Adelstein, "A Yakuza War is Brewing in Japan – and the Police are Taking Sides," *vice news*, 22 September 2015, <https://news.vice.com/article/a-yakuza-war-is-brewing-in-japan-and-the-police-are-taking-sides>; Trevor Mogg, "Japanese police plan to battle drones with even bigger drones, equipped with nets," *digital trends*, 10 December 2015, <http://www.digitaltrends.com/cool-tech/japan-cracks-down-on-hobbyist-drones-with-new-laws/>.

³⁵ Thomas P. Hughes, "The Evolution of Large Technological Systems," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, ed. Wiebe E. Bijker, Thomas P. Hughes, and Trevor Pinch (Cambridge, MA: MIT Press, 2012), 45.

³⁶ "DJI Introduces New Geofencing System for its Drones," news release, DJI Inc., 18 November 2015, <http://www.dji.com/newsroom/news/dji-fly-safe-system>.

perspective, as they were more concerned about its broader potential to aid society as a whole than any potential personal impact such as an invasion of their privacy.³⁷ Similarly, an earlier survey within the US in 2012 found a public generally ignorant of the potential non-military uses for drones, but simultaneously largely supportive of uses within the public safety and commercial categories.³⁸ Finally, and perhaps most importantly, a British design company recently completed a project for the Arts Council of England to investigate the implications of dense civil drone environments on the future of urban life and found, to their surprise, an already well-established acceptance of drones in society. Throughout their process of demonstrating and filming various scenarios in public venues, the common reaction from bystanders was “oh look...there’s another drone.”³⁹ Not only have civil drones already invaded everyday life, they are already common enough in developed societies that the average citizen barely pays any attention to them anymore.

Following the Trajectory

The rapid development of small drones within the last five years and their limited proliferation throughout all sectors of society represents the beginning of what some industry experts refer to as the Global UAS Revolution.⁴⁰ Drone manufacturers and operators alike continue to innovate and challenge the current limits of technology and accepted applications as they chase highly dynamic projections of the potential profits associated with the drone industry. By no means unconstrained, this expansion faces significant technological, regulatory, and social barriers in the way of reaching its still undetermined potential. Developing a better understanding of both the potential impact and likelihood of this future environment provides a framework to assess its impact on military operations.

³⁷ Reece A. Clothier et al., “Risk Perception and the Public Acceptance of Drones,” *Risk Analysis* 35, no. 6 (June 2015): 12.

³⁸ Joe Eyerman et al., *Unmanned aircraft and the human element: Public perceptions and first responder concerns* (Research Triangle Park, NC: Institute for Homeland Security Solutions, June 2013), 3.

³⁹ Tekendra Parmar, “Imagining Our Drone-Filled Future Cities,” *Center for the Study of the Drone at Bard College*, 16 April 2015, <http://dronecenter.bard.edu/interview-anab-jain-superflux/>.

⁴⁰ Begley, email.

Diffusion of Civil Drones

The topic of diffusion may seem an academic afterthought with over two million civil UASs operating across all civil sectors within the US; however, the current number of civil drones represents only a starting point for the future trajectory of drone proliferation. Diffusion theory offers a first step towards understanding whether or not civil drones represent lasting capabilities or simply a passing fad. Further, the proliferation of civil drones will not only affect the relative advantages between commercial entities, but also reshape the broader security environment and the fundamental planning assumptions for military campaign planning. Understanding the drivers of proliferation is key to assessing the future operating environment.

Diffusion Theory. Innovation is the life-blood of Western society. Nations, militaries, and corporations alike endlessly strive for the next big innovation, the next great leap forward, which will secure their dominance in their respective field or allow them to unseat the dominant player. However, until employed, that innovation represents little more than potential. On the other hand, once one successfully employs an innovation on the world stage, it reaches what diffusion authors refer to as its “debut” or “demonstration” point.⁴¹ From that point forward, the process of diffusion takes over as competitors attempt to replicate, surpass, or otherwise undermine the effectiveness of the latest innovation. Everett Rogers, the father of diffusion theory, defined diffusion as “the process by which (1) an innovation (2) is communicated through certain channels (3) over time (4) among the members of a social system.”⁴² Through this framework, diffusion theory attempts to describe and predict how fast and how far a new military innovation, be it a new technology, concept, or otherwise, will spread among nations.

Although nominally based on the concept of inter-state and inter-military competition, particularly from a neorealist perspective, diffusion theory acknowledges numerous factors which motivate organizations to attempt to adopt another’s innovation.⁴³ Other factors which increase the likelihood of adoption include efforts to emulate an international leader, seeking a level of prestige associated with an innovation

⁴¹ Michael Horowitz, *The Diffusion of Military Power* (Princeton, NJ: Princeton University Press, 2010), 8.

⁴² Quoted in Horowitz, *Military Power*, 19.

⁴³ Emily O. Goldman and Leslie C. Eliason, ed., *The Diffusion of Military Technology and Ideas* (Stanford, CA: Stanford University Press, 2003), 8.

or, similarly, seeking a level of international legitimacy.⁴⁴ On the other hand, items such as cultural compatibility and an organization's limited resources may hinder efforts to adopt an innovation.⁴⁵ Ultimately, these factors merge with broader organizational, political and individual-level dynamics to form a highly contextual situation that leads to the key decision on whether or not to pursue an innovation.⁴⁶

The situationally dependent nature of the choice to pursue an innovation drives different nations to pursue or disregard it at different times and with different levels of commitment. When looking at the spread of an innovation from a global perspective, instead of from a particular nation's or organization's perspective, this phenomenon creates an S-Curve pattern: initially slow diffusion followed by a rapid rate of increase as the broader community recognizes the benefits gleaned by early adopters. The rate eventually slows again as "laggards" continue to hold out until forced to adopt the innovation as a prerequisite to participate or compete in the new international environment. Whether or not a nation adopts an innovation early or late in the cycle, diffusion theory focuses on the spread of the concept and a nation's decision to adopt it, not on the ultimate success or failure in integrating and employing the innovation, as that depends too highly on contextual factors.⁴⁷

Adoption capacity theory. Taking the above discussion as a fundamental baseline, Michael Horowitz focused further on numerous case studies throughout history in which the classical neorealist explanation of inter-nation and inter-military competition failed to predict the decisions of states in choosing to adopt or reject an emerging innovation. Instead, Horowitz develops a diagnostic framework consisting of the resource commitment (*financial intensity*) and level of organizational change (*organizational capital*) required to adopt an innovation and uses the relationship between the two to explain national-level decisions on adopting innovations. Under this model, high per-unit costs and low levels of commercial utility drive high levels of *financial intensity* and result in a slower rate and extent of diffusion.⁴⁸ Similarly,

⁴⁴ Horowitz, *Military Power*, 58.; Goldman, *Military Technology*, 379.; Emily O. Goldman, "Receptivity to Revolution: Carrier Air Power in Peace and War," in Goldman, *Military Technology*, 269.

⁴⁵ Goldman, *Military Technology*, 385.; Goldman, "Receptivity to Revolution," 269.

⁴⁶ Goldman, *Military Technology*, 402.

⁴⁷ Horowitz, *Military Power*, 19, 58.

⁴⁸ Horowitz, *Military Power*, 30-32, 209.

significant changes to the nontechnical aspects of employing an innovation, such as changes to doctrine, training, and force structure drive high levels of *organizational capital* and similarly hinder diffusion.⁴⁹ Innovations requiring significant resources and changes in the adopting organization, such as the development of an air service, will thus diffuse much slower than those requiring low levels on both counts, such as the integration of new small arms into an existing Army structure. Although Horowitz is quick to admit its limitations, the Adoption-capacity model provides significant insight into the financial and organizational constraints limiting a nation's or organization's ability to pursue an innovation.

Applying Diffusion Theory to Drones. Unmanned aircraft, as demonstrated by Michael Kreuzer as part of his doctoral research, provide an outstanding example for further exploring the implications and utility of the Adoption-capacity theory. In his analysis, Kreuzer separates the broad category of UASs into high-capability *strategic* systems and lower-capability *tactical* systems in order to predict how their relative financial intensity and organizational capacity will dictate their relative rates of diffusion.⁵⁰ Through this framework, Kreuzer demonstrates that diffusion rates for strategic UASs will remain low due to barriers imposed by their high per unit costs and significant organizational, manning, and training requirements. Cheap, low-end tactical systems, on the other hand, will diffuse more rapidly due to their low financial intensity and organizational capacity requirement. This observation plays out in his analysis of the current state of the industry where almost 80 governments now operationally employ tactical UASs and less than 15 employ strategic systems.⁵¹

Although nominally focused on the spread of military innovations, diffusion theory equally applies to commercial innovations as corporations strive to maintain a competitive edge. As professor John Arquilla notes, the topic of diffusion exists within standard business literature, but there authors tend to discuss diffusion under the guise of “growth” or “development.” Furthermore, the commercial sector is particularly susceptible to rapid diffusion after a successful demonstration, and innovations tend to

⁴⁹ Horowitz, *Military Power*, 32-34.

⁵⁰ Michael P. Kreuzer, “Remotely Piloted Aircraft: Evolution, Diffusion, and the Future of Air Warfare” (PhD diss., Princeton University, September 2014), 325.

⁵¹ Kreuzer, “Remotely Piloted Aircraft”, 27, 327.

spread through imitation of a successful competitor.⁵² Given that foundation, the application of diffusion theory to the field of civil drones can provide numerous insights.

The application of adoption-capacity theory and the broader field of diffusion theory illustrates many of the reasons why civil drones had not proliferated significantly prior to 2011 and, on the other hand, why they will continue to proliferate well into the future. Although the potential utility of remote-control systems had existed for decades, the barriers to effectively employing them for routine and commercial uses kept them from proliferating beyond a core-user group. These barriers, to include items such as limited systems capabilities per unit cost, training requirements, and reliability issues have largely disappeared within the last five years. Industry and society have recognized the potential of civil drones and made the decision to pursue those capabilities. The low financial intensity and organizational capital associated with civil drones should drive their rapid proliferation well into the future.

While Kreuzer asserted that tactical systems would diffuse faster due to their lower per-unit cost and need for training and organizational support, he significantly downplayed their impact on the battlefield. He argues that tactical systems largely replace previously existing capabilities such as traditional aircraft or helicopters and therefore provide a quantitative and purely evolutionary increase in capability, particularly in the case of major military powers. On the civil side of the issue though, the vast majority of users are not utilizing civil drones to replace or augment previously existing aerial capabilities, but will instead acquire new ways of entering and operating within and through the air domain with civil drones.⁵³ From that perspective, tactical or small drones possess the potential to provide a revolutionary, and therefore far greater, impact on modern society as opposed to an evolutionary impact on the battlefield.

Industry Forecasts

Identifying the current applications for civil drones answers only a portion of the diffusion question. It is not clear if industry can answer the mounting demand and provide the capabilities desired by the various civil sectors. Nor is their motivation to choose to pursue the drone revolution a foregone conclusion. Industry experts assessing

⁵² John Arquilla, "Patterns of Commercial Diffusion," in Goldman, *Military Technology*, 348-349.

⁵³ Kreuzer, "Remotely Piloted Aircraft", 17, 110.

the future potential for the drone industry typically focus on three basic areas: profits, timelines, and markets. Due to the relative youth of the civil-drone market and its highly dynamic nature caused by rapidly evolving technologies and applications, forecasts within all three of these areas of analysis vary wildly; however, they do provide enough insight for planners and strategists to formulate a reasonable planning baseline.

In 2013, the AUVSI assessed the proliferation of civil drones within the US and rocked the industry with its prediction of \$82.1 billion in potential economic impact and over 100,000 new jobs within the US between 2015 and 2025.⁵⁴ Other industry experts, such as IBISWorld, predict more modest growth amounts of \$4.3 billion and 10,000 new US jobs by 2020.⁵⁵ As a point of comparison, the entire global commercial aviation sector posted a net profit of \$19.6 billion in 2014 alone.⁵⁶ Whether or not any of these, or numerous other, industry predictions accurately depict the course of the drone industry, the 2013 AUVSI economic impact assessment remains one of the most commonly cited forecasts within commercial and civil drone literature and professional discussions. Drone manufacturers and potential operators alike are planning towards and chasing a piece of that \$82.1 billion pie.

Given the significant monetary incentive looming on the horizon, the question then becomes one of focus. Tracking the markets where developers are placing the majority of their effort aids in understanding which areas represent the most likely opportunities for near-term proliferation. Of all the potential civil-drone applications, the most discussed and most sought after remain the precision agriculture and e-commerce-goods-delivery markets. In AUVSI's 2013 forecast, the economic impact from the agriculture industry amounted to 92% of the projected \$82.1 billion revenue with the impact of public-sector applications placing a very distant second.⁵⁷ More recent forecasts estimate that US farmers could save up to \$1.3 billion annually through the use of drones while increasing crop yields.⁵⁸ Fully aware of this incentive to farmers, the

⁵⁴ Association for Unmanned Vehicle Systems International, *Economic Impact*, 2.

⁵⁵ Canis, *Commercial Outlook*, 6.

⁵⁶ Federal Aviation Administration, *Aerospace Forecast*, 9.

⁵⁷ Association for Unmanned Vehicle Systems International, *Economic Impact*, 20.

⁵⁸ Christopher Doering, "Drones could save farmers millions, study finds," *The Des Moines Register*, 21 July 2015, <http://www.desmoinesregister.com/story/money/agriculture/2015/07/21/drones-farm-savings-agriculture-millions/30486487/>

drone industry is actively pursuing ways of meeting this need. For example, DJI Inc, the world leader in small-drone production, recently introduced a drone specifically designed for crop dusting.⁵⁹ Although only a small number of US farmers currently use drones for precision agriculture applications, how fast this revolution will spread still depends on FAA regulations. AUVSI predicts that the impact in the first three years alone after the FAA produces comprehensive regulations will amount to \$13.6 billion across the entire drone industry.⁶⁰

Drone developers are also aggressively targeting the “last mile” of the e-commerce delivery chain. Nearly \$500 billion of the total \$800 billion expense of simply delivering e-commerce goods each year falls to pushing small goods weighing less than 2 kg through the “last mile.”⁶¹ Goods of this size fall well within the current capabilities of small civil drones, and developers are aggressively attempting to shave every possible percentage point off of that \$500-billion price tag. This does not mean, however, that one should discount the proliferation of smaller-scale operations. Approximately 84 percent of the FAA’s first 1,000 approved commercial exemption requests came from small businesses within the US.⁶² The push for smaller-scale operations is also alive and well.

Given the high level of motivation and low requirement for both financial intensity and organizational capital, the next question becomes one of rate of proliferation. Once again the predictions vary wildly. One forecast, from a 2014 interview with drone developer CyPhy Works Inc., outlined its expectations that industry growth would start in small scale entertainment and recording applications in 2014, move to public safety and inspection applications in 2015-2016, followed by broader management applications in 2017-2018 and then widespread delivery and transportation networks by 2019.⁶³ Other developers see similar trends, but the consensus generally falls to drones being a persistent and ubiquitous presence in global society within as little

⁵⁹ “DJI Introduces Company’s First Agriculture Drone,” news release, DJI Inc., 27 November 2015, <https://www.dji.com/newsroom/news/dji-introduces-company-s-first-agriculture-drone>

⁶⁰ Association for Unmanned Vehicle Systems International, *Economic Impact*, 2.

⁶¹ Taylor Soppe and Chad McClymonds, “Matternet Dreams Up Drug Delivery By Drone,” *Forbes.com*, accessed 16 January 2016. <http://www.forbes.com/video/4137007346001/>.

⁶² Association for Unmanned Vehicle Systems International, *First 1,000*, 2.

⁶³ Canis, *Commercial Outlook*, 6.

as three to five years.⁶⁴ If that timeline comes to fruition, it doesn't leave much room for the military to adjust to this emerging environment.

Limitations to Proliferation

Despite all of the momentum and incentives aiding in accelerating the proliferation of civil drones, several significant hurdles remain in place that continue to hamper their broader integration into society. From a technological perspective, civil drones will need consistent and reliable sense-and-avoid capabilities to augment their automatic waypoint-following functionality.⁶⁵ Without that ability, the risk to public safety caused by small drones running into people, cars, buildings, power lines, or even other drones will prevent public officials from allowing full drone integration into otherwise densely populated or trafficked areas. Along those same lines, the industry needs a new air traffic control (ATC) system geared toward managing large numbers of small drones, routing them through desired corridors and working to deconflict their flight paths.⁶⁶

Further, as discussed in the drone-technology overview, the limitations which still exist within the basic capabilities of each platform continue to limit their utility. However, future expansion of their endurance and payload envelopes will greatly enhance their ability to integrate into the fabric of society. Researchers and developers are aggressively working towards rectifying the biggest hurdles and have already demonstrated sense-and-avoid capabilities and simple drone ATC systems.⁶⁷ None of the major technological challenges appear insurmountable at this point in time, and planners should therefore not artificially limit their expectations for proliferation based on current technical constraints.

In May of 2014, at an AUVSI DoD Leadership Panel, US military leaders responsible for advancing unmanned systems within their respective services opined that public perception and public policy had replaced technology as the biggest barriers to

⁶⁴ Begley, e-mail.; Soppe, "Matternet Dreams Up."

⁶⁵ Canis, *Commercial Outlook*, 11.

⁶⁶ Mark Harris, "US testing an 'air traffic control system' for drones," *theguardian*, 26 November 2015. <http://www.theguardian.com/technology/2015/nov/26/drone-regulations-united-states-testing-air-traffic-control-system-precisionhawk>.

⁶⁷ Adam Conner-Simons, "Self-flying drone dips, darts and dives through trees at 30 mph," *CSAIL*, 26 October 2015, http://www.csail.mit.edu/drone_flies_through_forest_at_30_mph

their efforts.⁶⁸ That opinion is unique neither to those leaders nor to the military use of unmanned systems. AUVSI, for example, has consistently voiced concerns over the ongoing inability to solidify public policy concerning drone integration into the National Airspace System (NAS).⁶⁹ Although the FAA introduced the COA-exemption process in May 2014 and later streamlined the process in March 2015, the policies outlining the approval process still placed significant limitations on operating altitudes and locations.⁷⁰ In 2013, AUVSI estimated that the continued failure to integrate civil drones into the NAS due to poor FAA policy equated to nearly \$28 million per day and \$10 billion per year in lost economic impact.⁷¹ Between these levels of economic incentive and mounting Congressional pressure after the FAA missed its 2015 deadline to integrate civil drones into the NAS, the FAA is not likely to continue delaying the development of a substantive civil-drone policy for much longer.⁷²

Outside of the US, however, exists a significantly different regulatory picture, one which actually bears more weight on the discussion of civil drones in battlefield scenarios. Whereas the FAA began integrating civil drones within the NAS in 2014, the global integration began much earlier. Most European nations, for example, began approving plans to integrate drones within their respective airspace in 1994, with Canada following suit in 1996.⁷³ More recently, the European Union vowed to enhance the developer-friendly environment even further with an updated regulatory framework and drone-focused bilateral accords with numerous nations across the global market in early 2016.⁷⁴ The more amenable regulatory environments in these global markets enabled more rapid development, testing, and fielding cycles for new capabilities and applications. Both Amazon and Google, for example, have turned abroad to test their e-commerce delivery systems.⁷⁵ Even developing countries have begun to embrace the

⁶⁸ Grant Begley (keynote address, 24th International Council on Systems Engineering International Symposium, Las Vegas, NV, June 30 2014), <https://www.youtube.com/watch?v=u9FfpmrZXzg>.

⁶⁹ Association for Unmanned Vehicle Systems International, *Economic Impact*, 2.

⁷⁰ Association for Unmanned Vehicle Systems International, *First 1,000*, 13.

⁷¹ Association for Unmanned Vehicle Systems International, *Economic Impact*, 2.

⁷² Keith Laing, "Senate to question FAA chief after missed drone deadline," *The Hill*, 26 October 2015, <http://thehill.com/policy/transportation/258153-senate-committee-to-weigh-drone-expansion>.

⁷³ Begley, email.

⁷⁴ Andrew Rettman, "EU promises new dawn for drone makers," *euobserver*, 7 December 2015, <https://euobserver.com/economic/131418>

⁷⁵ Canis, *Commercial Outlook*, 13.

integration of civil drones, with Rwanda, for example, set to break ground in 2016 on their first “droneport” dedicated to enabling rapid delivery networks throughout the country.⁷⁶ The integration of civil drones into modern society is not an issue for US regulation alone, but a much broader international issue. Whether any one country decides to follow or not, the world at large is embracing the integration of civil drones into the very fabric of society.

As a subset of the public-policy debate within the US, public perception, particularly concerning safety and privacy concerns, remains one of the most noted barriers to integrating drones in society. Throughout 2014 and 2015, increases in encounters between manned aircraft and drones, in combination with a significant increase in media reporting of those incidents, drove drone safety to become a “highly visible and potentially concerning issue” within the public psyche.⁷⁷ In 2015, the Bard College Center for the Study of the Drone conducted a detailed review of all FAA-documented incidents between December 2013 and September 2015 and concluded that the majority of the incidents involving such encounters occurred within restricted zones around airports and at altitudes above 400 feet, all areas outside of approved civil-drone operating environments. The authors then concluded that relatively simple solutions ranging from concrete regulations and enforcement to better education for drone operators would alleviate the vast majority of these incidents.⁷⁸ While these types of concerns within society could work to reshape, or socially construct, the civil drone industry, a 2014 public-perception survey in Australia found that respondents were actually quite receptive to, and desirous of, more information on civil drones. The authors suggested that this presents a potential mechanism for industry to instead reshape society to civil drone innovation and alleviate the alleged public anti-drone sentiment.⁷⁹

Although barriers to the full integration of civil drones across the globe still exist, they are no longer insurmountable. The technologies are within reach, the global regulatory environment is becoming more drone-friendly every day, and the global

⁷⁶ Jacopo Prisco, “Star architect designs the world’s first ‘airport for drones’,” *CNN.com*, 5 October 2015, <http://www.cnn.com/2015/10/05/architecture/gallery/rwanda-droneport-foster-epfl/>

⁷⁷ Gettinger, *Drone Sightings*, 4.

⁷⁸ Gettinger, *Drone Sightings*, Executive Summary.

⁷⁹ Clothier, “Risk Perception,” 20.

public, barring an unforeseen catastrophic event, appears willing to engage in constructive dialog on the appropriate place for drones in society. Predicting which industry will advance the most rapidly or how much money it will generate remains a highly speculative endeavor. As the barriers to proliferation continue to fall, the implied potential for significant gains in the civil-drone market will drive equally significant efforts from both manufacturers and operators to increase the speed of civil-drone integration into society. The only really common ground amongst all of the various industry forecasts remains their recognition that the civil-drone industry is still in its infancy and that all indications point towards a lasting presence and continued growth for the foreseeable future.

Envisioning a Broader Integration into Society

Given a starting point and a trajectory, one can then attempt to extrapolate a trend into the future. Extrapolation, in any scenario, is a dubious exercise, much more so in cases like the highly dynamic field of civil drones. Failing to extrapolate, however, would present an equally dubious outlook in the face of clearly emerging trends. This section therefore attempts to split that difference.

Emerging Drone Applications

Depending on how one defines the term *emerging*, most civil-drone applications previously discussed could fall into that general category. With few exceptions, those applications represent uses employed on a very limited scale. They are real and operational, but by no means prolific. Thus, the first consideration in understanding the future expansion of civil-drone usage lies in the further diffusion of those applications already operationally in use throughout society. Further, it is important to distinguish between highly speculative applications and those which manufacturers and entrepreneurs are currently developing and testing, both of which appear in the tables in Appendix A. Although this discussion on emerging applications will necessarily include speculative applications, the remainder of this study pulls from only those currently in development and therefore most likely within any reasonable future projection.

Within the public sector, most of the ongoing drone development revolves around the subcategories of public safety and utilities. This includes the expansion of medical-delivery routes into formal networks to service remote populations as well as drones with

actual medical functionality. In 2014, for example, a graduate student in the Netherlands developed and demonstrated a flying defibrillator for deployment in urban areas to decrease the response time for cardiac emergencies.⁸⁰ On the other end of the emergency-management spectrum, Tactical Robotics Ltd. is currently testing a mid-size drone capable of transporting two victims as an aerial ambulance, a use particularly geared toward battlefield or disaster-response scenarios.⁸¹ Utilities, however, represent the area with the most potential due to the almost complete lack of current applications in that category. Projects currently under development include Matternet's postal-delivery system in Switzerland and Facebook's internet-service-provider project.⁸² One of the purely speculative examples which illustrates the vast potential for civil-drone applications lies in the concept of self-repairing cities where swarms of drones automatically assess and repair infrastructure damage.⁸³ Each of these emerging applications has the potential to significantly alter how the public sector accesses and views the air domain.

On the commercial side, the near-term focus resides in the expansion of precision agricultural and goods-delivery applications. Most of the agricultural applications, such as crop dusting and crop-health monitoring, already exist in limited forms with future efforts aimed at expanding the breadth of their usage and increasing the capacity and endurance of the platforms. Current applications geared towards delivering goods cover niche markets with small payloads and tightly controlled flight profiles. The expansion of each of those variables remains the major focus for much of the commercial sector, with long-term speculation including significantly larger payloads and the replacement of long-haul services with drones.⁸⁴ More so than the other sectors, growth of the

⁸⁰ TU Delft, "TU Delft's ambulance drone drastically increased chances of survival of cardiac arrest patients," TU Delft, 27 October 2014, <http://www.tudelft.nl/en/current/latest-news/article/detail/ambulance-drone-tu-delft-vergroot-overlevingskans-bij-hartstilstand-drastisch/>.

⁸¹ Michael Rundle, "AirMule 'drone ambulance' makes first untethered flight," *wired.co.uk*, 12 January 2016, <http://www.wired.co.uk/news/archive/2016-01/12/air-mule-drone-ambulance>.

⁸² Jonathan Vanian, "Behind the scenes with Facebook's new solar-powered Internet drone and laser technology," *Fortune*, 30 July 2015, <http://fortune.com/2015/07/30/facebooks-solar-power-drone-internet-earth/>.

⁸³ Linda Poon, "Drones Do the Dirty Work in a 'Self-Repairing City'," *The Atlantic – City Lab*, 20 October 2015, <http://www.citylab.com/tech/2015/10/in-a-self-repairing-city-drones-do-the-dirty-work-of-infrastructure-maintenance/411526/>.

⁸⁴ "Factsheet 1: Civil unmanned cargo aircraft," Platform Unmanned Cargo Aircraft, accessed 16 January 2016, <http://www.platformuca.org/factsheet-1-civil-unmanned-cargo-aircraft/>.

commercial sector depends on public policy and regulations; once those solidify, proliferation will likely skyrocket.

The private and criminal sectors present fewer defined examples of future applications currently in development, primarily due to the basic nature of the sectors. These sectors favor more opportunistic mindsets with individuals taking advantage of readily available capabilities. In that vein, the majority of discussion concerning emerging private-sector use revolves around closing the technological and price gaps between commercial-grade drones and consumer-grade drones. As those gaps close, drone use within the private and criminal sectors will more closely resemble those currently seen in the public and commercial sectors.

Social Dependence on Drones

Before departing an investigation of the relationship between civil drones and modern society to investigate the military perspective, one further topic requires some discussion. Whether one supports the concepts of technological determinism, social construction, or the systems model, the broader field of technological innovation inherently assumes the concept of perpetual progress. Societies may reshape innovations to their liking, decide not to incorporate them, but they cannot reverse their invention.⁸⁵ Presupposing for a moment that a threat to military operations will exist within an environment of persistent civil drone operations, the military forces at risk may choose to restrict the use of the air domain to their own operations and prohibit civil usage, for all intents and purposes, temporarily reversing the invention of civil drones within that society. Understanding the possibility and effects of prohibiting civil-drone operations within a society necessitates an understanding of that society's level of dependence on civil drones.

Radical Innovations. Thomas Hughes, a specialist in the history of technology, categorized innovations in two basic categories, conservative and radical, in accordance with their relationship to existing technological systems. Those that evolved within and enhanced or expanded upon existing systems were conservative, and those that resulted in entirely new capabilities and technological systems were radical.⁸⁶ The dual approach

⁸⁵ Jacques Ellul, *The Technological Society*, trans. John Wilkinson (New York: Alfred A. Knopf, 1964), 89.

⁸⁶ Hughes, "Technological Systems," 51.

to radical and conservative innovations provides a useful framework through which to assess the concept of social dependence on innovations. In terms of illustrating the development of a social dependency, radical innovations present the most straightforward mechanism and thus a logical point to start the discussion.

As any innovation emerges, society reshapes itself to create a new social norm, adjusted to and counting upon that new innovation. Under this new social norm, the existence of the new technology becomes “a precondition for the reproduction of the entire social order.”⁸⁷ In the case of radical innovations, these social adjustments represent revolutionary changes in response to completely new capabilities. The social and commercial reorientation around the deployment of the Global Position System (GPS) represents a prime example of social dependence on a radical innovation. The precision navigation and timing capabilities which GPS provides were unprecedented at the time of their unveiling. Since that time, GPS has developed significant technological momentum as society reshaped itself to the existence of offshoot technologies, including navigation systems in vehicles, in precision farm equipment, on transoceanic cargo ships, and even in the palms of hands. Interestingly, the GPS system, developed to support military operations, includes the capability for military personnel to deny positioning data to anyone other than US military forces; however, the military largely ignores and rarely employs this capability due to the likely collateral damage of disrupting the significant social dependence that evolved around the radical innovation of GPS. For radical innovations like GPS, society does not have a fallback system upon which to rely if those innovations suddenly disappear.

Only a few of the current and future applications for civil drones present scenarios similar to potentially radical innovations. Examples of applications that provide entirely new capabilities include the use of drones to provide internet access or deliver medical supplies and health diagnostic tools in remote situations. Less obviously radical examples include airborne intelligence, surveillance, and reconnaissance (ISR) capabilities for small-town police departments where, as opposed to larger precincts, they may not have previously had regular access to airborne platforms. Once fielded, these

⁸⁷ Merrit Roe Smith and Leo Marx, ed., *Does Technology Drive History?* (Cambridge, MA: MIT Press, 1994), xi.

innovations will reshape society to their presence without providing any alternative options, thus creating a direct social dependence on their continued existence.

Conservative Innovations. Whereas radical innovations provide revolutionary changes in capabilities, conservative innovations improve upon and present an alternative to an existing technology, potentially supplanting it as they mature. The mechanism for the development of social dependence on conservative innovations is less evident, but no less disruptive. As opposed to radical innovations, society possesses alternative options to conservative innovations, but reverting to those previous options may be as equally disruptive as losing access to a radical innovation.

Consider, as an example, the emergency management communication system. A 2011 paper from the Federal Emergency Management Agency (FEMA) identified a significant risk to future emergency medical services (EMS) nation-wide due to their dependence on cellular phone networks for communication and coordination of responses and on electronic medical records in providing patient care. Should those services disappear due to a power outage, overcrowding of the cellular networks, or even a cyberattack, that situation would severely degrade the ability of emergency-response personnel to handle emergent, even routine, medical situations.

The cases of cellular communication networks and electronic patient records both represented conservative innovations at their deployment. They enhanced an existing technological system and therefore imply the existence of alternative fallback options should they fail. As each of those technologies evolved, however, they led in turn to the development of organizations, processes, and entire industries around their existence and simultaneously supplanted those required for non-cellular communications and paper records management. Hughes refers to this phenomenon as the development of technological momentum.⁸⁸ If a conservative innovation is mature enough, the technological momentum it generates serves as a significant barrier to reverting to a previous technology. Voluntary regression, though possible, would require society to recapitalize and effectively re-innovate the hardware and intellectual necessities for that previous paradigm, all of which would require time, money, and human capital.

⁸⁸ Hughes, "Technological Systems," 70.

The majority of current and in-development applications for civil drones fall within the conservative innovation category as they provide significant, but evolutionary, increases in capabilities to existing systems. E-commerce delivery drones, for example, may eventually supplant the majority of “last mile” delivery operations due to their potential reduction in delivery time and cost. Reverting to the current truck-based system after fully embracing drone delivery, however, would require recapitalization of the terrestrial-delivery vehicles, personnel, distribution, and management processes in place today. As a less extreme example, the defibrillator-drone concept intends to augment existing ambulance-based EMS capabilities instead of supplanting them entirely, but will similarly develop its own technological momentum, which will resist regression to its previous paradigm. In this case, the processes and human capital may remain in place, but those processes may adjust to lower response-time standards due to their reliance on the drone network. Regression to the non-drone-enabled system, though possible, would require time and resources and likely result in the loss of lives along the way.

Conclusion

With over two million small drones in operation today and global projections of billions of dollars in future economic impact, civil drones are here and are likely here to stay. The relatively unique combination of simultaneously low financial intensity and organizational capital requirements for adopting civil drones presents a clear example of the more prolific cases according to diffusion theory. Although significant barriers to the full integration of drones into society still exist, they are almost universally primed to fall. When that occurs, the rapid proliferation of, and reliance upon, drone applications will fundamentally alter the global military operating environment. The next chapter focuses on assessing those implications.

Chapter 4

Civil Drones on the Battlefield

On April 15, 1953, Private First Class Herbert Tucker and Corporal William Walsh lost their lives in a communist air raid on a clandestine island outpost off of North Korea. As unfortunate as their deaths were, that incident has become an often-cited point of pride within the US Air Force as it marks the last time that members of a US ground force lost their lives to an enemy air attack.¹ For sixty-three years and counting, that incident has come to represent the assumption of a near-guarantee of US air supremacy throughout the full range of military operations. Recently, however, key leaders within the US military have begun to view the last sixty years as a cautionary tale, warning against the overreliance on nearly instantaneous air supremacy, particularly in the face of mounting anti-access and area-denial (A2/AD) threats around the globe.² This interpretation of the post-Korea War era has become the rallying-cry for increased funding for air superiority and counter-A2/AD capabilities. However, an alternative interpretation of the events of April 15, 1953 raises a nearly opposite, but equally alarming, set of concerns.

One associates an aerial attack on ground forces with a contested air domain, a front-line struggle between near-peer adversaries to gain air superiority, but that was not the case in Korea on April 15, 1953. By that time, the Air Force and Navy, armed with the world's most advanced fighters, ensured general air superiority throughout Korean airspace. The attack on April 15 came, not from an advanced near-peer aircraft, but from a canvas-covered biplane operating under the cover of darkness in a series of nighttime attacks known as "Bed Check Charlie" raids. Despite overall US air superiority, these aircraft operated with near impunity through June 1953 before the Air Force and Navy were able to neutralize the tactic.³ The proliferation of small drones presents a similar scenario where, despite possessing overall air superiority and enjoying an asymmetric advantage in aircraft capabilities, US forces will remain vulnerable to attack through the

¹ Peter Grier, "April 15, 1953," *Air Force Magazine* 94, no. 6 (2011), 55.

² "An Interview with Gen Mark A. Welsh III: Twentieth USAF Chief of Staff," *Strategic Studies Quarterly* 6, no. 4 (2012), 8.

³ Grier, "April 15, 1953," 55-57.

air due to a unique combination of expanding threat capabilities and a changing operational environment.

Over the next three to five years, the emergence of a ubiquitous civil-drone presence across a wide variety of applications and throughout all sectors of society will begin to positively influence many aspects of society, but it also brings a threat. The threat of nefarious actors using drone systems for illicit purposes is not new, but it has increased rapidly with the growth of the consumer drone market. Militaries and civil organizations around the globe now recognize these emerging threats and are devising ways to counter them, but these countermeasures consider the drone threat in isolation, outside of a prolific civil-drone environment. Considering the proliferation of civil and illicit drones in unison presents an entirely different threat picture, one with a potentially negative impact to the security of US and allied ground forces across the full range of military operations.

Drone Threats to Ground Forces

The idea of employing small, commercially available unmanned aircraft to attack military or civilian targets has existed within the public consciousness for over two decades. In 1994, as part of a broader counter-proliferation discussion, then-Senator Sam Nunn presented a fictitious, but plausible, terrorist scenario concerning the use of remote-controlled aircraft, loaded with weaponized anthrax, to attack the President's annual State of the Union address at the US Capitol.⁴ The next year, in 1995, the Japanese terrorist group Aum Shinrikyo experimented with using remote-controlled helicopters to deliver sarin nerve gas bombs against the Tokyo subway, but ultimately decided against their use due to difficulties in controlling and coordinating the attack.⁵ It is unknown how the drones may have changed the outcome, but even without them, Aum Shinrikyo was able to kill thirteen people and injure over 6,000 others.⁶ Over twenty years later, there are still no documented cases of individuals successfully using drones to conduct a terrorist attack, but the capabilities to accomplish these missions are now readily available, and non-state

⁴ Marc Goodman, "Attack of the drones – The dangers of remote-controlled aircraft," *Janes Intelligence Review*, 16 December 2011, 5.

⁵ Goodman, "Attack of the drones", 5.

⁶ Charlotte Alfred, "20 Years Ago, A Shadowy Cult Poisoned The Tokyo Subway," *The Huffington Post*, 20 March 2015, http://www.huffingtonpost.com/2015/03/20/tokyo-subway-sarin-attack_n_6896754.html.

actors around the globe routinely employ drones for a variety of other nefarious purposes and actively pursue weaponized drone systems.⁷

Categorizing the Drone Threat

In an attempt to shape the burgeoning academic discussion on drone threats, professors Ryan Wallace of Polk State College and Jon Loffi of Oklahoma State University recently analyzed 68 reports, studies, and articles concerning instances of illicit drone usage in an attempt to deduce thematic tendencies and better conceptualize the phenomenon. Their efforts resulted in a useful framework that categorizes both past and future instances of drone use for illegitimate purposes. Arranged into three broad categories and 15 subcategories, Wallace and Loffi's framework covers drone threats ranging from mere nuisances to the delivery of weapons of mass destruction (WMD).⁸ These threats pose a new and growing concern for military forces and civilian populations alike.

Commercial Off The Shelf (COTS) Threats. The first, and most prolific, usage category covers those that require little or no modification to the drone and are available to most actors immediately upon acquiring a drone. Wallace and Loffi further divide this category into five subcategories: Nuisance, Airspace Interference, Monitoring, and Kinetic.⁹ Nuisance applications involve those that interfere with general civil rights or activities and include examples such as trespassing, border incursions, political activism, and privacy violations, as in an incident in Hawaii where a resident found a drone peering in through her bedroom window.¹⁰ Beyond criminal usage, this category also presents the most likely scenarios for individuals inadvertently breaking laws while conducting otherwise legitimate operations, whether through negligence or losing control of the drone. Further, as Wallace and Loffi point out, the current anonymity provided by civil drones allows nefarious actions to appear accidental or otherwise thwart attribution

⁷ The Remote Control Project and Open Briefing, *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets* (London, United Kingdom: The Remote Control Project and Open Briefing, January 2016), 12.

⁸ Ryan J. Wallace and Jon M. Loffi, "Examining Unmanned Aerial System Threats & Defenses: A Conceptual Analysis," *International Journal of Aviation, Aeronautics, and Aerospace* 2, no. 4 (October 2015), 4-6.

⁹ Wallace, "Threats & Defenses", 6-7.

¹⁰ Kellan Howell, "Drone hovers outside Hawaii woman's window; no crime committed," *The Washington Times*, 12 August 2015, <http://www.washingtontimes.com/news/2015/aug/12/drone-hovers-outside-hawaii-womans-window-no-crime/>.

efforts.¹¹ From a military perspective, nuisance threats simply add additional distractors and hazards for operators and security personnel, but do not generally pose lethal or operationally significant threats.

The airspace-interference and kinetic subcategories present more direct threats to military forces. Incidents of airspace interference concern airspace safety issues, such as the FAA's 921 documented incidents of drone sightings by manned aircraft between December 17, 2013 and September 12, 2015, 158 of which were within 200 feet of the manned aircraft.¹² Kinetic uses result in injuries or the destruction of property from a drone impact.¹³ These events can involve deliberate collisions or inadvertent collisions such as an October 2015 incident in Los Angeles, California, where a hobbyist's drone collided with power lines and caused a three-hour power outage.¹⁴ Of the two, the airspace-interference applications pose the greatest risk to military forces with direct, potentially catastrophic, threats to aircraft during takeoff and landing or when operating at low altitudes.¹⁵ Of particular concern for each of the COTS applications is the potential use of not one drone, but the emerging ability for single operators to direct swarms of drones in pursuit of a single objective. Swarm scenarios would present much higher risks in both the airspace-interference and kinetic-attack applications.

The vast majority of illicit drone uses to date fall within the monitoring category; the final group of nefarious applications available to users with COTS equipment. This category includes information-gathering functions typically associated with intelligence, reconnaissance, and surveillance (ISR) missions.¹⁶ The inherent capabilities within consumer-drone systems allow their operators relatively free geographic reign and the ability to easily monitor static and mobile targets from potentially unobserved standoff distances and altitudes. On the civil side, nefarious actors such as drug cartels regularly employ COTS drones in these ISR roles.¹⁷ The military implications for widespread and

¹¹ Wallace, "Threats & Defenses", 9.

¹² Wallace, "Threats & Defenses", 8.; Dan Gettinger and Arthur Holland Michel, *Drone Sightings and Close Encounters: An Analysis* (Washington, DC: Center for the Study of the Drone at Bard College, 11 December 2015), Executive Summary.

¹³ Wallace, "Threats & Defenses", 9.

¹⁴ Kashmir Hill, "Drone knocking out power in West Hollywood is convenient for those calling for drone registry," *Fusion.net*, 27 October 2015, <http://fusion.net/story/222260/drone-knocks-out-power-in-la/>.

¹⁵ Gettinger, *Drone Sightings*, 15.

¹⁶ Wallace, "Threats & Defenses", 7-8.

¹⁷ Wallace, "Threats & Defenses", 8.

easily accessible airborne ISR capabilities are readily apparent. Although limited in comparison to military-grade systems, COTS drones already provide groups like the so-called Islamic State in Iraq and al-Sham (ISIS) with unprecedented capabilities to enhance artillery accuracy, conduct information operations, and actively coordinate tactical engagements on the ground.¹⁸

Payload Threats. The same capabilities that allow legitimate users to bypass washed-out roads and otherwise impassible obstacles from the ground also allow nefarious users to circumvent terrestrial-based security measures while carrying goods for illicit purposes.¹⁹ This second of Wallace's three categories represents those applications which simply require carrying a payload. With little or no modification, drones are already transporting drugs across state borders and contraband into prison yards around the globe.²⁰ One study estimated that, since the first documented use in 2010, drug cartels have delivered nearly two tons of drugs through more than 150 drug-carrying drone flights over the US-Mexican border.²¹ Although smuggling does not present a direct military threat, in addition to making insurgent supply lines harder to detect and interdict, the influx of drugs and other black-market goods can drive social instability and undermine local governance, thereby complicating stability operations.

Weaponized Threats. Whereas little debate exists about the viability of applications within Wallace and Loffi's COTS and payload threat categories, one cannot say the same for their third and final category of weaponized threats. Described as applications which required the deliberate construction or modification of a drone system to enable it to employ weapons, industry experts continuously debate the effectiveness of these applications due to payload and other performance limitations.²² One cannot debate, however, the existence of drone systems that meet the criteria laid out by Wallace and Loffi. Each of the weaponized-threat subcategories of non-lethal systems,

¹⁸ Larry Friese, N.R. Jenzen-Jones and Michael Smallwood, *Emerging Unmanned Threats: The use of commercially-available UAVs by armed non-state actors*, special report (Perth, Australia: Armament Research Services (ARES), February 2016), 40-44.

¹⁹ Wallace, "Threats & Defenses", 10.

²⁰ Remote Control Project, *Hostile Drones*, 12.; Friese, *Emerging Unmanned Threats*, 48.

²¹ Remote Control Project, *Hostile Drones*, 12.

²² Wallace, "Threats & Defenses", 10.; Dan Gettinger, "Domestic Drone Threats," *Center for the Study of the Drone at Bard College*, 20 March 2015, <http://dronecenter.bard.edu/what-you-need-to-know-about-domestic-drone-threats/>.

projectiles, weapons of mass destruction (WMD), explosives, and electronic-attack systems include examples of currently operational systems.²³

Commercial vendors currently offer small drones designed to carry and employ both non-lethal and lethal projectile systems suitable for uses ranging from crowd control to intimidation and even assassination. In 2014, an international mining company purchased twenty-five Skunk drones, identified as a “riot control copter” by its manufacturer, capable of firing paintballs and pepper balls.²⁴ Although theoretically limited to military customers, similar small drones exist that are able to employ grenade launchers, stun guns and other small arms.²⁵ Further, in 2015 a private US citizen successfully conducted a live-fire test of homemade system containing a drone-mounted semi-automatic pistol.²⁶ Whether or not these types of systems prove to be accurate and effective in real-world scenarios, their employment would prove psychologically intimidating, challenge existing rules of engagement, and necessitate deliberate responses in military situations.

Considered a nightmare scenario by many industry experts, the employment of a weapon of mass destruction (WMD) from a drone remains a fortunately speculative application. Despite concrete examples of nefarious actors pursuing WMD-delivery capabilities, as in the cases of Japanese terrorists in 1995 and al Qaeda operatives in 2013, the utility of such systems remains highly disputed.²⁷ One study, for example, speculated as many as 1.5 million infections and 123,000 deaths from 900 grams of weapons grade anthrax dispersed upwind of a major US city. Others are much more skeptical of WMD applications due to the difficulty in weaponizing chemical, biological, radiological, and nuclear (CBRN) agents, dispersal issues, and the exposure levels necessary to produce any significant effects.²⁸ Again, regardless of their actual

²³ Wallace, “Threats & Defenses”, 10-12.

²⁴ Remote, 13.; <http://www.desert-wolf.com/dw/products/unmanned-aerial-systems/skunk-riot-control-copter.html>

²⁵ Goodman, “Attack of the drones”, 4.

²⁶ Wallace, “Threats & Defenses”, 11.

²⁷ Alfred, “20 Years Ago”.; Wallace, “Threats & Defenses”, 12.

²⁸ Eugene Miasnikov, *Threat of Terrorism Using Unmanned Aerial Vehicles: Technical Aspects*, (Dolgoprudny, Russia: Center for Arms Control, Energy and Environmental Studies at Moscow Institute of Physics and Technology, March 2005), 6-8.

effectiveness, the potential utility for terrorists intending to cause mass panic and fear of a WMD-equipped drone, or even a water-filled crop-dusting drone, is immense.

Similarly, although several non-state actors have pursued explosive-drone applications, successful employment continues to elude them, but it is likely only a matter of time because states have already demonstrated that capability. The US Switchblade system, as one example, is a small fixed-wing UAS that is operational within the US Army and designed to loiter for up to 10 minutes and then ram targets up to six miles away, delivering a small-explosive charge which is lethal to trucks or individuals.²⁹ Through a careful review of existing systems, analysts at private intelligence agency, Open Briefing, found off-the-shelf drones readily capable of delivering “the equivalent of a pipe bomb, with the equivalent of five to ten kilograms of TNT.”³⁰ Al Qaeda, Hamas, and other terrorist organizations have already demonstrated the intent to pursue these types of capabilities.³¹ As alluded to in the introductory vignette, the utilization of explosive-filled drones against military forces and installations could present serious issues throughout all phases of military operations, regardless of how limited the effects of any single incident might be, particularly in the case of numerous simultaneous strikes in a drone-swarm scenario.

In their final threat category, Wallace and Loffi address the potential for electronic attack (EA) from small drones.³² Given their payload limitations, drone-mounted EA systems will not rival the power and sophistication of the electronic warfare (EW) capabilities found on larger, conventional aircraft or ground-based systems for the foreseeable future. However, that does not negate the potential utility of drone systems for spoofing or jamming communication and GPS signals, particularly since drones have the potential advantage of significantly closer proximity if hovering over or even landing on the target. In one example, hackers demonstrated the ability to intercept cellular phone calls by mimicking cellular tower signals; and they could also hijack phones

²⁹ David Hambling, “Will 2016 be the Year of the Portable Lethal Drone?” *Defense Tech*, 15 January 2016, <http://www.defensetech.org/2016/01/15/will-2016-be-the-year-of-the-portable-lethal-drone/>.

³⁰ Clive Irving, “Will ISIS Launch a Mass Drone Attack on a Stadium?” *The Daily Beast*, 23 February 2016, <http://www.thedailybeast.com/articles/2016/02/24/will-isis-launch-a-mass-drone-attack-on-a-stadium.html>.

³¹ Goodman, “Attack of the drones”, 3-4.; Wallace, “Threats & Defenses”, 11.; Miasnikov, *Threat of Terrorism*, 25.

³² Wallace, “Threats & Defenses”, 12.

through wireless internet signals, all from drone-mounted systems.³³ Another developer demonstrated the ability, albeit extremely limited, to use one drone to hijack and then control another drone, all while in flight.³⁴ While this level of EW would not rival that found on a conventional battlefield, it could interfere with operational missions utilizing static, ground-based systems around airfields and forward-operating bases.

Overall, the threat to ground forces and civil society posed by drone-based capabilities is still a hotly disputed topic. The constraints imposed by a drone's inherent performance parameters, such as payload capacity, speed, and endurance, limit the effectiveness and lethality of any drone-based threat. As summarized in Appendix B, however, users have already demonstrated a wide variety of capabilities which represent both direct and indirect threats to both military forces and civil society as a whole. The next step in assessing this threat is to examine the likely proliferation to nefarious users, now that drone capabilities have reached a public-demonstration point.

Nefarious Diffusion

The review of diffusion theory in the previous chapter demonstrated that, although the majority of academic work in the field has centered on state-level decision-making processes, diffusion theory applies equally to decision processes for other organizations, such as corporations. Similarly, through an investigation of the spread of the innovation of suicide bombing amongst terrorist organizations, Michael Horowitz, the developer of the adoption-capacity theory, demonstrated the broader applicability of diffusion theory to non-state, nefarious actors as well.³⁵

Adoption-Capacity Theory and Nefarious Drone Use. In assessing whether or not a state, corporation, or non-state actor would decide to pursue an emerging innovation, Horowitz relied on two key variables in that decision calculus: *financial intensity* and *organizational capacity*.³⁶ Michael Kreuzer subsequently applied that

³³ Goodman, "Attack of the drones", 2.

³⁴ Jonathan Fincher, "SkyJack: The drone that hijacks other drones in mid-air," *GizMag*, 8 December 2014, <http://www.gizmag.com/skyjack-hijacks-other-drones/30055/>.

³⁵ Michael C. Horowitz, *The Diffusion of Military Power* (Princeton, NJ: Princeton University Press, 2010), 205.

³⁶ Horowitz, *Military Power*, 30-32.

analytical model to state-level UAS diffusion.³⁷ The key now is to apply that same methodology to the diffusion of illicit drone usage amongst non-state actors.

From a *financial intensity* perspective, non-state actors face a very low barrier to implementing small-drone innovations in most application areas. Drones are cheap and readily available. One can acquire a drone from most major retailers or directly from the manufacturers for prices ranging from a few hundred dollars to a few thousand.³⁸ Further, the wide availability of component pieces and parts, in addition to the emergence of 3D-printing technology, mean drones are also readily customizable for specific missions. Although drone-repair companies and instruction manuals are now emerging, the cost and availability of drones also leads toward their inherent disposability on the battlefield.³⁹ If a nefarious actor cannot recover a drone at the end of a mission, it does not pose a significant financial burden to simply replace the drone. As the drone market continues to mature, the inherently dual-use aspect of the technology will play an important role in ensuring both the expansion of capabilities and minimization of costs.

When he assessed the diffusion of suicide bombing amongst terrorist organizations, Horowitz found a similarly low financial barrier to entry, but identified a high organization-capital requirement. This organization requirement stemmed from the training and propaganda requirements for first recruiting and convincing would-be bombers, overcoming the political backlash from using those tactics, and also from the constant need to replace operators killed in the actual attacks.⁴⁰ The use of drones, on the other hand, presents none of these issues. The ease of use inherent in the current generation of commercially available drones results in very limited training requirements necessary to achieve a minimal level of operational proficiency. Manning requirements are similarly limited as, although single-person operations are feasible, the nominal manning ratio is only two or three operators to each drone with little need for support

³⁷ Michael P. Kreuzer, "Remotely Piloted Aircraft: Evolution, Diffusion, and the Future of Air Warfare" (PhD diss., Princeton University, September 2014), 26-27.

³⁸ Remote Control Project, *Hostile Drones*, 5.

³⁹ Carson Chambers, "Local with engineering background finds niche in drone repair," *ABC Action News*, 26 January 2016, <http://www.abcactionnews.com/news/local-news/local-with-engineering-background-finds-niche-in-drone-repair>.

⁴⁰ Horowitz, *Military Power*, 178.

personnel.⁴¹ Further, the limited maintenance and command-and-control requirements for small-drone operations further limit the need for organizational flexibility. The result is a correspondingly low *organizational capital* requirement.

According to adoption-capacity theory, the resulting low financial intensity and low organizational-capital requirements creates a situation primed for the rapid diffusion of drone use among non-state actors. Kreuzer makes a similar assessment of tactical UAS diffusion between states; however, his associated caveats and conclusions do not necessarily transfer from state to non-state examples. First, although Kreuzer highlights the potentially rapid diffusion of tactical UASs, he assesses their impact on the future battlefield as limited to a relatively minor increase in already-existing capabilities.⁴² While this may hold true for state-level militaries, access to and use of the air domain through the use of drones presents non-state actors with a fundamentally new capability set that has the potential to significantly alter their modes of operation. Second, Kreuzer further dismisses the possibility that hostile entities could employ both strategic and tactical UASs in non-permissive environments where their users lack overall air superiority.⁴³ Air superiority, however, does not imply the complete inability of the inferior side to utilize the air domain for its purposes. Particularly in the case of nefarious uses, the drone-engagement profiles and scenarios will lend themselves to successfully operating under an otherwise restrictive air-superiority umbrella. Third, Kreuzer highlights the “longstanding obstacle to airpower in small wars – persistent airspace coverage and reasonable discrimination between combatants and civilians” as a limitation to employing UASs. However, these issues restrict state actors to a much greater degree than nefarious non-state actors with a more limited geographic view and a propensity for indiscriminant violence.⁴⁴ Finally, Kreuzer highlights the user’s fear of losing UAS platforms as a constant barrier to their use in high-risk, and therefore more-impactful, scenarios. This will not, however, create as much of a limitation if actors view drones as disposable assets or are unconcerned about attribution.

⁴¹ Robin R. Murphy, *Disaster Robotics* (Cambridge, MA: MIT Press, 2014), 123; Remote Control Project, *Hostile Drones*, 10.

⁴² Kreuzer, “Remotely Piloted Aircraft”, 17.

⁴³ Kreuzer, “Remotely Piloted Aircraft”, 9.

⁴⁴ Kreuzer, “Remotely Piloted Aircraft”, 42.

Particularly when compared with the employment of a small manned aircraft, drones present non-state actors, and particularly those pursuing nefarious aims, with a highly advantageous alternative. Drones lack the relatively high financial intensity of a conventional aircraft's acquisition, maintenance, and support costs. Drones lack the significantly higher organization-capacity requirement for the maintenance, manning, and training support necessary for manned platforms. Under these circumstances, adoption-capacity theory highlights the high potential and likelihood that drones used for illegitimate purposes will proliferate rapidly amongst non-state actors.

Expanding Illicit Use of Drones. The capabilities of remote-controlled aircraft, their ease of use, and reduction in unit cost have come a long way since Aum Shinrikyo decided against using them in 1995. The steadily dropping financial intensity and organizational-capacity requirements have led to an ever-increasing rate of proliferation. While the tables in Appendix B depict the wide variety of demonstrated illicit drone uses, it also shows a clear pattern of increasing frequency, despite the limited sampling.

Although Aum Shinrikyo, al Qaeda, Hezbollah, and several other groups have attempted to use remote-controlled aircraft for illicit purposes, the general rate of illicit drone activity noticeably increased around 2011.⁴⁵ At that point, the combination of miniaturized consumer electronics and the earliest consumer drone products presented a sharp decline in the barriers to accessing the air domain. In 2011, the FBI foiled an al Qaeda plot to launch explosive-filled drones against the US Capitol and the Pentagon. Libyan rebels also began employing drones for ISR support and, as mentioned earlier, hackers demonstrated the ability to use drone-mounted electronic systems to hijack smartphones.⁴⁶ By 2014, both militaries and non-state actors alike were operating COTS drones in combat operations in Iraq, Syria, and Ukraine. Unknown perpetrators also caused public panic by overflying French nuclear power plants and spying on soccer teams preparing for the 2014 World Cup in Brazil.⁴⁷ Incidents such as these were so common by 2015 that illicit-drone activity routinely received national news coverage.

⁴⁵ Miasnikov, *Threat of Terrorism*, 25.; Goodman, "Attack of the drones", 3.

⁴⁶ Goodman, "Attack of the drones", 2,4.; Friese, *Emerging Unmanned Threats*, 48.

⁴⁷ Remote Control Project, *Hostile Drones*, 10.; Friese, *Emerging Unmanned Threats*, 37-44.; "More drones spotted over French nuclear power stations," *the guardian*, 31 October 2014. <http://www.theguardian.com/environment/2014/oct/31/more-drones-spotted-over-french-nuclear-power-stations>.

New scenarios reported in 2015 included drones peering into bedroom windows in Hawaii, causing blackouts in Hollywood, smuggling drugs across the US-Mexican border, participating in mob wars in Japan, and causing anxiety throughout aviation communities around the globe due to near-miss incidents with manned aircraft.⁴⁸

Terrorists, insurgents, crime syndicates, and activists alike are increasingly incorporating drones into their nefarious plans, and society has taken notice. As just one of countless indications of the mounting concern, the US Department of Homeland Security (DHS) issued a warning in August 2015 to police departments throughout the US concerning an increased threat and likelihood of drone use by terrorist and criminal organizations.⁴⁹ Civil and military organizations around the globe are now scrambling to develop methods to counter the small-drone threat.

Countering the Drone Threat

Modern air forces have a long history with countering airborne threats, but drones present several new challenges that negate many existing counter-air capabilities. Among other factors, their small sizes and correspondingly low radar cross sections make drones hard to detect, and their inherent range and endurance limitations actually create distressingly short engagement timelines for defending forces. Many entities already possess and employ counter-drone capabilities, also known as counter-UAS (C-UAS) in some circles. Usually begun as modifications to traditional counter-air capabilities, many of these systems, however, have limited ability against small drones, particularly in urban environments. Only recently have developers begun to focus their efforts on more tailored approaches to the counter-drone issue.

Emerging Counter-Drone Focus

In the same study where they looked for common themes amongst drone-based threats, Wallace and Loffi also surveyed 39 distinct efforts to counter the growing drone threat. Although they succeeded in categorizing a broad range of counter-drone

⁴⁸ Gettinger, *Drone Sightings*, Executive Summary.; Hill, "Drone knocking out power."; Nick Valencia and Michael Martinez, "Drone carrying drugs crashes south of U.S. border," *CNN*, <http://www.cnn.com/2015/01/22/world/drug-drone-crashes-us-mexico-border/>; Wallace, "Threats & Defenses", 7.; Jake Adelstein, "A Yakuza War is Brewing in Japan – and the Police are Taking Sides," *vice news*, 22 September 2015, <https://news.vice.com/article/a-yakuza-war-is-brewing-in-japan-and-the-police-are-taking-sides>.

⁴⁹ Jeff Pegues, "Homeland Security warns drones could be used in attacks," *CBS News*, 31 July 2015, <http://www.cbsnews.com/news/homeland-security-warns-drones-could-be-used-in-attacks/>.

capabilities, two of their overall observations call into question much of the future impact of these initial efforts. First, of the 39 efforts studied, very few offered realistic and currently feasible methods of countering the threat and none offered a broad-based solution. Second, and more importantly, they could not identify any government or civil organizations with an overarching strategy or integrated plan towards developing counter-drone capabilities.⁵⁰ While the vast majority of current efforts amount to little more than technology demonstrations, that does not mean that those counter-drone solutions are not worth pursuing, nor does it mean that nobody is looking at the bigger picture. The major implication is that, despite all of the ongoing efforts and the recognized need, the hard work of selecting and fielding an integrated counter-drone solution still lays ahead.

One of the efforts taking a broader view of the emerging drone threat is a program run out of the Department of Defense's (DoD) Joint Integrated Air and Missile Defense Organization (JIAMDO) known as Black Dart. In existence under various parent offices since 2002, the Black Dart program provides opportunities for developers to demonstrate and test counter-drone capabilities while simultaneously allowing the DoD to further evaluate the problem and inform its requirements, acquisition, and training processes.⁵¹ In its annual live-fly and live-fire exercise in 2015, Black Dart and its 700 participants pitted 55 counter-drone systems against 16 targets over the course of over 100 sorties and 20 kinetic and non-kinetic engagements.⁵² Further, for the first time and in recognition of the growing threat and the increased concern shown by Combatant Commanders, the 2015 exercise featured and focused on drones in the small-UAS categories. Although still largely shrouded in secrecy, Black Dart has yielded valuable knowledge on the limitations and capabilities of both currently fielded and developmental systems in addressing the drone threat.⁵³

⁵⁰ Wallace, "Threats & Defenses", 12-13.

⁵¹ Yasmin Tadjdeh, "Inside Black Dart: How the Military Prepares for a Future Drone War," *National Defense*, September 2015. <http://www.nationaldefensemagazine.org/archive/2015/September/Pages/InsideBlackDartHowtheMilitaryPreparesforaFutureDroneWar.aspx?PF=1>.

⁵² Tadjdeh, "Inside Black Dart"; Richard Whittle, "Marine Sniper In Helicopter Kills a Drone! Black Dart Results," *Breaking Defense*, 27 August 2015, <http://breakingdefense.com/2015/08/marine-sniper-in-helicopter-kills-a-drone-black-dart-results/>.

⁵³ Tadjdeh, "Inside Black Dart".

Unlike a purely military threat where countermeasure development rests solely within the military's purview, the broad applicability of drones for illicit purposes is forcing organizations at all levels of government and society to pursue, often independently, counter-drone capabilities. In the wake of the 2013 Boston Marathon bombing and the fear of a drone-based repeat attack that thankfully never materialized, event organizers in 2015 fielded a rudimentary drone-detection system and armed police officers with drone-capturing net cannons.⁵⁴ Similar systems were deployed for the 2012 Olympics in London, the G8 Summits in 2013 and 2014, and even around the set of "Star Wars: The Force Awakens" in 2014 to prevent any early release of movie footage.⁵⁵ In Japan, the use of drones by the Yakuza mob has reached such an extent that local police departments are creating specific counter-drone units to address the threat.⁵⁶ As shown by the FAA's imposition of a "No Drone Zone" for the 2016 Super Bowl in Santa Clara, California, planning for and including counter-drone capabilities are rapidly becoming baseline requirements for many civic events.⁵⁷

In late 2015, the MITRE Corporation, a not-for-profit company supporting the US government, announced a competition specifically aimed at the civil side of drone defense. While MITRE intends to evaluate defensive systems based on their technical viability and overall affordability, the major piece it added to the discussion is the concept of "domestically viable" solutions.⁵⁸ This concept acknowledges that many of the counter-drone engagement technologies under development, particularly kinetic- and jamming-based systems, would simultaneously pose a threat to both the target drone and the local population and civil infrastructure. Although others, such as managers of the

⁵⁴ Kelsey D. Atherton, "Drone-proofing the Boston Marathon," *Popular Science*, 21 April 2015, <http://www.popsci.com/drone-protection-company-brought-net-guns-boston-marathon>.

⁵⁵ Allyson Versprille, "Small Off-the-Shelf Drones Causing Alarm in Security Circles," *National Defense*, May 2015, <http://www.nationaldefensemagazine.org/archive/2015/May/pages/SmallOfftheShelfDronesCausingAlarmInSecurityCircles.aspx>; Jeff Stone, "How to Shoot Down a Drone: Ray Guns, Nets and Malware are Being Used to Knock Drones Out of the Sky," *IBTimes*, 11 December 2015, <http://www.ibtimes.com/how-shoot-down-drone-ray-guns-nets-malware-are-being-used-knock-drones-out-sky-2222510>.

⁵⁶ Kelsey D. Atherton, "Tokyo Police Form Anti-Drone Squad," *Popular Science*, 10 December 2015, <http://www.popsci.com/tokyo-police-form-anti-drone-squad>.

⁵⁷ Federal Aviation Administration, "New FAA video explains that the Super Bowl is a No Drone Zone," accessed 26 January 2016, <https://www.faa.gov/news/updates/?newsId=84766>.

⁵⁸ "The MITRE Challenge: Countering Unauthorized Unmanned Aircraft Systems," *MITRE*, accessed 26 January 2016, <http://www.mitre.org/research/mitre-challenge>.

Black Dart program, have also raised this concern, it has not been a focal point of their efforts, particularly those efforts geared towards more traditional battlefield environments.⁵⁹ The many corners of society independently pursuing counter-drone capabilities, begin to raise significant questions about the impact of the proliferation of counter-drone systems.

Counter-Drone Capabilities

After reviewing 39 unique counter-drone concepts, Wallace and Loffi created an organizational scheme based upon a defense-in-depth model consisting of prevention, deterrence, denial, detection and active defenses.⁶⁰ While this presents a useful framework, for the purposes of this study, a simpler method of categorizing techniques only as either pre-engagement or engagement capabilities provides a more useful framework, as it allows for a more focused discussion on the interaction of civil drones and military forces in a battlefield environment. In this new framework, Wallace and Loffi's prevention, deterrence, and denial categories comprise the pre-engagement capabilities and the engagement capabilities consist of their detection and active defense categories and mirror the DoD's find, fix, target, track, engage, and assess (F2T2EA) engagement model.⁶¹ Although the current study reviews capabilities in each category, the general focus will remain on those engagement capabilities with the most battlefield-relevant implications.

Pre-Engagement Capabilities. Ideally, a defender would prefer to simply prevent an actor from employing drones for illicit purposes at all. The most effective method of preventing non-state actors from using drones for nefarious purposes would be to deny their access to the necessary drone technologies in the first place. The concept of counter-proliferation is common throughout the defense industry and sets the foundation for the counter-drone plans espoused by many defense experts.⁶² Under this concept, regulations and monitoring policies would restrict access to both critical components as well as drones with higher payload, endurance, speed, and other technical parameters. Taking this to the extreme, some countries such as The Netherlands and South Africa

⁵⁹ Tadjdeh, "Inside Black Dart".

⁶⁰ Wallace, "Threats & Defenses", 12-22.

⁶¹ Joint Publication (JP) 3-60, *Joint Targeting*, 31 January 2013, II-23.

⁶² Remote Control Project, *Hostile Drones*, 19.; Wallace, "Threats & Defenses", 14.

have even opted to effectively ban the use of drones within their borders.⁶³

Unfortunately, given the dual-use nature of drone technologies, the vast resources available within the do-it-yourself community, and the vast network of retailers around the globe, non-proliferation efforts have little chance of succeeding over the long term.

Once a nefarious actor acquires drone capabilities, the pre-engagement efforts must shift into preempting any action through intelligence and law-enforcement channels or deterring any action through the threatened or actual enforcement of criminal penalties or perceived neutralization of those drone capabilities.⁶⁴ The combination of the widespread availability of drone capabilities and the almost complete lack of high-profile incidents implies that efforts to curtail plots at an early stage have been succeeding quietly in the background. Since 2011, nations around the globe have thwarted at least six terrorist plots involving drones and have begun aggressively prosecuting criminal-drone usage.⁶⁵ Other examples of currently operational preemption schemes include anti-drone netting around outdoor events and geo-fencing software that actively inhibits drones from overflying restricted areas.⁶⁶ Similar systems will likely become more commonplace as civil-drone use steadily expands.

Of course, as is often quoted in investment circles, past performance does not necessarily guarantee future results. With drones already employed on numerous battlefields and the limited effectiveness of regulations and legal mechanisms in deterring terrorist and criminal activity, the odds are good that civil or military authorities will have to actively engage and defeat a drone threat in the near future. ISIS, for instance, is “reportedly obsessed with launching a synchronized multi-drone attack on large numbers of people in order to recreate the horrors of 9/11.”⁶⁷ It is likely only a matter of time until someone must engage in counter-drone operations.

⁶³ Remote Control Project, *Hostile Drones*, 15.

⁶⁴ Wallace, “Threats & Defenses”, 13-16.

⁶⁵ Kelley Saylor, *A World of Proliferated Drones: A Technology Primer* (Washington, DC: Center for New American Security, 2015), 12.; Ben Popper, “The UK has secured its first conviction against a drone pilot,” *The Verge*, 15 September 2015, <http://www.theverge.com/2015/9/15/9331385/man-arrested-fined-for-flying-drone>.; David Nield, “Drone Pilot Arrested After Buzzing Past and LAPD Helicopter,” *Digital Trends*, 12 September 2015, <http://www.digitaltrends.com/cool-tech/drone-pilot-arrested-after-buzzing-past-an-lapd-helicopter/>.

⁶⁶ Wallace, “Threats & Defenses”, 15. Remote Control Project, *Hostile Drones*, 16.

⁶⁷ Remote Control Project, *Hostile Drones*, 12

Engagement Capabilities. The engagement category consists of those capabilities required to detect, identify, track, and neutralize a drone that is actively participating in illicit activities. Further, this category represents the focus of most counter-drone efforts and the most relevant to understanding the impact of drones on military operations.

To date, developers have utilized a wide variety of sensors, both active and passive, to detect, identify, and track incoming-drone threats. Although they are the mainstay of conventional aircraft detection, radar systems continue to suffer severe limitations when addressing the drone threat. Labeled by the military as “low, slow and small UASs,” the Group 1 and 2 drones continue to cause problems with radar filters designed to mitigate interference with wildlife, ground clutter, and even weather. This same problem, among other issues, led to a US citizen successfully evading detection in Washington DC and landing a decidedly larger manned gyrocopter on the lawn of the US Capitol in 2015.⁶⁸ Even when radars can accurately detect an incoming drone, the ability to discriminate that drone, with its inherently small radar cross section, from even an adjacent bird continues to elude most systems.⁶⁹

The limitations of existing radar systems have pushed many developers to other methods of detecting nefarious drones. The drone-detection system DroneShield, which augmented event security at the 2015 Boston Marathon, uses acoustic information to detect and track a drone’s engine and propeller noise.⁷⁰ Unfortunately, although acoustic systems have demonstrated detections as distant as 350 meters, their performance is severely limited by background noise, with detection performance dropping to a mere 100 feet in noisy environments.⁷¹ Other systems rely on visual and thermal imaging or detecting and triangulating the control signal transmissions between the drone and its operator.⁷² Developers are also beginning to integrate multiple technologies into a fused-

⁶⁸ Richard Whittle, “Military exercise Black Dart to tackle nightmare drone scenario,” *The New York Post*, 25 July 2015, <http://nypost.com/2015/07/25/military-operation-black-dart-to-tackle-nightmare-drone-scenario/>.

⁶⁹ Wallace, “Threats & Defenses”, 16-17.; Tadjdeh, “Inside Black Dart”.

⁷⁰ Atherton, “Drone-proofing.”

⁷¹ Wallace, “Threats & Defenses”, 17-18.

⁷² Remote Control Project, *Hostile Drones*, 16.

sensor system to overcome the inherent limitations within each of the separate detection and identification mechanisms.⁷³

Having detected and identified a nefarious drone, defenders must then neutralize the threat. These efforts can include directly engaging the operator, jamming or spoofing the drone's control or GPS signals, hacking into the drone's control system, capturing the drone, or physically destroying it.⁷⁴ Successful examples of defense forces intercepting a drone's operator include a 2015 strike on an ISIS drone operator in Fallujah, Iraq after they had completed an ISR mission and a 2015 event where the US Secret Service identified an individual operating a drone near the President's motorcade in Hawaii and ordered him to cease flight operations.⁷⁵ This method, however, remains highly dependent on the context of the engagement scenario for a successful outcome.⁷⁶

Capturing a drone while in flight is one of the few domestically acceptable options available to defense forces attempting to avoid injuring bystanders with falling drones, inadvertently detonated payloads, or other forms of collateral damage. Direct approaches to capturing drones often utilize nets to envelope the drone or ensnare its rotors and include both ground-based and drone-based net cannons and nets hanging from drones like giant flypaper.⁷⁷ Some police departments have even turned to nature and are now experimenting with eagles trained to capture drones mid-flight and carry them to an uninhabited area for safe disposal.⁷⁸ More subtle forms of capturing a drone include remotely taking control of it by either sending it false GPS signals or through introducing malicious code directly into its system.⁷⁹ Electronic and cyber-attack methods, however,

⁷³ Remote Control Project, *Hostile Drones*, 17.

⁷⁴ Wallace, "Threats & Defenses", 18-22.; Remote Control Project, *Hostile Drones*, 17-18.

⁷⁵ Andrew Tilghman, "ISIS drone destroyed in airstrike," *Military Times*, 19 March 2015, <http://www.militarytimes.com/story/military/pentagon/2015/03/19/isis-drone/25027743/>; "Drone Flying Alongside Obama's Motorcade in Hawaii Stopped by Secret Service," *sUAS News*, 29 December 2015, <http://www.suasnews.com/2015/12/40985/40985/>.

⁷⁶ Wallace, "Threats & Defenses", 19.

⁷⁷ Atherton, "Drone-proofing."; Ed Oswald, "This anti-UAV octocopter uses a ballistic net cannon to disable smaller drones," *Fox News*, 13 January 2016, <http://www.foxnews.com/tech/2016/01/13/this-anti-uav-octocopter-uses-ballistic-net-cannon-to-disable-smaller-drones.html>; Gareth Jennings, "Tokyo police use flying net to capture illicit UAVs," *IHS Jane's 360*, 30 December 2015, <http://www.janes.com/article/56871/tokyo-police-use-flying-net-to-capture-illicit-uavs>.

⁷⁸ "Watch a police eagle take down a drone," *Fox News*, 1 February 2016, <http://www.foxnews.com/tech/2016/02/01/watch-police-eagle-take-down-drone.html>.

⁷⁹ Marc Goodman, *Future Crimes* (New York, NY: Doubleday, 2015), 304.; Remote Control Project, *Hostile Drones*, 17.

suffer from the potential that many of these effects require knowledge of the target drone's specific model; and their use on different models could produce unpredictable results, such as uncommanded turns or unintended system failures.⁸⁰

Next to physical destruction, jamming is the most-often-noted method for defeating a nefarious drone; however, it also suffers from some significant limitations. By overpowering the control or GPS signals upon which a drone relies, jamming systems could successfully cause a mission failure. But the dual-use aspect of consumer drones means that the control signals exist in the same frequency ranges as other consumer systems.⁸¹ Jamming a drone's control link could simultaneously jam local cellular telephones, wireless internet, Bluetooth connections, or even legitimate drone usage. In a battlefield scenario, jamming a civil drone may also inhibit friendly communication and control through a form of electronic fratricide. Further, although it might still degrade a mission's effectiveness, a simple waypoint-following routine could mitigate the loss of a control link. Jamming a drone, although often touted as the best counter-drone approach, comes with some significant baggage.

The final engagement method falls to actually destroying a drone in flight with kinetic or directed-energy weapons.⁸² Previous Black Dart exercises have included successful destructive engagements from, among other things, shipborne lasers, helicopter-mounted cannons and Hellfire missiles, and even a US Marine sniper firing from an airborne helicopter.⁸³ Airborne destruction, however, presents a high potential for collateral damage, particularly in urban environments. Depending on the size of the drone and its payload, the falling debris might actually result in more damage than the drone would have otherwise caused.⁸⁴

Another key concern with these engagement capabilities lies in their affordability. Conventional surface-to-air missile systems such as the Patriot and Avenger systems, for example, raise serious questions about trading expensive and limited-quantity missiles for the destruction of relatively cheap, and likely plentiful, drones. Affordability discussions

⁸⁰ Wallace, "Threats & Defenses", 19.

⁸¹ Remote Control Project, *Hostile Drones*, 17.

⁸² Wallace, "Threats & Defenses", 20.

⁸³ Whittle, "Military exercise"; Whittle, "Marine Sniper".

⁸⁴ Wallace, "Threats & Defenses", 20.

often lead one towards the use of directed-energy techniques such as lasers and microwave weapons. Developers in many countries have demonstrated the ability to shoot down drones with directed-energy weapons and are actively working to refine and field those systems. However, these methods carry many of the same concerns regarding collateral damage as kinetic weapons.⁸⁵ Further, the dwell-time requirements for directed-energy weapons to successfully destroy a target may negate their effectiveness in many likely scenarios. As one study pointed out, in the five seconds required for some lasers to dwell on their target, a drone traveling at 50 mph would traverse 112 meters. Particularly in a dense urban environment, the scenario may not allow for five seconds or 100 meters of buffer within an engagement timeline.⁸⁶

As previously discussed, counter-drone efforts are not limited to government or commercial entities; even individual citizens have begun to enter the mix. In 2015, police in Kentucky and New Jersey separately arrested two men on charges of using shotguns to shoot down unwelcome drones.⁸⁷ One ammunition company has gone so far as to market drone-specific shotgun shells to consumers.⁸⁸ Inventive individuals have even turned to impromptu weapons including fishing poles and soccer balls to take down unwanted drones.⁸⁹ In one documented encounter, a chimpanzee at a zoo in the Netherlands successfully ended one drone's flight by simply attacking it with a stick.⁹⁰ As ludicrous as they may be, these instances illustrate the extreme susceptibility of drones to external interference if successfully engaged. Unlike hardened military systems, commercially available drones are not designed to survive in hostile

⁸⁵ Remote Control Project, *Hostile Drones*, 18.

⁸⁶ Remote Control Project, *Hostile Drones*, 18.

⁸⁷ "Hillview man arrested for shooting down drone; cites right to privacy," *WDRB*, 31 July 2015, <http://www.wdrb.com/story/29650818/hillview-man-arrested-for-shooting-down-drone-cites-right-to-privacy>.; Craig McCarthy, "N.J. man faces prison for shooting down drone, cops say," *NJ.com*, 27 August 2015, http://www.nj.com/news/index.ssf/2015/08/nj_man_faces_prison_for_shooting_down_drone_cops_say.html.

⁸⁸ Eric Limer, "These are 'Anti-Drone' Shotgun Shells," *Popular Mechanics*, 19 August 2015, <http://www.popularmechanics.com/technology/a16967/drone-munitions-shotgun-shells/>.

⁸⁹ Kiona Smith-Strickland, "Watch a Fisherman Catch a Drone in Flight," *Gizmodo*, 9 August 2015, http://gizmodo.com/watch-a-fisherman-catch-a-drone-in-flight-1722948154_; Devin Coldewey, "Goal! Well-kicked soccer ball knocks drone out of the air," *NBC News*, 29 Oct 2015, <http://www.nbcnews.com/tech/innovation/goal-well-kicked-soccer-ball-knocks-drone-out-air-n454116>.

⁹⁰ Rachel Feltman, "Chimp that attacked a drone with a stick planned ahead, researchers say," *The Washington Post*, 4 September 2015, <https://www.washingtonpost.com/news/speaking-of-science/wp/2015/09/04/chimp-that-attacked-a-drone-with-a-stick-planned-ahead-researchers-say/>.

environments. Despite those limitations, however, they continue to elude many attempted engagements.

Counter-Drone Limitations. For all of the advances in counter-drone capabilities in recent years, significant limitations remain. In a post-exercise interview in 2015, the Black Dart program manager conceded that the quest for a successful counter-drone solution is far from over.⁹¹ Drones continue to be notoriously hard to detect and harder still to discriminate from background distractors such as birds, much less other drones. Regulations which attempt to limit the proliferation of drones or their critical sub-components oppose parallel efforts to promote innovation and growth within the commercial market and the do-it-yourself community. Perhaps most importantly, when present, the need to limit engagement capabilities to domestically acceptable solutions significantly reduces the number of available options. A related issue lies in the insidious assumption underlying most of the counter-drone discussion: the assumption, ripe for exploitation, that the nefarious drone is the only target in the air. Challenging this assumption requires approaching the problem from an entirely different perspective.

Impacts on Military Operations

By focusing on the threats posed by nefarious-drone use and the real and potential methods employed to counter those threats, most of the counter-drone discussions revolve around the technical analysis of the capabilities of specific drone and counter-drone systems and how they would interact. As the scenarios broaden and include more actors or swarms of drones, the analysis still devolves to drone-versus-counter-drone capability, albeit at a system-on-system scale. This analytical paradigm, however, is insufficient for the purposes of assessing the full implication of the civil-drone proliferation, as it ignores the impact on a military mission regardless of the technical ability to counter a drone. Few, if any, drone threats will exhibit a consistent impact on all missions or even all phases of a military operation. One must therefore investigate how that impact might vary across different types of military operations and how, if at all, it will change with the proliferation of drone and counter-drone capabilities.

⁹¹ Whittle, “Marine Sniper”.

Conceptualizing a Network of Civil Drones – The Aerial Littoral

In early 2016, the FAA made headlines with the announcement that the number of registered drone operators in the US had exceeded the 320,000 total number of registered manned aircraft in the US.⁹² As impressive as this announcement appears, it significantly downplays the current state of drone ownership and usage within the US, much less in the world. First, although the FAA may track 320,000 registered manned aircraft in the US, it also reports a declining active civil fleet of only approximately 206,000 commercial and general aviation aircraft.⁹³ In comparison, the number of 325,000 registered drone operators includes only the hobbyist registration database and does not include commercial operators or, more importantly, acknowledge the estimated two million drone aircraft in operation across all aspects of civil society within the US.⁹⁴ Comparing, instead, a growing fleet of 2,000,000 drones to a declining fleet of 206,000 manned aircraft illustrates an order-of-magnitude difference and raises some interesting concerns about where those aircraft will appear and how they will interact with each other.

To some degree, the FAA currently regulates or controls all airspace over the US from the surface of the earth up to altitudes of 60,000 feet.⁹⁵ Within that airspace, the FAA monitors, on average, over 30,000 take-offs and landings each day across the country's major airports, with approximately 7,000 aircraft airborne over the US at any given point in time.⁹⁶ While those numbers are impressive, these aircraft operate within a large volume of airspace and are actively deconflicted by air traffic control (ATC) systems. Civil drones, on the other hand, operate in significantly higher numbers and in a significantly smaller volume of airspace. The FAA currently restricts small-drone use to

⁹² Joan Lowy, "There are more drone operators than there are pilots in the US," *Business Insider*, 8 February 2016, <http://www.businessinsider.com/ap-faa-more-registered-drone-operators-than-licensed-pilots-2016-2>.

⁹³ Federal Aviation Administration, *FAA Aerospace Forecast: Fiscal Years 2015 – 2035* (Washington, DC: Federal Aviation Administration, 2014), 29,32.; U.S. Department of Transportation, *National Transportation Statistics* (Washington, DC: Office of the Assistant Secretary for Research and Technology, January 2016), Table 1-11, accessed 26 January 2016, http://www.rita.dot.gov/bts/sites/rita.dot.gov/bts/files/publications/national_transportation_statistics/index.html.

⁹⁴ Grant Begley (former board member, Association for Unmanned Vehicle Systems International), e-mail message to author, 17 January, 2016.

⁹⁵ "How it all works: Airspace," *flight training*, accessed 26 January 2016, <http://flighttraining.aopa.org/learntofly/works/airspace.html>.

⁹⁶ Federal Aviation Administration, "Operational Metrics," accessed 26 January 2016, http://www.faa.gov/data_research/aviation_data_statistics/operational_metrics/.

altitudes below 500 feet, creating an emerging environment of highly dense airspace close to the earth's surface without the benefit of an active ATC system. To mitigate this issue, key stakeholders are developing and proposing methods of implementing a drone ATC system, some versions of which envision tracking and deconflicting drone activity through cellular-tower communication systems and implementing further altitude and usage delineations within that 500 feet of airspace.⁹⁷

The concentration of an unprecedented number of aircraft below 500 feet will quickly challenge the long held “big sky theory” approach to aviation. Instead, the emerging environment will begin to resemble those seen in the maritime and land domains where, instead of 320,000 registered aircraft, they respectively track 12 million registered maritime vessels and 256 million registered highway-capable vehicles, numbers which include large quantities of personal, commercial, and public applications; something unprecedented in the air domain.⁹⁸

As the lower portion of the air domain begins to resemble its earth-bound counterparts, the problem of countering a threat within that environment becomes much harder. At that point, a defender can no longer count on a one-on-one engagement or even that a hostile threat is the only target in the air. Now the air is potentially filled with not just threats, but also the aerial equivalents of ambulances, utility vehicles, postal delivery trucks and bicycles, the disruption of which could have significant effects throughout civil society. Although relatively unique within the air domain, the idea of a highly congested seam between two domains is not new and has been studied in depth, at least from a naval perspective, in the case of the littorals.

The littoral region, the highly trafficked seam between purely land and sea domains, presents an appropriate analogy for the emerging civil-drone environment for several reasons. First, as in the case of blue-water navies, conventional air forces train and equip for operations in a more sparsely populated environment consisting of fewer, but more capable, adversaries and may be ill-prepared for the high-density, low-

⁹⁷ Mark Harris, “Nasa and Verizon plan to monitor US drone network from phone towers,” *the guardian*, 3 June 2015, <http://www.theguardian.com/technology/2015/jun/03/verizon-nasa-drones-cellphone-towers>.; Matt McFarland, “Amazon details its plan for how drones can fly safely over U.S. skies,” *The Washington Post*, 28 July 2015, <https://www.washingtonpost.com/news/innovations/wp/2015/07/28/amazon-details-its-plan-for-how-drones-can-fly-safely-over-u-s-skies/>.

⁹⁸ U.S. Department of Transportation, *National Transportation Statistics*, Table 1-11.

capability threat found in the civil-drone environment. Second, both seams play critical roles well beyond their military importance for broad portions of society as conduits for activities such as law enforcement, commerce and the provision of essential services. Third, the littoral represents a horizontal seam between the maritime and land domains that necessarily influences, and is influenced by, operations in both domains. From a vertical perspective, the increasingly dense and highly dynamic seam between the air and land domains resembles an “aerial littoral” with implications for operations in both the air and land domains. Unfortunately, unlike the maritime littoral seam, which existed before the advent of blue-water navies and was therefore an inherent part of maritime warfare from the start, the aerial littoral is emerging late in the history of the militarization of the air domain and does not necessarily comport with the current paradigm. However, this concept must underpin any assessment of the emerging threat inherent in the proliferation of civil drones to appreciate the effects of the broader operating environment.

Of course, as in the case of the maritime littoral, the presence of civil drones and the aerial littoral do not present a threat themselves, they simply create the backdrop upon which the threat exists. The aerial littoral will afford nefarious actors the ability to hide within, and mask their activity within, the stream of legitimate drone users. Instead of an easily identifiable threat, or swarm of threats, as in the Black Dart exercises, the aerial littoral will complicate that threat-identification with an overlay of dozens, if not hundreds, of legitimate drones in a given geographic region. Even if legitimate users operate all of the drones in the air, their proven susceptibility to hacking creates a kinetic and ISR threat to ground forces from almost any otherwise legitimate drone.⁹⁹ Further, the aerial littoral increases the risk of collateral damage when engaging known threats by surrounding those threats with legitimate drones, some of which may be conducting socially critical activities. This is the future counter-drone operating environment at home or abroad. Without the overlay of a civil-drone environment, an aerial littoral, the nefarious threat is just another friend-or-foe identification issue for the military; with the civil overlay, the situation is much more complex and has the potential to drastically alter military operations.

⁹⁹ Goodman, “Attack of the drones”, 5.

Military Operations within the Aerial Littoral

Few, if any, characteristics of an operating environment remain constant across, or similarly affect, all aspects of a military operation. The threat posed by the nefarious use of small drones is no different. A drone, for example, approaching a ground patrol or an active airfield poses a different threat and elicits a different response in a wartime scenario versus a peacetime one, whether domestically or abroad. Joint doctrine lays out six nominal phases of military operations which, although they will vary in context and details, encapsulate the general shifts in focus and strategic environments throughout a military campaign.¹⁰⁰ Assessing the potential impact of civil drones on each phase of a military operation provides critical insights into which of those phases might provide the most inherent vulnerability to drone threats, and therefore jeopardize the overall mission and require further investigation and investment.

Phase 0: Shaping. Within the Joint Operational Planning construct, most operations begin with, or plan to begin with, an effort to prepare the future operating environment before the outbreak of hostilities. Shaping operations include numerous functions aimed at simultaneously influencing other actors, be they allies or adversaries, into compliance with national objectives while simultaneously planning and preparing for that influence to fail.¹⁰¹ These operations occur during peacetime, before nations resort to the use of military force. Within an aerial littoral environment, the network of civil drones will exist during shaping operations, but a threat requiring military intervention will not. Whether properly regulated and administered or not, the aerial littoral will function as it should within its designated role in that specific society. The threat inherent in such a construct will remain a decidedly criminal or possibly terrorist threat and require host-nation policing or other similar responses.

Phase I: Deterring. The transition out of shaping operations and into deterrence operations represents a deliberate decision to exercise the nation's military capability to coerce an adversary to comply with a communicated set of political aims.¹⁰² As an activity still deliberately short of armed conflict, deterrence operations can include the

¹⁰⁰ Joint Publication (JP) 5-0, *Joint Operation Planning*, 11 August 2011, III-38.

¹⁰¹ JP 5-0, *Joint Operation Planning*, III-42.

¹⁰² JP 5-0, *Joint Operation Planning*, III-42.

initial mobilization and forward deployment of forces into theater, inherently placing them closer to any threat, but not within an actual hostile area. The existence of the aerial littoral and latent threats inherent within it could serve to complicate this aspect of deterrence operations as it could provide a means for an adversary to hold US forces at risk within an otherwise secure area without presenting an actionable threat to counter.

Further, depending on the location of debarkation and marshalling points, associated host-nations may refuse to authorize the employment of non-domestically acceptable counter-drone capabilities. By holding the military's ability to sustain, protect, and maneuver its forces into theater at risk through the threat of aerial attack, an adversary could present a viable counter-deterrence mechanism and force a deliberate escalation of tensions or abandonment of the desired political objectives. Preempting this threat will likely require assisting, or increasing the capacity of, host-nation civil counter-drone efforts.

Phase II & III: Seizing the Initiative & Dominating. Phases II and III of a military operation represent the traditional use of military forces in armed combat and therefore the clearest case of a deliberate threat to military forces. At the same time, however, the seizing-the-initiative and dominating phases present clearer opportunities for alleviating the threat within the aerial littoral. In these contexts, the voluntary sustainment of civil drone usage within an ongoing-armed conflict is unlikely. Further, host nations and operational commanders are much more likely to authorize and enforce the cessation of civil-aviation functions in both phase II and phase III operations. Depending on the context and proximity to urban areas, a significant threat and the need for domestically acceptable counter-drone capabilities may still exist, but this phase of military operations would likely alleviate the need to distinguish between civil and nefarious drones and allow for more flexible rules of engagement.

The phase II and phase III operations also encapsulate the scenarios most commonly envisioned to precipitate the interaction of military forces with both UAS and drone systems and therefore require counter-drone capabilities. In late 2015, for example, the Army conducted its first live exercise that included consumer-grade drones operating as part of an opposing force, but did not take the exercise beyond phase II and

III operations.¹⁰³ Similarly, despite their recent focus on small drones and acknowledgement of the issue of domestically acceptable solutions, the engagement capabilities tested by the Black Dart program heavily focus on testing and demonstrating destructive systems more applicable to these phases.¹⁰⁴

Although the illicit use of drones in phases II and III poses a threat to ground forces and holds a commander's ability to execute various joint functions at risk, the absence of a viable aerial littoral will keep the task more manageable. The transition out of the dominating phase and into stability operations changes that calculus entirely.

Phase IV: Stabilizing. The proliferation of civil drones and the emergence of the aerial littoral present the biggest impact in the case of stability operations. In this phase, military forces focus on restoring essential services and governance to a location while still facing some level of direct threat.¹⁰⁵ Depending on the context, restoring essential services and local governance may rely heavily on the reemergence or deliberate development of the aerial littoral. This may particularly be the case in situations where the use of drones would allow non-governmental organizations and others in the area to rapidly bypass degraded roads and other infrastructure systems.

The reemergence of a civil-aviation system, particularly in the form of the aerial littoral, will also reintroduce an adversary's capacity to utilize the air domain for nefarious purposes. Having transitioned out of phase III operations, however, the operational commander, local aid workers, and the local populace will likely dismiss the idea of completely shutting down the aerial littoral as a viable countermeasure. Further, the counter-drone capabilities utilized in phase III operations may not suffice as domestically acceptable options, particularly in urban environments. In urban settings, the scenarios will also significantly reduce the engagement timelines as nefarious actors hide their drones, not only within the aerial littoral, but also in and around buildings to mitigate a ground force's detection and identification capabilities. In all, overlaying the

¹⁰³ John Andrew Hamilton, "Drones used for NIE 16.1 recon missions at White Sands Missile Range," US Army, 30 October 2015, http://www.army.mil/article/157980/Drones_used_for_NIE_16_1_recon_missions_at_/.; Michael Francis (engineer, US Army Program Executive Office for Simulation, Training, & Instrumentation, Redstone Arsenal, AL), interview by the author, 10 February 2016.

¹⁰⁴ Tadjdeh, "Inside Black Dart".

¹⁰⁵ JP 5-0, *Joint Operation Planning*, III-43.

aerial littoral on phase IV operations presents more challenges and fewer opportunities than the previous phases.

Phase V: Enabling Civil Authority. As the local government begins to retake the lead on governance and administration of the region, the joint force commander takes on a more supporting role in enabling the success of the local government. The force has largely ceased combat operations and the threat to the forces and their missions has diminished from one requiring a robust military response to one within the capacity of the local policing force. An aerial littoral within a phase V operation will fall under civil authority and return to providing those socially critical services and capabilities. As with phase 0 operations, addressing and countering threats within the aerial littoral revert to civil law-enforcement functions, and the residual threat no longer hinders military efforts.

Viewed across the full spectrum of a military operation, the drone threat will likely result in the greatest mission impact when it is coupled with a robust civil drone environment and a populated location. Phase 0 and phase V operations may encounter an aerial littoral region in a populated environment, but will lack a militarily relevant threat. Phases II and III, on the other hand, will exhibit a threat, but likely lack a pervasive civil-drone presence. Phases I and IV present scenarios with all three attributes, but the threat is more tangible and focused against the military in stability operations. The next chapter will further explore the potential impact to Phase IV stability operations.

Conclusion

The threat to both civil society and military forces posed by the illicit use of small drones is no longer hypothetical. These threats exist and present almost daily challenges around the globe. Coupled with both a rapidly emerging civil-drone environment and robust civil and military counter-drone industries, this trend has the potential to upend how US forces conceptualize both air superiority and the air domain itself. The rise of the aerial littoral and the corresponding unprecedented-level of civil capability, access, and power within the air domain are poised to create an operating environment where, despite the broader force's best efforts, ground forces may operate under a persistent lack of air superiority. Under this paradigm, ground forces may have more to fear of flying pipe bombs than an adversary's strike fighters, a potentially humbling end to over sixty years of assured air superiority.

Chapter 5

Impact of Civil Drones on Stability Operations

In stark contrast to today, upon graduating from the United States Military Academy in the early 1800s, US Army officers had little prospect of participating in major operations far from American shores. Instead, the Army routinely assigned new officers to posts throughout the American West, conducting what would now pass for stability operations. These officers defended settler populations from native attacks, provided humanitarian relief, underwrote local economies, built local infrastructure, conducted law-enforcement activities, and supported the establishment and legitimacy of local governments.¹ In the Mexican-American War, the US Army's first major operation outside of its borders, US soldiers performed similar tasks within both annexed and occupied territories; tasks that required significant non-combat assistance in the form of food distribution, election monitoring, and other efforts geared toward sustaining local governance.² From its earliest days, the US military repeatedly learned, forgot, and relearned the importance of understanding and effectively conducting stability operations.

In 2005, the US Army's Combat Studies Institute requested that its longtime expert on stability operations, Dr. Lawrence Yates, consolidate his thoughts and experience for future generations prior to his upcoming retirement. In the resulting monograph, Dr. Yates emphasized the pressing need at the time to reinvigorate the study of stability operations because of US involvement in Iraq and Afghanistan and further highlighted several recurring themes from his studies that warranted particular attention. Among those areas was an all too common failure to understand the unique differences between the operating environments of conventional and stability operations.³

Of primary concern when studying the effect of civil drones on military operations, the stability-operations environment marks the transition between combat operations and a properly functioning society and therefore inherently brings military forces and civil society into close and regular contact. The primacy of political

¹ Lawrence A. Yates, *The US Military's Experience in Stability Operations, 1789-2005* (Fort Leavenworth, KN: Combat Studies Institute Press, 2006), 3-4.

² Yates, *The US Military's Experience*, 5.

³ Yates, *The US Military's Experience*, 29.

considerations and the need to interact with a wide variety of non-military entities, two focus areas highlighted by Dr. Yates, will drastically alter how the military interacts with drones in these scenarios.⁴ As societies across the globe begin to adopt the use of civil drones for everyday tasks, they simultaneously alter, both physically and politically, the potential operating environments for future stability operations.

Overview of Stability Operations

At their most basic level, stability operations are conducted to assist struggling host nations in their attempt to re-emerge as, or become, properly functioning states. Joint Publication (JP) 3-07, *Stability Operations*, defines stability operations as “various military missions, tasks, and activities conducted outside the US in coordination with other instruments of national power to maintain or reestablish a safe and secure environment, provide essential governmental services, emergency infrastructure reconstruction, and humanitarian relief.”⁵ This contemporary umbrella of stability operations covers a wide variety of previously distinct contingency scenarios such as, peace operations, counterinsurgency, foreign humanitarian assistance, and the protection of civilians.⁶

More so than most types of military operations, successful stability operations rely on the effort and leadership of a wide variety of government agencies, non-governmental organizations and other actors not traditionally associated with military operations. For its part, the military’s primary contribution to stability operations is the creation and maintenance of a secure environment, one which protects the local population and ultimately enables the other players to more efficiently and effectively pursue their relief and reconstruction tasks.⁷ Beyond security, joint doctrine identifies four additional military functions for stability-operations scenarios: humanitarian assistance, economic stabilization and infrastructure, rule of law, and governance and participation.⁸ The Army similarly identifies five specific tasks within its field manual, *Stability*: establish civil security and civil control, restore essential services, support

⁴ Yates, *The US Military’s Experience*, 29-35.

⁵ Joint Publication (JP) 3-07, *Stability Operations*, 29 September 2011, vii.

⁶ Army Field Manual (FM) 3-07, *Stability*, June 2014, 1-6-7.

⁷ JP 3-07, *Stability Operations*, vii.

⁸ JP 3-07, *Stability Operations*, xv.

governance, and support economic and infrastructure development.⁹ While these appear as military-oriented functions and tasks within joint and service doctrine, they are anything but unique to the military. These functions cover the majority of efforts required to reestablish a functioning state, regardless of which organization coordinates them.

To that end, joint and service doctrine identify how military forces can assist in each of these functional areas, but routinely qualify those recommendations with the position that the agent of choice for each of these tasks is the host nation, followed by Intergovernmental Organizations (IGO) and Non-Governmental Organizations (NGO) with military forces only as an option of last resort. Furthermore, whereas a military force regularly assumes the lead role for the security function, it will usually assume a supporting role for the remaining functions. Regardless of who leads the effort, the desired end-state associated with each stability function is to return ownership and responsibility for that function to the host nation as soon as possible.¹⁰

Another key caveat to the stability functions lies in the extreme variability of stability operations. Joint and service doctrine are quick to note the extreme dependence on context and uniqueness of each stability operation¹¹. No two are alike and no single operational plan or prescribed balance among the various functions will suffice for all stability scenarios. Some stability operations, for example, require the continuation of combat operations to support the maintenance of security, where others, such as instances of humanitarian assistance following a natural disaster, may lack any discernable security threat and instead focus entirely on the restoration of essential services. Understanding the players, the functional underpinnings, and goals of stability operations is a critical prerequisite to assessing how the proliferation of civil drones might affect their future.

Security

Put simply, a reasonably secure environment is a prerequisite for stability. The security function attempts to create and sustain a safe and secure environment to allow the local population, the host nation, and other necessary actors the opportunity to

⁹ FM 3-07, *Stability*, 1-2.

¹⁰ JP 3-07, *Stability Operations*, xv.

¹¹ JP 3-07, *Stability Operations*, 12.; FM 3-07, *Stability*, 1-10.

address the issues plaguing the nation without fear of violence.¹² To achieve that end, typical sub-tasks include the reestablishment of physical and territorial security, the cessation of large-scale violence, the restoration of public order, and the restoration of the host-nation's sole monopoly on the use of violence.¹³ Potential roles for military forces include, among others, disarming and reintegrating belligerent parties, controlling national borders, directly protecting the lives and property of civilians and relief personnel, protecting public infrastructure and supporting the restoration of public order through policing activities.¹⁴ Ultimately, the goal is to increase security and reduce the amount of violence to a point where the host nation's government can retake responsibility and effectively control the situation.

Of particular note in the context of stability operations is the need to balance one's concern for force protection versus the protection of civilians. Particularly when facing fickle domestic support at home or in the wake of large-scale troop losses, US commanders have, at various points in history, prioritized the security of their troops over all other considerations. The counter-argument to favoring force protection, however, lies in the concepts of proportionality and constant-care where commanders should make all reasonable efforts to protect civilians and civilian infrastructure, including efforts that actually increase risk to their own personnel or their missions. This issue becomes particularly important when balancing security operations against the other stability functions.

Humanitarian Assistance

Perhaps somewhat counterintuitively, the threat of violence inherent in insecure environments does not necessarily represent the most prominent source of death and suffering. Natural disasters and armed conflicts alike often create second- or third-order effects which undermine a host nation's or region's ability to provide the essential services necessary to sustain life. The resulting lack of food, water, shelter, health services, or similar basic needs can lead to significant humanitarian crises which can, in turn, perpetuate the internal conflict and insecurity which created the original crisis. The

¹² JP 3-07, *Stability Operations*, III-4.

¹³ JP 3-07, *Stability Operations*, III-6.

¹⁴ JP 3-07, *Stability Operations*, III-8-12

humanitarian-assistance function aims to stop this cycle of violence by providing the basic goods and services necessary to end human suffering.¹⁵ Beyond meeting the basic needs of survival, this function also aims to restore access to education services, locate and resettle refugees, and resolve internal social issues and root causes of the conflict.¹⁶ With the potential exception of emergent and first-responder situations, military forces usually assume a supporting role within humanitarian-assistance efforts. That support often revolves around the provision of transportation capabilities, such as airlift and sealift assets, to assist in the delivery of humanitarian aid.¹⁷

Of particular concern to the military commander is the interplay between the humanitarian assistance and security functions. As previously alluded to, the population's desire to survive in humanitarian disaster scenarios can significantly increase the level of instability and insecurity in a region as those populations attempt to gain access to, or control access to, the limited resources available. Further, perpetual insecurity may hinder the ability of external relief organizations to effectively distribute relief supplies and curb the suffering. These issues can drive additional security requirements when the distribution of an essential good or service revolves around a specific location, such as a food distribution point or a water well, as those locations take on an inherent value for any actor who can control them. The military commander must understand the dynamic nature of this situation and ensure the protection of the population's access to those locations and services as the situation evolves.

Economic Stabilization and Infrastructure

As with the other stability-operations functions, the economic-stabilization-and-infrastructure function aims to restore two more aspects of a routine and predictable local environment and reinforce the personal and local desire for and investment in stability. The economic aspect focuses on restoring a market economy, generating employment opportunities, and eliminating threats to the long-term sustainment of that economy from illicit actors such as looters or corrupt officials.¹⁸ The infrastructure portion of this function, on the other hand, aims to restore the infrastructure needed for basic

¹⁵ JP 3-07, *Stability Operations*, III-18.

¹⁶ JP 3-07, *Stability Operations*, III-22.

¹⁷ JP 3-07, *Stability Operations*, III-19-20.

¹⁸ JP 3-07, *Stability Operations*, III-29.

government and utility services necessary for a properly functioning society. Examples of this include the infrastructure required for typical essential services, collectively known as SWEAT-MS (sewage, water, electricity, academics, trash, medical, and safety), as well as broader requirements such as transportation systems.¹⁹

Actors within the civilian sector almost always lead this function, but, depending on the specific context, they may require extensive military support to initiate and sustain their efforts. Military tasks in support of this can include establishing employment markets and monetary and fiscal policy, providing funding or materials for construction projects, directly rebuilding damaged electrical systems and even assisting in the restoration of both wired and wireless communications systems.²⁰ Ultimately, however, the military's primary role in supporting of each of these critical lines of effort is to provide the necessary security for their implementation.

Rule of Law

Without the reestablishment of the rule of law, the host nation cannot legitimately lay claim to governing. Reestablishing or reinforcing the rule of law aims to develop a consistent and enforceable legal framework, public and private accountability and access to the law, and an overall "culture of lawfulness" where most citizens recognize and follow the law. In situations where the rule of law is notably absent upon the arrival of military forces, or after the transition out of combat operations, those forces may need to institute interim legal systems, reestablish indigenous police forces, provide for the protection of personal property, or initiate war-crime tribunals.²¹ Ideally, the host nation will possess a current legal framework which only requires reinforcement or a historical framework upon which to build a new system.²² Particularly in either of those situations, the military role is decidedly one in support of the host nation's efforts and requires less in the way of dictating local policy.

¹⁹ JP 3-07, *Stability Operations*, III-27.; Keith Crane, Olga Olikier, Nora Bensahel, Derek Eaton, S. Jamie Gayton, Brooke Stearns Lawson, Jeffrey Martini, et al., *Guidebook for Supporting Economic Development in Stability Operations*, Technical Report TR-633-A (Santa Monica, CA: RAND, 2009), 3.

²⁰ JP 3-07, *Stability Operations*, III-31-34.

²¹ JP 3-07, *Stability Operations*, III-44-47.

²² JP 3-07, *Stability Operations*, III-41.

Governance and Participation

The final of the five stability-operations functions centers on enabling and empowering host-nation political processes and governance. This function includes those efforts necessary “to help the people to share, access, or compete for power through nonviolent political processes and enjoy the collective benefits and services of the state” and therefore intimately relies upon the processes, capabilities, and infrastructure created through the other stability-operations functions.²³ These efforts are fundamentally reliant on civilian leadership, but can also require military involvement through the provision of expertise, security and logistical support to political planning events, elections, local governance initiatives, and even anticorruption efforts.²⁴

When considering the various functions inherent in the effective conduct of stability operations, it is easy to consider them in isolation; however, military forces will likely face, and must prepare for, executing all of the stability functions at the same time. The functions are intimately linked and dependent on the proper execution of each other for their success. The governance-and-participation function fully encapsulates this issue as restoring security, essential services, a functioning economy and the rule of law are fundamentally prerequisites to citizens concerning themselves in higher level affairs such as electing public officials or writing new constitutions. Commanders must understand this interdependency and appropriately balance their efforts, along with those in the civilian sectors, across each of the stability functions or risk long-term failure due to ignoring or under-resourcing even one of the functions.

Wargaming Drones in Stability Operations

Understanding the five functions within stability operations is necessary, but not sufficient, to assessing the potential impact of civil drones on military operations. The critical piece of this assessment is determining how drones will affect those functions; however, that will be highly dependent on the context of a specific scenario. To that end, this section examines the counter-factual integration of civil drones into an historic stability-operations scenario in order to envision how that might affect future scenarios.

²³ JP 3-07, *Stability Operations*, III-47.

²⁴ JP 3-07, *Stability Operations*, III-49-51

For several reasons, this analysis focuses on the US and United Nations (UN) intervention in Somalia in 1992-93. First, this scenario provides ample examples of each of the stability-operations functions and a wide variety of state and non-state actors. Further, it is a well-researched and well-understood case study which provides a solid foundation upon which to build the decidedly speculative drone discussion. More contemporary examples, such as the conflicts in Ukraine or Syria, which do exhibit actual small-drone operations, are not yet sufficiently understood and would introduce too much uncertainty in the analysis. Similarly, with the passage of time, the Somalia example allows for a more dispassionate review than an example based on Iraq or Afghanistan.

The intent here is not to rewrite history or depict with certainty how drones operate within and influence future missions, but instead to illustrate potential ways in which civil drones may interface with military operations and prompt further research into those possibilities.

Historical Baseline – Somalia, 1992

Somalia has a long history of political unrest and both internal and external conflict stemming from its emergence from colonial rule as an independent state in 1960.²⁵ In January 1991, that longstanding internal conflict reached a new apex and resulted in the overthrow of the Somali government and ouster of President Mohammed Siyad Barre by a loose alliance of three opposition movements. Unable to consolidate their collective political and economic power and restore order to the country, the opposition warlords refocused their efforts onto an internal power struggle and, in the process, exacerbated an already existing humanitarian crisis.²⁶

As the opposition warlords closed in on Siyad Barre's stronghold in the capital of Mogadishu and then expanded out again in their ensuing power struggle, the fighting decimated the farms and livestock herds that formed the foundation of Somalia's agriculture-centric economy and its population's primary food source.²⁷ In addition to the 14,000 people killed and 30,000 wounded in the civil unrest, the subsequent famine resulted in the deaths of up to 300,000 Somalis and the displacement of another

²⁵ Ioan Lewis and James Mayall, "Somalia," in *United Nations Interventionism: 1991-2004*, ed. Mats Berdal and Spyros Economides (New York: Cambridge University Press, 2007), 108.

²⁶ Lewis, "Somalia," 113.

²⁷ Lewis, "Somalia," 113-114.

700,000.²⁸ With an estimated 1.5 million additional Somalis, out of a total population of roughly 5 million, on the brink of starvation by August 1992, the UN decided to intervene in an attempt to stem the tide of the rapidly spreading waves of famine, disease, and destruction.²⁹

Over the next year, UN intervention occurred in fits and starts. Already minimally involved since dispatching 50 ceasefire observers to the region in United Nations Operation in Somalia I (UNOSOM I) in April, the UN's August 1992 authorization included an additional 500 troops to provide security for food-distribution services.³⁰ When that effort did not produce the desired results, the UN authorized the additional deployment of a US-led multi-national task force consisting of 35 countries and an eventual 33,656 personnel in December 1992.³¹ The Unified Task Force (UNITAF), participating in Operation Restore Hope, quickly restored security within Mogadishu and began expanding its influence throughout nine designated humanitarian relief sectors in southern Somalia.³²

Although not absolute, the level of security that UNITAF provided allowed the 49 Non-Governmental Organizations (NGO) and other humanitarian relief efforts in Somalia to rapidly expand their food distribution, and reconstruction efforts.³³ While the UNITAF forces largely focused on securing food-distribution nodes and transportation routes, NGOs still faced direct security threats at other operating locations and often resorted to hiring local Somali guards under a local warlord-run protection racket.³⁴ Furthermore, widespread looting and banditry manifested itself in events ranging from direct theft of food and relief supplies to the regular disappearance of water pumps in rural areas that later wound up for sale in local markets.³⁵ Beyond security issues, NGOs

²⁸ Lewis, "Somalia," 119.

²⁹ Lewis, "Somalia," 122.

³⁰ Lewis, "Somalia," 122.

³¹ Lewis, "Somalia," 124.

³² Richard W. Stewart, *The United States Army in Somalia: 1992-1994* (Washington, DC: U.S. Army Center of Military History, 2002), 10-11.

³³ Stewart, *United States Army in Somalia*, 10.

³⁴ John M. George, "The Politics of Peace: The Challenge of Civil-Military Cooperation in Somalia," *Public Administration & Management* 10, no. 2 (2005): 185.

³⁵ John G. Sommer and Carole C. Collins, *Humanitarian Aid in Somalia: The Role of the Office of U.S. Foreign Disaster Assistance (OFDA) 1990-1994*, Report PN-ACA-865 (Washington, DC: The Refugee Policy Group, November 1994), 13.

also faced an almost complete lack of supporting infrastructure. In describing the situation, one author opined, “Imagine a country without telephones, banks, postal services, faxes and other communication facilities and with few good roads and one can understand the isolation of Somaliland NGOs and appreciate the circumstances in which they work.”³⁶ Despite these issues, the various NGOs pushed forward with efforts to restore essential services by distributing food, restoring water services, developing community health and vaccination programs, and revitalizing the languishing agricultural and livestock industries.³⁷ As some sense of security and normalcy spread, the civilian population reopened local markets, began to travel again, and generally returned to established routines.³⁸

Not solely dedicated to protecting the local civilian and NGO populations, UNITAF forces also directly participated in efforts spanning the full range of military roles in stability operations. In addition to daily patrols, UNITAF forces restored damaged transportation infrastructure by repairing over 1,800 kilometers of roads and reopening and operating ports and airports. They also assisted in efforts to restore existing water and irrigation systems, rebuild schools, identify additional vulnerable populations, and provide medical assistance and outreach efforts throughout their assigned sectors.³⁹

While assessments of UNITAF’s overall mission success vary wildly, particularly with the addition of hindsight, when they returned the mission to UN control under the newly formed UNOSOM II in May 1993, the famine was largely under control and local actors were making sustained, albeit slow, progress towards restoring governance.⁴⁰

Part of that apparent success, however, stemmed from the local warlords simply biding their time; knowing that UNITAF forces would leave relatively quickly and be replaced by less-capable forces. Barely one month after the transition to UNOSOM II, one of the local warlords, General Mohamed Aideed, launched an all-out assault on the

³⁶ Mohamed Sheik Abdillahi, *Somaliland NGOs: Challenges and opportunities* (London, UK: Catholic Institute for International Relations, 1997), 2.

³⁷ Sommer, *Humanitarian Aid*, 27.

³⁸ Stewart, *United States Army in Somalia*, 13.

³⁹ Stewart, *United States Army in Somalia*, 13.; George, “The Politics of Peace,” 169.

⁴⁰ Lewis, “Somalia,” 125.; George, “The Politics of Peace,” 175.

UN forces, killing or wounding 68 Pakistani soldiers on June 5, 1993.⁴¹ This event precipitated a rapid escalation in combat operations on both sides with UN and US forces mounting concerted efforts over the next several months to capture Aideed. His forces and sympathizers routinely ambushed UN forces with small arms, command-detonated mines, and rocket-propelled grenades (RPG).⁴²

The culminating event, portrayed in Mark Bowden's *Black Hawk Down*, occurred on 3 October 1993 when Aideed's forces shot down two MH-60 Blackhawk helicopters involved in a snatch-and-grab raid and then proceeded to engage UN and US forces well into the early hours of 4 October. The resulting death of 18 US service members, several more non-US coalition members, and up to 1,500 Somali fighters and civilians shocked the US public and forced President Bill Clinton to eventually withdraw all US forces from Somalia by 31 March 1994.⁴³ Unfortunately, despite the progress made during the UN's initial efforts, after all UN and US forces withdrew in March 1995, southern and central Somalia still lacked any semblance of a central government or longer-term path to reconstruction. International intervention had succeeded in ending the famine, but failed to resolve its root causes.⁴⁴

Drones in a Somalia Scenario

Unmanned aircraft were not present in the 1992 conflict in Somalia. At the time, the US and Israeli militaries were just beginning their 1990s era explosion of UAS development, and the civil drone industry was virtually non-existent.⁴⁵ The intent of introducing civil drones into the Somalia scenario is not to show a direct cause and effect of how drones would have changed the results, but to show how the various actors may have used drones to address issues that future forces are likely to face while accomplishing similar missions and speculate about those interactions. To that end, the following assessment assumes a Somalia-like scenario set in 2020, assumes a

⁴¹ Stewart, *United States Army in Somalia*, 16.

⁴² Stewart, *United States Army in Somalia*, 16-19.

⁴³ Stewart, *United States Army in Somalia*, 19-24.

⁴⁴ Lewis, "Somalia," 137.

⁴⁵ Laurence R. "Nuke" Newcome, *Unmanned Aviation: A Brief History of Unmanned Aerial Vehicles* (Reston, VA: American Institute of Aeronautics and Astronautics (AIAA), 2004), 96-99.

conservative projection of civil-drone capabilities, and investigates their use from the perspectives of military, NGO, and illicit actors present in the original scenario.

Military UASs. The military use of UASs in a Somalia-like scenario would likely resemble military UAS usage today. Between the Army and Air Force, the military would employ a wide variety of UASs, ranging from smaller tactical ISR units to larger systems with kinetic or electronic-engagement capabilities. The main use for these systems would remain ISR-centric, particularly focused on protecting and surveying food distribution routes and locations within and between cities. Further, tactical systems would also shadow ground units on their daily patrols and perform base, port, and airport-perimeter surveillance. Additionally, Army units could utilize smaller UASs to assist in the distribution of leaflets and as a conduit for other information operations. From a military perspective, each of these UAS applications represent additional capacity, but not additional capabilities as the UNITAF forces did exercise each of these functions with their manned helicopters and tactical airlift systems, albeit in a much more limited scale.⁴⁶ As Michael Kreuzer predicted, by augmenting or supplanting existing capabilities, the addition of military UASs would present a marked increase in capacity, but would most likely not revolutionize the operation.⁴⁷ The addition of UASs could provide for increased efficiencies as ground commanders better utilize and employ their forces, but the basic functions, and employment schemes and issues, exhibited in the actual 1992 Somalia scenario, would remain the same.

NGO Drones. As the second major player in the Somalia scenario, NGOs would benefit the most from the addition of drones to their existing operations. NGOs are already delivering food and medical supplies, surveying disaster areas, and monitoring wildlife activity with drones, so their use of drones in a Somalia scenario does not present too far of a logical leap.⁴⁸ UNITAF forces and NGOs did make limited attempts to

⁴⁶ Stewart, *United States Army in Somalia*, 13-16.

⁴⁷ Michael P. Kreuzer, "Remotely Piloted Aircraft: Evolution, Diffusion, and the Future of Air Warfare" (PhD diss., Princeton University, September 2014), 17.

⁴⁸ Scott Mitchell, "Drones are Being Tested in the Fight Against a Tuberculosis Epidemic in Papua New Guinea," *Vice News*, 3 December 2014, <https://news.vice.com/article/drones-are-being-tested-in-the-fight-against-a-tuberculosis-epidemic-in-papua-new-guinea>; Thomas McMullan, "The unmanned aerial vehicles that are giving drones a good name," *the guardian*, 4 May 2015, <http://www.theguardian.com/technology/2015/may/04/unmanned-aerial-vehicles-giving-drones-a-good-name>; Kim Helfrich, "South Africa's UAVs – Crime Fighters and Job Creators," *defenceWeb*, 9 September 2015, http://www.defenceweb.co.za/index.php?option=com_content&task=view&id=40639&catid=35&Itemid=107.

airdrop food packages to remote locations in Somalia, but it was a measure of last resort due to its cost and the inability to ensure delivery of the food to the intended recipients and not, instead, into the hands of the local warlords.⁴⁹ Direct drone delivery of small quantities of food and water in emergencies or larger amounts to designated distribution points could potentially alleviate those issues. Further, the use of drones would allow NGOs to quickly bypass poor infrastructure or particularly insecure areas and still deliver much-needed aid. In one actual example, Somali relief personnel waited six days to finally reach a remote village due to the unavailability of military escorts to cover the route, all while hundreds of children died each day in that village alone.⁵⁰ Furthermore, the aerial delivery of food, medicine, and water could alleviate some of the insecurity around food distribution points by dispersing those crowds to more remote and potentially more secure locations.

Beyond the fixed locations near relief-distribution points, the broader physical security situation for the NGOs on the ground in Somalia would also benefit from the use of civil drones. In most cases, the military focused almost entirely on securing critical nodes in the food-distribution systems such as the ports and airports, the food-distribution centers, and the transportation routes and hubs between those points.⁵¹ Beyond those areas, NGOs had to provide for their own physical security. The use of surveillance drones for routine patrols of NGO housing and work sites, food and supply storage points, and critical infrastructure systems, such as water pumps, would increase the effectiveness of the NGOs' limited security capabilities and provide at least a modest level of deterrence against theft and destruction. As many NGO personnel carried their own small arms prior to the arrival of UNITAF forces, the use of drones armed with non-lethal projectiles for crowd-control purposes around food distribution points or NGO housing areas may fit this scenario.⁵² Though not an option which the US or UN forces aggressively pursued, several real-world reports indicated the local Somali police force was a professional and capable force in desperate need of force-multiplying capabilities. Any of these drone-based ISR and engagement capabilities would also suit those

⁴⁹ Sommer, *Humanitarian Aid*, 24.

⁵⁰ George, "The Politics of Peace," 173.

⁵¹ George, "The Politics of Peace," 173.

⁵² Sommer, *Humanitarian Aid*, 20

purposes. The employment of drones for security purposes by NGOs or local police forces would decrease the reliance on military forces for securing specific locations and allow them to broaden their general security effort.

Beyond its applicability to security and food-distribution problems, the potential use of drones in a future Somalia-like scenario encompasses a wide variety of problems that otherwise hinder the success of numerous NGO missions. First, the aerial-survey applications which are rapidly emerging in the commercial and public sectors would significantly enhance an NGO's ability to rapidly identify vulnerable populations and degraded essential service infrastructure, including roads, wells, farms, or even communications systems. Beyond identifying potential problem areas, aerial-survey capabilities also allow these organizations to plan their response options more accurately and assess potential impediments such as local-militia operations or degraded roads. Each of these tasks would allow the relief organizations to utilize their limited time and resources more efficiently. Other emerging drone applications such as telemedicine, communications and internet services, postal delivery, crop dusting, and small-goods delivery would also directly address known issues from the Somalia scenario.

A major contributing factor to the outpouring of aid and the simultaneous international clamor for intervention in Somalia stemmed from extensive media coverage of the widespread suffering from the combination of famine, drought, conflict, and economic collapse. International media outlets and NGOs alike utilized images of fly-covered children starving in the streets to both rally support for intervention and elicit monetary aid for the relief efforts.⁵³ Despite security concerns, media coverage continued throughout the conflict, even after Somali crowds killed several journalists in the streets of Mogadishu and displayed their bodies for all the world to see.⁵⁴ The use of drones for aerial videography would greatly enhance any reporters or filmmaker's capabilities, particularly for small teams with limited assets. A lone reporter, armed with a handheld drone, could upload high-quality personal reporting and aerial footage and appear regularly on the nightly international news with reduced personal danger and little logistics footprint. The operational flexibility provided by this light-logistics footprint

⁵³ Stewart, *United States Army in Somalia*, 6.

⁵⁴ Stewart, *United States Army in Somalia*, 16.

would allow the reporter to remain sufficiently flexible and mobile to convey a much broader understanding of the situation to international audiences than an otherwise terrestrially-bound reporter or filmmaker.

Unlike the inclusion of UASs from the military's perspective, the use of drones by NGOs in a Somalia-like scenario does not replace or even augment a previously existing aerial capability. Instead, drones represent completely new sets of capabilities to NGO and other civil sector actors and could tangibly alter their effectiveness in a Somalia-like scenario. The expanded flexibility and geographic reach would allow NGOs to shift their resources more rapidly to those areas most in need, while at the same time providing increased security for both the NGO employees and the local population in general. Whether or not the use of drones by civil-sector actors significantly changes the outcome of the scenario is beyond the scope of this paper; however, their mere existence within the area of operations creates the aerial-littoral environment, which will complicate the military's ability to mitigate the threat from the Somalia scenario's next set of actors.

Nefarious Drones. Like the civil organizations within the Somalia scenario, the warlord, criminal, and jihadist actors lacked access to any aerial capabilities in 1992. Access to drone capabilities would therefore present these organizations with a new and asymmetric capability, one which similar organizations have already employed in conflicts in Syria, Libya, and Ukraine.⁵⁵ As previously discussed, once adequately demonstrated in these types of venues, the use of small drones by nefarious actors is highly likely to spread amongst similar organizations. Given that baseline, a future scenario similar to the conflict in Somalia would present ample motivation and opportunity for nefarious actors to employ drones in pursuit of their objectives.

In the 1992-93 events in Somalia, particularly in Mogadishu, Aideed's forces routinely exchanged small arms fire and eventually escalated to the use of improvised explosive devices (IED) against patrols, RPGs against both ground patrols and helicopters, and mortars against the ports and airport.⁵⁶ Although Aideed's forces proved relatively successful with these techniques, an explosive-laden drone would significantly

⁵⁵ Larry Friese, N.R. Jenzen-Jones and Michael Smallwood, *Emerging Unmanned Threats: The use of commercially-available UAVs by armed non-state actors*, special report (Perth, Australia: Armament Research Services (ARES), February 2016), 10.

⁵⁶ Stewart, *United States Army in Somalia*, 16-19, 23.

increase the effectiveness of these strikes due to the addition of precision-guidance capabilities, whether directly commanded or homing independently based on a visual or thermal image. By simply massing their RPGs, Aideed's forces successfully downed four Black Hawk helicopters and critically damaged at least two others.⁵⁷ Even without explosive payloads, drones threaten aircraft and helicopter engines through kinetic attacks, and warlords could use this threat to saturate the area in order to simply clutter the air picture within the aerial littoral or force military aircraft out of the area or to higher altitudes where they will be less effective in a complex urban environment. Among other force-protection and base-defense issues, the illicit use of drones within an aerial littoral environment would drastically increase the risk to flight operations, particularly for low-level helicopter operations. This would force military commanders to accept that additional risk, alter the flight profiles for those helicopters, or otherwise divert resources in order to mitigate the drone threat.

Similarly, by conducting strikes against fixed locations and against aircraft on takeoff and landing, swarms of flying IEDs could hinder operations at the local airport well beyond the minimal impact of mortars in 1993. Since the events of 1992-93, the urban areas of Mogadishu have encroached upon the city's airport to the point where buildings which could provide cover for insurgent activity now exist as close as across the street from the terminal building and just beyond the end of the flight line. Not unlike many airports around the globe, this proximity provides ample cover to launch drone attacks against the airfield and confront defenders with very short engagement timelines. The local Somali ports present similar encroachment issues. Even if drone strikes proved militarily ineffective, their value as tools of terror and indiscriminate violence would serve as ample deterrents to the domestic publics of the intervening nations as well as the local populations, particularly when those nefarious actors are not overly concerned with discerning between military targets and civilian bystanders.

Beyond these armed applications, the commercial-off-the-shelf capabilities available in current drones provide ample ISR capabilities for any militant group. In the Somalia scenario, Aideed's forces already utilized a network of human observers linked via radios and cellular phones to track the movement of UN forces in order to both

⁵⁷ Stewart, *United States Army in Somalia*, 19-23.

maneuver around them and plan ambush attacks.⁵⁸ The use of drones, as demonstrated by both Hezbollah and the so-called Islamic State in Iraq and al-Sham (ISIS), to monitor regular activity patterns and observe units on patrol would provide a highly flexible alternative to the human observers. Furthermore, although the various Somali warlords were able to circumvent the UN weapons embargos at some points, the use of drones for smuggling purposes would provide them with increased flexibility and dispersion of their illicit goods and therefore reduce their odds of detection and seizure.⁵⁹

Within this scenario, the illicit use of drones for electronic warfare purposes would pose several distinct threats. First, despite the use of communications jammers in 1993, the use of drone-based communication jammers would wreak havoc on an already sparse civil-communications network, particularly one that is as heavily reliant on radio and cellular communications as is modern-day Somalia.⁶⁰ Second, the low regulatory environment of a failed state and the extensive diversity of actors within the aerial littoral in this scenario present fertile ground for nefarious actors to hack into legitimate systems in order to use their video feeds or control them for actual kinetic purposes, both capabilities which already exist in limited situations.⁶¹ Finally, the simple presence of additional drones in the skies could potentially saturate the portions of the radio-frequency spectrum used for other legitimate communication and command-and-control functions.

Counter-drone capabilities. One cannot assess the potential implication of the addition of drones to any given scenario without also considering the application of counter-drone capabilities. In that vein, the Somalia scenario presents two distinct counter-drone environments: the densely populated urban area around Mogadishu and the more sparsely populated outlying regions. Although the concept of domestically acceptable counter-drone systems would exert an influence in both cases, counter-drone operations in and near Mogadishu pose greater challenges than those that military forces

⁵⁸ John R. Murphy, "Memoires of Somalia," *Marine Corps Gazette*, 82, no. 4 (April 1998): 20-25.

⁵⁹ Ray Murphy, *UN Peacekeeping in Lebanon, Somalia and Kosovo* (New York: Cambridge University Press, 2007), 54.

⁶⁰ Murphy, "Memoires of Somalia," 25.; Immigration and Refugee Board of Canada, *Somalia: Prevalence of cell phones and Internet cafes in Mogadishu, including the ability to use cell phones for financial transfers (2012-February 2015)* (Ottawa, Canada: Research Directorate, Immigration and Refugee Board of Canada, 5 March 2015), <http://irb-cisr.gc.ca/Eng/ResRec/RirRdi/Pages/index.aspx?doc=455769&p1s=1>.

⁶¹ Marc Goodman, *Future Crimes* (New York, NY: Doubleday, 2015), 304.

would face outside of an urban environment. In those areas, military commanders would likely need to refrain from the use of kinetic counter-drone systems and communications jammers in deference to the local population and relief organizations and therefore need to resort to less extreme and possibly less effective measures. Once again, the balance between protecting civilians and local infrastructure and accomplishing the military objective and protecting military forces generally favors protecting civilians.

Given the prevalence of military and civil drones in the scenario, the overall difficulty in restricting access to drone technologies, and the proven ability to smuggle weapons throughout the real-world Somalia example, counter-proliferation efforts would likely slow the spread, but ultimately fail to keep small drones out of the hands of nefarious actors. Once counter-proliferation efforts fail, if commanders try them at all, the problem becomes one of detection and identification of the threat in a drone-dense aerial-littoral environment. As a first step, the local commander might implement a drone air traffic control (ATC) system and mandate participation in order to facilitate the identification of friend or foe (IFF) process. However, these systems are voluntary in nature and require a high degree of compliance in order to delineate between legitimate and illegitimate aircraft. One only has to look at the mass confusion generated within the Federal Aviation Administration's control centers after terrorists turned off their IFF transponders on 9/11, a move that instantly negated the entire paradigm of voluntary self-identification.⁶² Particularly in a highly unregulated environment such as Somalia, if only a modest portion of activity within the aerial littoral fails to comply with the ATC mandates, then the IFF problem would remain a considerable challenge.

Further, an ATC system would not alleviate the threat of hijacked drones as ISR or kinetic threats or the threat from rooftop- or alleyway-launched drones in short-duration engagements and significantly limit available response time. The local commander would face similar issues with implementing "no-drone zones," approved flight corridors, or entry and inspection points around the city due to the similarly voluntary nature of those processes. Further, these options would only assist in the

⁶² Lynn Spencer, *Touching History: The Untold Story of the Drama That Unfolded in the Skies over America on 9/11* (New York: Free Press, 2008), 12-13, 32-33, 70.

identification of a threat and would still necessitate the use of an engagement system to neutralize the threat.

One promising passive counter-drone system for this scenario is the use of anti-drone netting strung between buildings or at strategic locations around the city. Similar to methods already used to protect crowds at sporting events or other public venues; this involves erecting a net canopy over and around food-distribution points to prevent kinetic attacks on either crowds or security forces. However, this would not counteract surveillance missions or other nefarious uses such as a crop-dusting style terror attack and, unless carefully coordinated, could hinder the operations of those relief organizations similarly reliant on drone capabilities. The same issues would also hold true for creating specific zones of communications jamming put in place to shut down all drone operations around relief distribution or other secure sites, particularly because defense forces would have to make the location of the jamming zones public knowledge.

Outside of the city, in more sparsely populated regions, the second-order effects of destructive counter-drone capabilities are less worrisome, but not insignificant. Food-distribution points, water pumps, medical clinics and other public-gathering locations still represent targets for nefarious actors that require protection while simultaneously increasing the risk of inadvertently injuring civilians when countering a drone threat. In these situations, although security forces could likely handle a lone aerial threat with net cannons or a similar domestically appropriate system, the significant threat takes the form of a swarm of drones or hostile drones operating in the clutter of legitimate-drone activity. This scenario complicates the problem and drastically reduces the chances of military forces successfully neutralizing that threat without collateral damage to legitimate drones or innocent bystanders.

Assessing the civil-drone scenario. Although it does not address all potential implications of a civil-drone system, the Somalia case presents many of the factors which will complicate the execution of military operations in this emerging environment. Due to the dynamic nature of both this type of operational scenario and the evolving civil-drone phenomenon, one cannot accurately predict the explicit impact of a future capability on a notional scenario; however, this thought exercise does reveal some general implications which warrant further investigation.

First, the capabilities provided by the emerging civil-drone systems have broad applicability to a wide range of scenarios encountered under the umbrella of stability operations. Aerial-surveillance capabilities and the ability to bypass degraded or destroyed transportation infrastructure make drones highly useful tools for humanitarian-intervention and disaster-relief scenarios such as in Somalia in 1992, Indonesia in 2004, Haiti in 2010 or Japan in 2011. As capabilities mature, local governments and NGOs will likely continue to incorporate drones into their everyday operations. Given the general desire for NGOs to distance themselves, as much as possible, from relying on military support, the utility and flexibility provided by access to the air domain via civil drones is too enticing to ignore.⁶³

Second, the inclusion of civil drones in stability-operations scenarios will complicate the already fine balance between force-protection requirements and protecting civilian populations and infrastructure. The need to adopt domestically acceptable counter-drone solutions will significantly limit the ability of operational commanders to neutralize drone threats to both their own forces and the broader civil population. Further, the current state of counter-drone capabilities is not sufficient to adequately address this situation and requires additional focus on domestically acceptable solutions.

Third, similar to the delicate balance between force protection and civilian protection, these scenarios would drive further issues in balancing force protection and mission requirements. As the Somalia scenario suggests, helicopter operations within an aerial littoral environment will become particularly risky. Similarly, airfields and forward-operating bases located in close proximity to urban environments will face increasingly precise and deadly engagements and shorter engagement timelines from small-drone threats. The resulting drive for even more remote operating bases and decreased, dispersed or diminished aerial support will increasingly isolate the military forces on the ground and require them to encounter both the aerial threat and focused ground threat on their own. This increased risk could drastically alter the strategic environment in situations such as the intervention in Somalia, where US domestic audiences have an extremely low tolerance for combat casualties.⁶⁴ The resulting

⁶³ George, "The Politics of Peace," 173.

⁶⁴ Murphy, *UN Peacekeeping*, 61.

limitations and risks to the tactical, operational or even strategic employment of force could drastically change how the military confronts these types of scenarios.

Finally, the lagging ability to rapidly and accurately detect and identify drone threats, especially against an aerial littoral background, will continue to hinder the successful neutralization of these threats. In failed-state or otherwise unregulated aerial environments, the identification-and-discrimination problem will increase due to the inherently voluntary nature of most IFF protocols and the inability to sufficiently deter non-compliance without the ability to successfully interdict non-compliant systems. At a minimum, saturating the aerial environment with numerous disposable targets to clutter the air picture, interfere with legitimate uses of the air domain, or simply terrorize the public becomes an increasingly easy task in these scenarios. The implications to both military operations and civilian-relief efforts are anything but trivial.

Conclusion

In his final monograph before his retirement in 2005, Yates noted that although the US military has participated in fewer than a dozen conventional wars throughout its history, over the same period it has engaged in several hundred stability operations.⁶⁵ Stability operations are not an aberration that the military must occasionally encounter; these contingencies have been and will likely continue to be the norm. The introduction of civil- and illicit-drone usage may not decisively alter the outcome of any specific scenario, but that introduction and its revolutionary access to the aerial domain presents numerous opportunities for both civil and nefarious actors to exploit. Within the resulting aerial-littoral environment, even minor threats can significantly influence a military force's ability to execute its assigned mission, particularly when political considerations limit their response options to "domestically acceptable" means.

⁶⁵ Yates, *The US Military's Experience*, 1.

Chapter 6

Conclusions and Recommendations

The proliferation of civil drones is universally expanding society's access to the air domain in previously unimaginable ways. Once solely the realm of states and large corporations, the drone revolution now allows small businesses, private citizens, and local governments alike to take to the skies in order to deliver goods, inspect bridges, photograph weddings, and conduct a whole host of traditionally ground-based activities. Not just an issue within the United States, the low cost to procure and operate civil drones is driving their proliferation to all corners of the globe. In many cases, the international community has embraced the integration of civil drones into their daily lives to a greater extent than within the US. Civil access to the air domain no longer resides solely in the pages of science-fiction novels, it is here now and it is poised to expand rapidly in new and innovative directions in the coming years.

Conclusions

With society's expansion into the air domain comes the increased likelihood of civil drones interacting with military operations. This interaction is already happening within peacetime conditions both at home and abroad. The transition to peacekeeping or combat missions will not stop that trend. The more civil actors use drones for daily and essential tasks, the more their use will persist after the introduction of military forces. Further, criminal organizations and armed non-state actors have begun to embrace the utility of drones for a wide range of illicit activity in both peacetime and combat operations. It is no longer a question of whether drones will begin affecting military-operating environments, they already are. Non-state actors in Ukraine, Libya, Syria, and Iraq are utilizing commercial-off-the-shelf systems to conduct battlefield reconnaissance and coordinate combat operations. If they have not done so already, it is only a matter of time before they begin arming those drones.

As the use of civil drones spreads and their capabilities increase, so too does the severity of small-drone threats to military operations. Drone operators have already demonstrated the ability to jam communications, smuggle illicit goods across borders, conduct prolonged surveillance, and even conduct kinetic strikes in support of nefarious

objectives. As payloads and control capabilities increase, particularly with swarming capabilities, the potential severity of the small-UAS threat to military operations will only increase. The combined increase in both likelihood of interaction and severity of the potential threat result in an overall increased risk to military operations and warrants further investigation.

Both civil and military organizations have begun to recognize the growing threat posed by the nefarious use of drones and are developing methods to counter them. Unfortunately, current counter-drone capabilities, although potentially effective in controlled-test environments, face two mounting issues: the challenge of domestic acceptability and the rise of the aerial littoral. The challenge of domestic acceptability restricts otherwise effective counter-drone options, such as kinetic destruction or electronic jamming, that would interfere with, or increase the risk of collateral damage to, civilians or local infrastructure, particularly when employed in urban environments. Both developers of counter-drone capabilities and their future operators understand this conundrum, and it is beginning to reshape their efforts. The rise of the aerial littoral, on the other hand, still eludes the broader discussion.

With upwards of two million civil drones already in operation within the US alone and their proliferation not showing any signs of abating, the addition of so many new participants into already congested airspace has the potential to fundamentally alter the current conceptualization of the air domain. The emergence of a near-earth layer of highly congested air traffic comprised of drones conducting both legitimate and illegitimate operations will complicate any counter-drone efforts by increasing the likelihood of collateral damage and providing effective concealment for nefarious drones. Not only will this trend increase the density of air traffic, but also the dependence of the public and commercial sectors on access to and utilization of the air domain. Completely shutting down civil access to the air domain during military operations may become infeasible, particularly once public-safety requirements begin to rely on and dictate its use.

From a military perspective, the result of combining an increased threat of nefarious-drone use, the political realities of domestically viable counter-drone solutions, and the overlay of a civil-drone environment presents a significant challenge. This

combination will most likely arise during future stability operations where, despite the presence of a sustained threat, military forces focus more on enabling reconstruction efforts than combat operations. Within those reconstruction efforts, the potential benefit of integrating civil drones in the efforts of host nations and non-governmental organizations is too great to dismiss. So too is the potential benefit to nefarious actors. The ability for military forces to counter an inherent drone threat decreases as legitimate civil organizations become reliant on drones to survey disaster areas, deliver medical supplies, and play critical roles in the provision of essential services. This dynamic will complicate the already fine balance between force-protection requirements, the need to protect civilian populations and infrastructure, and commanders' ability to execute their assigned missions.

Current and proposed US force postures, policies, and methods of employment in drone environments are not adequate to address the problems posed by the proliferation of civil drones and the rise of the aerial littoral, particularly in stability operations scenarios. The good news is that this combination of threats and the emerging aerial littoral are still in their infancy. This combination creates a potential risk, but not necessarily a real one yet. In this highly dynamic industry, estimates of how fast civil drones will proliferate vary; and governmental regulations and society's influence may still alter the proliferation timeline, but the general consensus predicts a mere three to five years until civil drones begin to exert a persistent influence on society and daily military operations. The potential rise of the aerial littoral within three to five years may be nothing more than a potential at this point, but the implications to military operations, particularly in stability scenarios, are too great to ignore.

Recommendations

No US ground force has realistically feared an attack from a hostile aircraft for over sixty years. In that time, American leaders have utilized military power in a wide variety of relatively permissive environments and come to expect nearly instantaneous and ubiquitous air superiority. Although military planners now realize the fallacy of that assumption in modern contested environments, the proliferation of civil UAVs may entirely negate the idea of air superiority as it is currently understood. By recognizing the issues associated with the proliferation of small drones as it approaches, instead of after

they arrive, the US military has the opportunity to address any necessary policy, organization, force structure and training changes in order to prepare for its arrival. The US military should take several deliberate steps toward addressing these concerns.

First, planners and policy makers must stop viewing military counter-drone operations and the proliferation of civil drones as separate issues. The drone threat to military forces extends well beyond the bounds of state-based UASs in Phase III combat operations and now includes use by non-state actors across all phases of military operations. By separating this growing threat from the concurrent expansion of civil drone operations, the military can only plan towards system-on-system engagements and not the broader changes in the operating environment.

Second, as the discussion of civil-drone proliferation expands, it must include reasonable extrapolations of their capabilities. Too many discussions, particularly academic debates, dismiss the utility and threat of civil drones due to their current performance limitations. Buying into the hype of, as Michael Kreuzer puts it, the “mythical ‘super [drone],’” equally stymies productive debate. Several of the more recent studies noted in this paper, such as those from Open Briefing and Armament Research Services, have come a long way in documenting the existing threat, but a gap remains in the need to project how that threat will evolve in the coming years.¹ Without taking into account a reasonable projection, counter-drone efforts will continue to cede the initiative to the creativity and imagination of nefarious actors.

Third, addressing this coming change will require rethinking the structure of the air domain. The concept of the aerial littoral must underpin any assessment of the emerging threat inherent in the proliferation of civil drones in order to appreciate the effects of the changing operating environment. Without the overlay of a civil-drone environment, this aerial littoral, the nefarious threat simply presents another friend-or-foe-identification issue; with the civil overlay, the situation is much more complex and has the potential to drastically alter military operations. Taking a proactive look at how

¹ The Remote Control Project and Open Briefing, *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets* (London, United Kingdom: The Remote Control Project and Open Briefing, January 2016).; Larry Friese, N.R. Jenzen-Jones and Michael Smallwood, *Emerging Unmanned Threats: The use of commercially-available UAVs by armed non-state actors*, special report (Perth, Australia: Armament Research Services (ARES), February 2016).

this change will occur allows the military strategist the opportunity to shape the growth of the aerial littoral as public discourse shapes the evolution of public policy and regulations concerning the use of civil drones.

Finally, the push for new counter-drone capabilities through the Joint Capabilities Integration and Development System (JCIDS) has already begun, and those must continue, but military planners must fully explore the other doctrinal, organizational, material, leadership, personnel, and facilities (DOTMLPF) options which may provide new alternatives to addressing the growing threat. If current capabilities-based approaches such as those demonstrated during recent Black Dart exercises are any indication, solely relying on new technologies and capabilities to overcome the drone threat will likely fail.

Final Thoughts

Prognostication is not easy, nor is it an exact science. As military historian Michael Howard noted, any attempt to forecast the growth of an innovation will be wrong; the trick is to not be too wrong and to simultaneously retain the ability to rapidly adjust to the new situation as it unfolds.² The highly dynamic civil-drone industry presents such a challenge. While it is likely that this study will miss the mark in some areas, the overall trends appear stable enough to provide a foundation for deliberate planning efforts. Civil drones are here and they are here to stay. Particularly when the broader international community is racing forward with efforts to integrate civil drones into the very fabric of their societies, few civil actors are likely to cede their newfound access to the air domain anytime soon. Instead, civil drones and their nefarious offspring will become more common each day as traditionally ground-based activities take to the skies. This is the new strategic environment which military forces will encounter across a wide range of military operations.

The next time a drone flies overhead one might assume that this study supports watching it with great suspicion. Then again, it is not common practice to view every passing car as a potential threat. Should a few hundred feet difference really alter that mindset? That few hundred feet, however, place that high-density traffic squarely within

² Michael Howard, "Military Science in an Age of Peace," *RUSI Journal* 119, no. 1 (March 1974): 3-11.

the domain of airmen, airmen who strive to identify and track every aircraft in the sky. As drones proliferate to all sectors of society, tracking the complete air picture is rapidly becoming unrealistic. The rise of the aerial littoral has the potential to fundamentally alter the existing paradigm within the air domain, but there is still time to prepare for that development. And prepare we must, lest the first American to lose their life to an aerial attack in over 60 years dies, under an umbrella of air superiority, from an attack by a “puny, insignificant drone”.



Appendix A

Selected Drone Applications

The following tables provide a sampling of a variety of both operational and envisioned civil-drone applications. Those listed as *current* have demonstrated limited operations, whereas *future* applications are currently in various stages of development or field test. Those future applications listed with an asterisk are still purely *speculative*.

Table A.1: Public-Sector Applications

Category	Current	Future (*Speculative)
Administration	Aerial survey	*Poverty mapping – ISR
	Document delivery	*Tour Guides
		*Urban management – ISR
Environmental	Archeology support	Climate change monitoring
	Counter-poaching	Hurricane hunting
	Ocean health monitoring	Pest management
	Wildfire fighting – ISR	*Cloud seeding
	Wildlife monitoring	
Infrastructure	Infrastructure inspection	*Self-repairing cities
Utilities & Services	Education –	Droneports
	Research & Development	Internet provider
	STEM support	Postal delivery
		*Pseudo-satellites (GPS type)
Public Safety	Disaster response	Crowd control
	Life guard augmentation	Disaster response – Rescue
	Police and Fire response - ISR	Drone defibrillator
	Medical diagnostics & supply	Telemedicine
	Search & Rescue	*Police – Engagement
	Event & border security	*EMS ambulance

Source: Author's collation of published data.

Table A.2: Commercial-Sector Applications

Category	Current	Future (*Speculative)
Agriculture	Precision crop dusting Crop health monitoring	
Delivery	Documents General goods (limited) Newspaper Restaurants (aerial waiter)	General goods Restaurants (Take-out) Pharmacy E-commerce delivery
Entertainment	Aerial photography Film making Airshows & light displays Sporting events – ISR Drone racing	
Information	Papparazii photography Journalism Aerial photography	
Logistics	Asset monitoring Infrastructure inspection – Oil rigs, bridges, pipelines Construction support Maritime operations support	Railyard Management Site security *Unmanned cargo aircraft *Unmanned airliners
Other	Insurance adjusting – ISR Drone insurance Aerial advertising UAS flight schools	Tour guides *Employee oversight *Mining support
Real Estate	Precision mapping Asset photography Landscaping	

Source: Author's collation of published data.

Table A.3: Private-Sector Applications

Category	Current	Future (*Speculative)
Entertainment	Aerial photography	*Hunting (armed / ISR)
	Drone Art	
	Drone-boarding	
	Fishing	
	Hobbyist	
	Personal ISR (Follow-me)	
	Personal journalism	
	Racing	
	Toys	
Transportation		*Personal vehicles
		*Personal goods delivery
Other	Home improvement	*Telecommute
	Landscaping	*Remote presence
		*Remote babysitting

Source: Author's collation of published data.

Table A.4: Criminal-Sector Applications

Category	Current	Future (*Speculative)
Surveillance	Crime planning	*Industrial espionage
Attack	Explosives delivery	Communications jamming
	Airspace interference	WMD delivery
		*Communications relay
Logistics	Smuggling –	
	Drugs/	
	Weapons	
Other	Cell phone hacking	

Source: Author's collation of published data.

Appendix B

Selected Real World Drone Threats

The following tables provide a sampling of real-world events that demonstrate the various types of drone threats and their increasing frequency. The overall categorization scheme for these tables is adopted from Wallace and Loffi's work "Examining Unmanned Aerial System Threats & Defenses: A Conceptual Analysis."

Table B.1: Commercial-Off-The-Shelf Threats

Category	Real World Examples
Nuisance	2004 – Hezbollah violates Israeli airspace with a mid-size Mirsad-1 UAS conducting a reconnaissance flight. 2013 – Political activists land a small drone near German Chancellor Angela Merkel at a campaign rally in protest of German surveillance policies. 2015 – A woman in Hawaii reports a drone observing her through a bedroom window. 2015 – Private citizens mistakenly violate airspace restrictions around the US White House in three separate instances. 2015 – Women on Waves activist group deliver abortion pills via drone in protest against Polish abortion laws.
Airspace Interference	2001 – Intelligence reports surface concerning al Qaeda plans to attack passenger aircraft with drones. 2014 – US Airways commercial aircraft nearly collides with a drone at an altitude of 2,300 feet in Florida. 2015 – FAA documents over 921 interactions between drones and manned aircraft over roughly two years, 28 of which require evasive maneuvers by the manned aircraft. 2015 – Polish Air Force F-16 sustains minor damage in collision with a small drone near Kizesiny Airbase.

	2015 – Wildfire fighters in California briefly suspend airborne operations due to interference by five hobbyist drones.
Monitoring	2004 – Hezbollah violates Israeli airspace with a mid-size Mirsad-1 UAS conducting a reconnaissance flight. 2005 – Pakistani Army finds weaponized drone used for surveillance in Al-Qaeda hideout. 2011 – Libyan rebels use quadcopter drone for surveillance support to ground forces. 2014 – Drone caught monitoring the French soccer team preparing for the 2014 World Cup in Brazil. 2014 – Islamic State of Iraq and Syria (ISIS) used drones to monitor their operations in Fallujah, Iraq. 2014 – Hobbyist's drone accidentally overflies a British Aerospace nuclear submarine testing facility in United Kingdom. 2014 – Ukrainian military and separatist forces begin using COTS drones for battlefield ISR. 2014 – Unknown actors fly drones over at least seven nuclear power plants in France in October alone. 2015 – Unknown actor uses a drone to surveil a Disneyland construction site in Shanghai, China. 2015 – Mexican drug cartels use drones to identify weaknesses in police coverage of Mexican-American border.
Kinetic / Kamikaze	2003 – Remote-control aircraft kills 13 year old girl after accidentally hitting her in the head at 50 mph. 2014 – Australian triathlete hit in head and injured after local videographer loses control of quadcopter drone. 2015 – Unknown actor crashes drone into power lines in West Hollywood, California and causes three-hour blackout. 2015 – Unknown actor crashes a small drone into the Sydney opera house.

Source: Author's collation of published data.

Table B.2: Payload Threats

Category	Real World Examples
Smuggling	2015 – Smugglers crash a drone in Tijuana while attempting to carrying 6 pounds of crystal meth across the US border. 2015 – Two citizens caught smuggling drugs and other contraband into a Maryland maximum-security prison.

Source: Author's collation of published data.

Table B.3: Weaponized Threats

Category	Real World Examples
Non-Lethal	2014 – Drone company Chaotic Moon successfully employs 80,000-volt, drone-based taser in live-fire demonstration. 2014 – South African drone company Desert Wolf sells 25 drones capable of employing pepper spray balls to an international mining company.
Projectile	2011 – Vanguard Defense markets drone capable of employing grenade launchers, stun guns, and small arms. 2011 – After market modifications allow users to add the ability to drop a payload on command to almost any drone. 2015 – Private US citizen successfully conducted a live-fire test of a drone-mounted semi-automatic pistol.
Weapon of Mass Destruction	1994 – During a counter-proliferation meeting, US Senator Sam Nunn speculates on possible terrorist scenarios, including a nominal remote-control aircraft delivered chemical attack on congress. 1995 – Japanese terrorists attack Tokyo subway with sarin gas. Their original plan included remote-control helicopters. 2004 – Al Qaeda plots to drone attack British House of Commons with anthrax. 2013 – Iraqi forces foiled an al Qaeda plot to use drones to conduct chemical attacks with mustard and sarin gas.

	2015 – Japanese protester lands a drone carrying a small amount of radioactive sand on the roof of the Prime Minister’s office.
IED / Explosive	2001 – Abandoned plot by Osama bin Laden to kill world leaders at the G8 summit in Genoa, Italy with explosive-filled remote-control airplanes. 2004 – Hamas members killed in accidental explosion while fabricating explosive-filled drones. 2006 – Israel shoots down three allegedly explosive filled drones launched by Hezbollah. 2011 – FBI arrests a terrorist attempting to attack the US Capitol and Pentagon with explosive-laden drones. 2015 – Kurdish forces allegedly recover a crashed ISIS drone carrying explosives in Syria.
Electronic Attack	2011 – US hackers demonstrate the ability to hack phones from a drone mimicking cellular towers. 2012 – University of Texas students remotely hijack a Department of Homeland Security drone and fly it off course. 2015 – A Singapore-based company demonstrates drone-based advertising capability to capture cell phone data and send targeted advertising directly to the phone.

Source: Author’s collation of published data.

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