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Instantly Basing Locust Swarms

New Options for Future Air Operations

Jonathan E. Burdick
Lieutenant Colonel, USAF

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Drew Paper No. 20

Air University Press
Air Force Research Institute
Maxwell Air Force Base, Alabama

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AIR UNIVERSITY PRESS

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Maxwell AFB, AL 36112-6026
afri.aupress@us.af.mil/

http://aupress.au.af.mil/
http://afri.au.af.mil/

AFRI AU PRESS
AIR FORCE RESEARCH INSTITUTE

Library of Congress Cataloging-in-Publication Data

Burdick, Jonathan E., 1972–
Instantly basing locust swarms : new options for future air operations / Jonathan E. Burdick, Lieutenant Colonel, USAF.
pages cm. — (Drew paper; no. 20)
Includes bibliographical references.
ISBN 978-1-58566-252-4
1. Drone aircraft—United States. 2. Swarming (Military science) 3. Air warfare —Case studies. 4. Nigeria—Strategic aspects. I. Title. II. Title: New options for future air operations.
UG1242.D7B87 2015
358.4'1422—dc23

2015012394

Published by Air University Press in January 2016

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This Drew Paper and others in the series are available electronically at the AU Press website: http://aupress.au.af.mil.

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Foreword

A key element of innovation involves arranging familiar things into new combinations. Flying airplanes from ships led to the demise of battleship dominance. Integrating tanks, airplanes, and radios in a unique way enabled blitzkrieg operations across Europe. Making dumb bombs smart by using satellite guidance provided the modern imagery and allure of pinpoint destruction. Most of the time—and in all of the examples above—such innovations involve cultural and organizational changes as well as the insights of forward-thinking people. And so it is with the new concept of airpower presented here, Instantly Basing Locust Swarms.

This study by Lt Col Jon Burdick asks a difficult question: Can unmanned aircraft launched and sustained from nontraditional sites create a persistent, effective projection of airpower? Can they swarm, or sustain convergent and coordinated attacks from multiple directions to achieve significant military and political effects while minimizing logistical and political capital? Colonel Burdick's thoughtful synthesis of technology, doctrine, institutional culture, geopolitics, logistics, economics, and strategic principles suggests it is not only possible but compelling.

Central to the proposal offered herein is the interrelated development of new logistical and operational constructs. The idea of "instant basing" slashes the traditional forward-based requirements of US airpower and thus influences cost, force protection, and the diplomatic calculus. It does so by exploiting the increasingly robust commercial lines of communication relevant to economic globalization as well as the lighter footprint associated with deploying small, remotely piloted aircraft (RPA) and their support teams via military airlift and sealift. In essence, this concept springs from the merging of global logistics with the growing stable of small, accurate, and lethal RPAs. Colonel Burdick describes how these RPAs and their relatively small logistical requirements—serving in a novel combination—can form the vanguard of a new airpower paradigm.

The Air Force's history of innovation is in many ways a story of creative destruction. New concepts of projecting power emerge that subvert traditional doctrine and supplant the status quo. This study presents an example of how that could happen in the near future and reminds us how new opportunities and demands of the strategic environment ultimately privilege innovation and change. This study received the Air University Foundation's award for the best School of Advanced Air and Space Studies thesis on the subject of technology, space, or cyberspace, and I am pleased to recommend it to those who value innovative thinking as a catalyst to strategic advantage.

Timothy P. Shultz
Colonel, USAF, Retired, PhD
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About the Author

Lt Col Jonathan Burdick is a graduate of the School of Advanced Air and Space Studies. He has operational experience in KC-135R and U-2S/TR-1 weapons systems, is a former instructor in both aircraft, and holds a master of science in strategic intelligence from the National Defense Intelligence College.

Acknowledgments

I would like to express my extreme gratitude to Col Timothy Schultz and Dr. Harold Winton for their expert advice and mentoring during this project. Their help was fundamental to the success of this paper. I would also like to thank Lt Col Jobie Turner, Lt Col Chris Macaulay, Lt Col Eric Murphy, Maj David Hood, and Mr. Michael Spehar for providing essential insight and references important to this research.

Abstract

This study explores the effects of airpower technologies and logistics on the application of US airpower. It finds that future swarms of small, remotely piloted aircraft (RPA) might provide significant force-projection capabilities using global military and commercial logistics infrastructures. This conclusion results from an examination of air operations during the Vietnam War, Operations Desert Storm and Enduring Freedom, existing RPA research and development, and projected Department of Defense developmental milestones involving swarms of small RPAs. The study also proposes a concept of operations, designated Locust Swarm, and a new logistics construct, called Instant Basing, that exploit the future capabilities of small, unmanned aerial vehicles. Such concepts may provide national policy makers relatively low-cost, low-risk options for international crises requiring the rapid deployment of airpower.

Chapter 1

Introduction

Developing a swarming force implies, among other things, radical changes in current military organizational structures.

—John Arquilla and David Ronfeldt

During the Battle of Britain, British Spitfires and Hurricanes scrambled aloft from geographically dispersed air bases to intercept attacking German fighters and bombers. Formations of Luftwaffe aircraft had already demonstrated their destructiveness during the opening campaigns of World War II, but the British people were unfazed and rallied behind Prime Minister Winston Churchill's famous call for "victory at all costs—victory in spite of all terrors."[1] Beyond national spirit, Britain's Royal Air Force (RAF) had another advantage. It had an integrated air defense system (IADS) consisting of Chain Home radar stations, centralized command and control centers, and fighter aircraft capable of responding to airborne threats on short notice.[2] By the end of this campaign, Fighter Command's effective use of its IADS greatly contributed to the destruction of 1,887 Luftwaffe aircraft and Adolf Hitler's decision to postpone the invasion of the British Isles.[3]

Great Britain's victory over Nazi aggression is one of many important events of World War II, and the Royal Air Force's use of swarm tactics to help achieve it was particularly significant. According to RAND theorists John Arquilla and David Ronfeldt, Britain's Fighter Command used a "deliberately structured, coordinated, strategic way to strike from all directions, by means of a sustainable pulsing of force and/or fire, close-in as well as from stand-off positions."[4] Great Britain's ability to gather and disseminate information throughout its IADS unified disparate fighting elements, allowing them to converge on enemy aircraft from all directions. Furthermore, Great Britain employed swarming from a defensive strategic position and used an indirect approach so that it could "await a change in the balance of force—a change often sought and achieved by draining the enemy's force, weakening him by pricks instead of risking blows . . . by local attacks which annihilate or inflict disproportionate loss on parts of his force; by luring him into unprofitable attacks; by causing an excessively wide distribution of his force; and, no least, by exhausting his moral and physical energy."[5] Britain's strategic defensive position enhanced its chances of survival.[6] Airpower history lacks, however, successful examples of swarming conducted from a strategically offensive position.[7]

Military forces employed within a strategically offensive strategy have often been unable to translate tactical-level swarming engagements into strategic victory because logistical constraints frequently prevented sustained operations.

At the tactical level, "the realm of the actual employment of armed forces," swarming is not a new phenomenon.[8] Germany used multidirectional hit-and-run tactics by irregular swarms of "shock troops" to exploit gaps and weaknesses in enemy lines of operation during World War I.[9] The Japanese navy also used swarms of kamikazes in an effort to overwhelm individual carrier groups during the Second World War.[10] In these examples, the conduct and arrangement of forces were intended to provide local advantage that aimed to destroy enemy forces through a series of tactical engagements.[11] Tactical victories could then potentially lead to operational results that might produce strategic effects. For example, the German army and Japanese navy hoped that local victories achieved by swarm tactics as part of their offensive strategy could then increase the likelihood of a "better state of peace" recognized by favorable terms at the cessation of hostilities.[12] When employed within their strategically offensive strategy, swarming methods were tactical means that had the potential to create operational momentum leading to strategic results.

According to military theorist Carl von Clausewitz, "Strategy is the use of the engagement for the purpose of the war. The strategist must therefore define an aim for the entire operational side of the war that will be in accordance with its purpose. In other words, he will draft the plan of the war, and the aim will determine the series of actions intended to achieve it."[13] Given the politician's purpose for military operations, commonly called *grand strategy*, the military commander determines how to use available forces as part of an overall plan.[14] As a result, military effects are referred to as *strategic*, *operational*, or *tactical* based on their intent to affect a conflict's overall purpose, military aim, or specific battlefield events. Colin Gray argues that the employment of any weapon could shape decisions made by political leaders and operational military leaders. He wrote, "All weapons and forces should be called strategic, which is precisely why no weapons or forces should be so designated."[15] Nevertheless, Gray's argument seems to miss the importance of intent and planning. Intent and planning are important because they provide objectives that serve as measures of effectiveness.

As noted, swarming attacks conducted by World War I storm troopers and World War II kamikazes were tactical means intended to provide operational effects by destroying enemy forces and controlling geographic territory or sea space. Each military force had the capacity to swarm only at the local level unless it received logistical support from external sources. German and Japanese swarms of attackers were limited by their range of motion, their ability to continue operations, and the size of their operating forces. For example, during the First World War, German *Stosstruppen* (storm troopers) were often dependent on exterior lines of communication for resupply, reinforcements, and artillery support. In cases where storm troopers made significant gains into enemy territory, they were often unable to continue fighting because the German army lacked sufficient rail lines and support forces to transport artillery and supplies to forward positions.[16] Furthermore, *Stosstruppen* gains could not generate operational momentum because their forward positions were often overrun or they were forced to retreat by reserve British, French, and/or US troops.[17] Consequently, German field marshal Erich Ludendorff's "Peace Offensive" failed primarily because of its inability to provide sustained logistical support.[18] Similarly, the effect of kamikaze forces was limited by aircraft range, their aircraft carrier's inventory of fuel and weapons, and the availability of qualified pilots.[19] Each of these fighting units' limitations relegated their episodic use to the tactical level. More importantly, the original intent behind Germany's and Japan's use of swarm tactics was to win local battles to gain operational momentum and potentially earn favorable terms in victory. In their strategic offensive, *Stosstruppen* and kamikazes intended to expand control of their region but only had the means to generate modest tactical forces.

In contrast to the previous examples, swarming operations during the Battle of Britain relied on a strategically defensive position because their grand-strategic aim was the protection of Britain's national sovereignty and survival.[20] Great Britain intended to prevent a German invasion so it could subsequently shift its grand-strategic aim toward the ultimate defeat of Germany. Undoubtedly, each air battle between RAF and Luftwaffe aircraft involved the tactical employment of force, yet each British fighter swarm that intercepted Luftwaffe aircraft did so for the strategic aim of mitigating damage to the British homeland and therefore supported the goal of national survival. Fighter Command's command-and-control (C2) organizational structure was designed to synchronize the capabilities of British fighter swarms, air defense artillery, early warning radar, and domestic logistical systems.[21] Furthermore, Great Britain relied on interior lines of communication and supply located throughout the British Isles. Unlike their opponent, the British could effect communication and resupply with relative ease because secure domestic logistics networks were within close proximity to airfields. National purpose, geography, military capabilities, technological advances, and logistics aligned such that swarming operations were realistic, were included within the strategic planning process, and contributed to strategic victory.

Contemporary operations such as Desert Storm, Allied Force, Enduring Freedom, and Iraqi Freedom may have included brief instances of swarming; however, they did not demonstrate sustained swarming operations. Arquilla and Ronfeldt's basic characteristics of maneuver warfare better define the latest US examples of air warfare. For example, modern operational concepts involve "complex, synchronized, fast-tempo, multi-linear operations to surprise, penetrate, and flank" the enemy and aim to apply mass at decisive points.[22] They do not, however, embody swarming characteristics involving small, dispersed, autonomous, or semiautonomous forces that use interconnected surveillance sensors in sustainable convergent attacks against the enemy.[23] This is not to say that strategic swarming has not been possible in the modern era; it simply suggests that US airpower has not been deliberately structured for sustained swarming operations. Specific examples of tactical swarming may have occurred, yet they were usually brief, discrete, and/or unintended.

This research proposes a concept of operations (CONOPS) and logistics for swarming. In doing so, it integrates ideas concerning scientific thought, military theory and doctrine, the current state of technological affairs, developments in logistics, expanding commercial infrastructures inherent to the globalized economy, and recent events pertaining to international politics. It also advocates a new concept of airpower in which individual and potentially expendable aircraft are launched as part of an overwhelming, persistent, and flexible constellation of vehicles.[24] Moreover, just as locusts emerge unexpectedly and devastate agricultural heartlands, this concept of operations provides a method to conceal the rapid buildup of air forces so their launch generates strategic surprise. It also describes a potent force capability that may reveal a new power-projection paradigm.

Problem Background and Significance

As previously noted, Arquilla and Ronfeldt defined *swarming* as the "deliberately structured, coordinated way to strike from all directions, by means of a sustainable pulsing of force and/or fire, close-in as well as from stand-off positions."[25] Early airpower advocate William "Billy" Mitchell alluded to the concept of swarming in his 1925 statement that "every air attack on other aircraft is based on the theory of surrounding the enemy in the middle of a sphere with all our own airplanes around the whole periphery shooting at it."[26] Although Mitchell intended to describe the three-dimensional characteristics of air combat at the tactical level of warfare, his ideas apply to modern concepts of operations involving swarming.

Swarming has three primary requirements: aircraft with sufficient range, a C2 system, and a logistics system capable of continuously supplying air operations. First, airpower capabilities must be positioned within range of targets to ensure continuous operations without capability lapses. The RAF could successfully employ swarming during the Battle of Britain because sufficient numbers of airfields were located within interception range of invading Luftwaffe aircraft.[27] Furthermore, the RAF enjoyed the huge benefit of interior lines. This advantage shortened response times and simplified the transportation, C2, and supply requirements of its air operations. Simply stated, Great Britain's wartime infrastructure was in place and close at hand during the Battle of Britain. In post–World War II conflicts such as the Korean War, Vietnam, and Operation Desert Storm (ODS), aircraft were based at distant locations within range of their targets. In those cases where aircraft range was not sufficient, air-refueling capabilities provided greater basing options since aircraft ranges were extended with in-flight refueling.[28] Although air operations supporting Operation Enduring Freedom include the use of bases located within Afghanistan, airpower capabilities employed in the Middle East are similarly transient in nature. These operations seem to rely on many exterior lines of communication and complex supply systems. Many C2, reconnaissance, air-refueling, and strike aircraft base their operations from locations geographically removed from Afghanistan and require long transit times.[29] As a result, the US Air Force has not demonstrated the ability to maintain constant levels of airpower capability in hostile theaters. Periodic lapses of capability may occur, for example, during aircraft changeovers, air refueling, maintenance aborts, and otherwise in a force stretched too thinly over a wide geographic expanse.

Second, strategic swarms must have robust command-and-control systems organized to use information effectively. As recognized by Department of Defense (DOD) joint doctrine, Air Force Doctrine Document (AFDD) 6-0, *Command and Control*, defines the concept as

> the exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. C2 functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission. . . . This definition acknowledges three central themes. The first theme, personnel, covers the human aspects of C2. . . . The second, the technology element, covers the equipment, communications, and facilities needed to overcome the warfighting problems of integrating actions and effects across space and time. . . . The third theme, labeled in this document as "processes," encompasses "procedures."[30]

Further explanation by AFDD 6-0 reveals that *command* involves a military leader's authority to conduct operations, and the term *control* involves the way in which the leader may "plan and guide operations."[31] Moreover, free exchange of information is a vital component to C2 systems. A commander must be able to communicate with all levels within the chain of command.[32]

In those cases in which timely information exchange has not been possible, decentralized execution of mission orders has been effective during air operations. During the Battle of Britain, for example, RAF fighter pilots were expected to accomplish general orders involving the intercept of Luftwaffe aircraft but had freedom to apply tactics and flight maneuvers according to their own interpretation of their flight environment.[33] Moreover, the British IADS balanced tactical necessity and strategic reporting requirements. Pilots had the responsibility to destroy enemy aircraft, and British commanders accepted the fact that they would not have timely visibility into the tactical events of each battle.[34] As a result, Great Britain's C2 system represented a felicitous marriage of human input and technological capability.

Although modern air operations still rely on decentralized execution of mission orders, technological advances in information systems and computer equipment have increased commanders' access to timely information throughout many aspects of operations. For example, full-motion video feeds and up-to-the-second electronic maps of air assets are prominently displayed in air operations centers (AOC).[35] Access to timely information is important, and military historian Martin van Creveld contends that commanders must have the ability to "telescope" selectively to specific issues of interest but should carefully avoid micromanagement.[36] As information systems and communication technologies eliminate the need for delayed reporting, the importance of C2 infrastructures will increase.[37] Furthermore, the use of unmanned remotely piloted aircraft (RPA), and the future possibility that formations of RPAs may operate autonomously, may require more robust real-time information flow between the battlefield and the commander.[38]

RPAs and/or formations of RPAs may possess the capability to deliver more destructive effects than current generations of manned aircraft, and their increasingly autonomous capabilities will not relieve commanders of their responsibility to command and control airpower assets. Commanders may require "telescoped" information relating to the swarm and/or individual aircraft. Such situations might increase information flow requirements between aircraft and C2 elements.[39] Consequently, C2 systems serve as a critical component of strategic swarming; however, they must also be capable of processing and disseminating the immense volume of information involved with modern networked weapon systems.

Just as C2 systems magnify military organizations' ability to process and disseminate information during operations, logistics systems ensure that supplies are delivered to war fighters as quickly as possible. Thus, swarming's third requirement involves logistics systems capable of timely delivery of equipment and personnel for sustained operations. During the Battle of Britain, the RAF possessed the advantage of interior lines of communication and an indigenous supply of personnel and equipment.[40] In modern operations, the United States has not enjoyed the same luxury. For example, during Operation Desert Storm a typical Air Force combat wing required the initial delivery of 1,000 to 2,000 tons of air- and ground-support equipment; once operations began, it required the daily delivery of 100 to 200 tons of ammunition and 500,000 to 1,000,000 gallons of fuel.[41] Moreover, complex global operations require capable information processing systems. Joint Publication (JP) 4-0, *Joint Logistics*, states, "The global dispersion of the joint force and the rapidity with which threats arise have made real-time or near real-time information critical to support military operations."[42] The ability to identify maintenance problems, coordinate the immediate replacement of equipment, and calculate fuel requirements for each vehicle and/or operating base in a timely manner will be essential to achieving seamless operations. Continuous operations without capability lapses may also prevent the enemy from detecting changes in force strength because real-time identification of supply or maintenance problems could allow one-for-one aircraft exchanges over the target area. Massed air attacks such as Brig Gen Billy Mitchell's 1,400-aircraft raid against Saint-Mihiel and bombing formations of thousands of aircraft in World War II were not continuous, but enemies had to deal with never-ending peril.[43]

Given swarming's three primary requirements of geographic positioning of air assets, effective C2, and robust, timely logistics, the central research question of this paper seeks to determine if remotely piloted aircraft can provide sustainable, effective swarm capability from nontraditional bases of operation. As in the Second World War, the Korean conflict, the Vietnam War, and Operations Desert Storm, Allied Force, and Enduring Freedom, large air bases were vital logistical nodes necessary for the sustenance of air operations, personnel, and equipment. RPAs based with manned aircraft played significant roles in every major operation since Allied Force.[44] In a general sense, manned aircraft and RPA basing decisions are similar because they both require extensive logistics, security, and geopolitical planning. However, RPAs may provide a more flexible and inexpensive airpower option if they require less logistical and security support and mitigate political challenges that often complicate the US use of foreign air bases. Furthermore, if RPAs demonstrate a capability to overwhelm, deter, dissuade, and/or punish adversaries via swarms launched from nontraditional locations, their concept of employment may spur doctrinal changes.

Weapon systems such as Predator B and Reaper RPAs currently possess the ability to find, fix, target, and kill the enemy with persistent intelligence, surveillance, and reconnaissance (ISR) and air-to-ground weapons.[45] According to senior Air Force leaders and authors such as P. W. Singer, RPAs are nearing the combat capability of manned aircraft in some circumstances and potentially offer capabilities yet unseen in the realm of military affairs.[46] However, RPAs have not demonstrated their ability to project force in denied airspace, and their complex operational infrastructures require theater launch bases, stateside pilot and sensor operator facilities, and distributed command-and-control centers.[47] Nonetheless, are they the missing link that will permit the maturation of flexible and persistent swarming operations?

Methodology and Categories of Analysis

Both primary and secondary sources form the foundation of this paper. Primary sources include joint and Air Force doctrinal publications, official correspondence, interview transcripts, and official briefings obtained from the Air University library, Air Force Historical Research Agency, and operational units. Secondary sources such as scholarly monographs, popular books, journal articles, and news articles provide background and contextual information. However, within the plethora of available literature regarding airpower, swarming, logistics, security, politics, and remotely piloted aircraft, there has not been an attempt to synthesize the available information into a novel, consolidated concept of operations and logistics for air operations involving small RPAs. Because the swarming concepts in this paper involve complex interrelationships of operational capabilities, geographic positioning, logistics, security, and geopolitics, they serve as the primary categories of analysis.

Assuming that future swarms of small RPAs and their associated C2 structures demonstrate a new means of projecting force, they will require adequate logistical support, force protection, access to geographic positions within range of their target, and political acceptance by host nations. Although RPA swarms will consume a modest amount of fuel, equipment, and weapons compared to manned aircraft, their ability to project persistent airpower will depend on resilient logistics networks capable of sustaining operations. This nontraditional concept of operations, moreover, confounds enemy actions that may ordinarily influence operations and logistical infrastructure and is less beholden to host-nation leaders who might otherwise seek to exert significant leverage on US air operations by limiting access to state facilities and territories.

Doctrine and contemporary events support the use of these categories of analysis. According to JP 3-0, *Joint Operations*,

> Sustainment is the provision of logistics and personnel services necessary to maintain and prolong operations through mission accomplishment and redeployment of the force. Sustainment provides the JFC [joint force commander] with the means to enable freedom of action and endurance and the ability to extend operational reach. Effective sustainment determines the depth to which the joint force can conduct decisive operations, allowing the JFC to seize, retain, and exploit the initiative. The ultimate goal is for logistics planners to develop a feasible, supportable, and efficient concept of logistic support and to be able to identify risks to the execution of the CONOPS.[48]

As described in JP 3-0, sustainment is a matter of logistics and supply. Moreover, just as the second law of thermodynamics dictates that "within a closed system the amount of useable energy decreases as it is employed," air operations require steady streams of supplies to maintain the status quo.[49] Without a continuous flow of supplies, the swarm dissipates.

In addition to internal force sustainment issues involving logistics and supply, two external constraints threaten continued operations. First, air bases and lines of communication are vulnerable to enemy attack, sabotage, and/or disruption. Thus, security is a vital consideration for sustained swarming operations. JP 3-0 describes security as a "protection function" and requires active and passive measures to preserve the "joint force's fighting potential."[50] Moreover, it specifically emphasizes "securing and protecting forces, bases, JSAs [joint storage areas], and LOCs [lines of communication]."[51] *Joint Operations* goes on to highlight numerous defensive measures that may thwart enemy actions.[52] Nonetheless, attacks against swarm bases and lines of logistics and communication could significantly affect their ability to generate airpower and demonstrate a sustained swarm effect over the target area.

Politics serves as the second external constraint to sustained swarming operations. Host-nation governments have the right to determine how the United States uses their territories and facilities. Foreign states hold sovereign authority over air bases and LOCs within their national borders. Moreover, they may use the basing of US forces for political and economic leverage, as the government of Kyrgyzstan demonstrated in 2009.[53] Fortunately, a shutdown of air operations from Kyrgyzstan's Manas Air Base was averted following diplomatic negotiations. Ultimately in 2010, the Kyrgyzstan government agreed to extend the US lease.[54]

Because host nations wield significant influence over airpower operations originating from and transiting their territory, US doctrine emphasizes host-nation relations. JP 1, *Doctrine for the Armed Forces of the United States*, recognizes diplomacy as an instrument of national power for "engaging with other states and foreign groups to advance US values, interests, and objectives."[55] JP 3-0 states, "Establishing, maintaining, and enhancing security cooperation among our alliances and partners is important to strengthen the global security framework of the United States and its partners."[56] Furthermore, Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 2300.02F, *Coordination of Overseas Force Structure Changes and Host-Nation Notification*, and Air Force Instruction (AFI) 10-504, *Overseas Force Structure Changes and Host Nation Notification*, emphasize communication and healthy relations between theater commanders and host-nation representatives.[57] Even with continued diplomacy and doctrinal and regulatory emphasis on host-nation relations, foreign leaders hold as much power to stop air operations as do enemy weapons to destroy US forward-deployed tools of war.

Limitations and Assumptions

This analysis does not include or rely on classified information and draws all of its conclusions from publicly available data. All open-source information regarding aircraft specifications, operational events, and military capabilities is assumed to be valid. Furthermore, because small RPA swarming has not been operationally demonstrated, the argument assumes that the current technological trajectory accurately portends the future utility of the Locust Swarm concept of operations and its associated Instant Basing concept of logistics.

Overview

The intent of this study is to develop a swarming concept of operations and logistics for the US Air Force and describe how it may apply to a variety of airpower scenarios. It assumes initial development by the Air Force but acknowledges that it will require coordination and cooperation with the other military services. Following successful demonstration, this concept may set the framework for a standard operational architecture that may be used within joint and coalition operations. This project considers existing airpower capabilities and doctrine and the potential implications of emerging technologies. To some degree, it extrapolates future technological capabilities based on the state of existing research and development. Regardless, the future will include difficult budgetary limitations, so another intent of this project is to examine how strategic swarming can be accomplished with modest resources.

Following this introduction, chapter 2 explores how the United States evaluates geographic positioning, command and control, and logistics to decide which foreign air bases are suitable for operations involving manned aircraft by providing examples of global and theater-level airpower operations. It explains how and why the United States used foreign airfields during the Vietnam War, Operation Desert Storm, and Operation Enduring Freedom (OEF). This chapter also briefly describes how the Air Force organized and based airpower assets to provide broad capabilities against enemy targets and concludes by explaining the reasons swarming has not been successful with manned aircraft and why future swarms of small RPAs may provide unique capabilities that might challenge the existing paradigm regarding the use of overwhelming force.

Chapter 3 focuses on operations involving remotely piloted aircraft. It explores the possibility that swarms of small, inexpensive RPAs might serve as a vanguard for a new airpower paradigm by surveying three subject areas. First, the chapter provides an overview of presently employed RPAs and their CONOPS. Second, it explores developmental RPA technologies necessary for swarming operations. Third, it describes an Instant Basing concept of logistics and examines the impact on the geographic positioning of forces, logistics, force protection, and politics and how such capabilities may inform policy at the grand-strategy level.

Chapter 4 notionally demonstrates the Locust Swarm concept of operations and Instant Basing concept of logistics. In a future scenario designed to test the findings of the previous two chapters, Locust Swarms help Nigerian constabulary forces regain security following crippling terrorist attacks. In the notional scenario, US policy makers fear a potential Nigerian genocide and oil supply disruptions that could damage the global economy. Because swarms of small RPAs are uniquely suited for low-cost, low-intensity conflicts requiring fast response to emerging crises, Locust Swarms are deployed throughout Nigeria. This chapter is notable for two reasons. First, it provides a glimpse of a Locust Swarm concept of operations. Second, it demonstrates the Instant Basing concept of logistics in action.

A concluding chapter provides a concise summary of findings, considerations, and shortfalls pertaining to swarming. It further assesses the potential implications of Locust Swarm and Instant Basing on US airpower and international politics. Finally, it examines whether or not the capabilities inherent within Locust Swarm and Instant Basing hold the potential to change the US paradigm involving the use of overwhelming force.

Notes

1. Winston Churchill, "Blood, Sweat, and Tears," in *World's Great Speeches*, 3rd ed., ed. Lewis Copeland and Lawrence W. Lamm (New York: Dover Publications, 1973), 431–33; and James S. Corum, *Luftwaffe: Creating the Operational Air War, 1918–1940* (Lawrence: University Press of Kansas, 1997), 182–223.

2. Stephen Bungay, *Most Dangerous Enemy:The Definitive History of the Battle of Britain* (London: Aurum Press, 2000), 61, 64–69.

3. Ibid., 368, 386, 388.

4. John Arquilla and David Ronfeldt, *Swarming and the Future of Conflict* (Santa Monica, CA: RAND Corp., 2000), vii, 9.

5. B. H. Liddell Hart, *Strategy*, 2nd rev. ed. (New York: Meridian, 1967), 321.

6. Carl von Clausewitz, *Principles of War*, ed. and trans. by Hans W. Gatzke (Mineola, NY: Dover, 2003), 53; and Clausewitz, *On War*, ed. and trans. by Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1984), 357, 370. A strategic defensive war is one "in which we limit ourselves to fighting the enemy in a theatre of war which we have prepared for this purpose." As written in *On War*, the object of a strategic defensive position is preservation and/or maintenance of the status quo.

7. Clausewitz, *Principles of War*, 58; and Clausewitz, *On War*, 357, 370. A strategic offensive war "pursues the aim of the war directly, aiming straight at the destruction of the enemy's forces."

8. Colin S. Gray, *Explorations in Strategy* (Westport, CT: Praeger, 1998), 61.

9. Frans P. B. Osinga, *Science, Strategy and War: Strategic Theory of John Boyd* (London: Routledge, 2007), 149.

10. Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, 34.

11. Clausewitz, *Principles of War*, 58.

12. Liddell Hart, *Strategy*, 338; and G. C. Wynne, *If Germany Attacks: Battle in Depth in the West* (Westport, CT: Greenwood Press, 1976), 148.

13. Clausewitz, *On War*, 177.

14. Liddell Hart, *Strategy*, 322.

15. Gray, *Explorations in Strategy*, 61–62.

16. Bruce I. Gudmundsson, *Stormtroop Tactics: Innovation in the German Army, 1914–1918* (Westport, CT: Praeger, 1995), 178; and Wynne, *If Germany Attacks*, 320.

17. Wynn, *If Germany Attacks*, 156–57.

18. Gudmundsson, *Stormtroop Tactics*, 155–68, 177–78; and Wynne, *If Germany Attacks*, 320.

19. Mark R. Peattie, *Sunburst: Rise of Japanese Naval Air Power, 1909–1941* (Annapolis, MD: Naval Institute Press, 2001), 75, 189.

20. Bungay, *Most Dangerous Enemy*, 23–25.

21. Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, 32–33.

22. Ibid., 17.

23. Ibid., 21.

24. P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the 21st Century* (New York: Penguin Books, 2009), 126.

25. Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, vii, 46. According to Arquilla and Ronfeldt, "sustainable pulsing" attacks are those "that repeatedly strike the adversary—with fire or force—from all directions, then to dissever from the attack, redisperse, and repeat the cycle as battle conditions require."

26. William “Billy” Mitchell, *Winged Defense: The Development and Possibilities of Modern Air Power—Economic and Military* (1925; repr., Tuscaloosa: University of Alabama Press, 2010), 8–9.

27. Richard J. Overy, “Air War in Europe, 1939–1945,” in *A History of Air Warfare*, ed. John Andreas Olsen (Washington, DC: Potomac Books, 2010), 30–32; and Bungay, *Most Dangerous Enemy*, 492. For a graphical depiction of the British main battle area, see the map provided at the end of *Most Dangerous Enemy*.

28. Dwayne A. Day, “Aerial Refueling,” Centennialofflight.net, http://www.centennialofflight.net/essay/Evolution_of_Technology/refueling/Tech22.htm (accessed 27 January 2012).

29. US Air Forces Central Command (AFCENT), “Factsheets: 380th Air Expeditionary Wing History,” http://www.380aew.afcent.af.mil/library/factsheets/factsheet.asp?id=12246; and AFCENT, “Units: 379th Air Expeditionary Wing,” http://www.379aew.afcent.af.mil/units/index.asp (both accessed 20 February 2012); and Benjamin S. Lambeth, “Operation Enduring Freedom, 2001,” in *History of Air Warfare*, ed. John Andreas Olsen (Washington, DC: Potomac Books, 2010), 258–59.

30. Air Force Doctrine Document (AFDD) 6-0, *Command and Control*, 28 July 2011, 2.

31. Ibid., 4–5.

32. Ibid., 19.

33. Bungay, *Most Dangerous Enemy*, 63.

34. Ibid.

35. AFCENT, “Factsheets: Combined Air and Space Operations Center (CAOC),” 6 February 2001, http://www.afcent.af.mil/AboutUs/FactSheets/Display/tabid/140/Article/217803/combined-air-and-space-operations-center-caoc.aspx.

36. Martin van Creveld, *Command in War* (Cambridge, MA: Harvard University Press, 1985), 272.

37. Antoine Bousquet, *Scientific Way of Warfare: Order and Chaos on the Battlefields of Modernity* (New York: Columbia University Press, 2009), 233–34.

38. Singer, *Wired for War*, 126.

39. Information technologies built into aircraft communications systems may allow commanders to gain real-time information on any group or single aircraft based on the design of networked airpower.

40. Richard J. Overy, *Air War: 1939–1945* (Washington, DC: Potomac Books, 2005), 31, 162–63, 165, 170.

41. Michael E. O’Hanlon, *Science of War: Defense Budgeting, Military Technology, Logistics, and Combat Outcomes* (Princeton, NJ: Princeton University Press, 2009), 147.

42. Joint Publication (JP) 4-0, *Joint Logistics*, 18 July 2008.

43. John H. Morrow Jr., “First World War, 1914–1919,” in *History of Air Warfare*, ed. John Andreas Olsen (Washington, DC: Potomac Books, 2010), 21; and Jeremy Black, *World War Two: A Military History* (London: Routledge, 2003), 184.

44. John Andreas Olsen, *History of Air Warfare*, 249, 270, 347.

45. Orville F. Desjarlais Jr., “Unmanned, Unmatched, Unafraid,” *Airman* 49, no. 6 (Summer 2005): 38. The MQ-1B Predator has a significant loiter time, cruises at approximately 84 miles per hour, has a range up to 770 miles, can provide full-motion video imagery, and can carry two Hellfire missiles. The MQ-9 Reaper also “has significant loiter time,” cruises at approximately 230 miles per hour, has a range of 1,150 miles, and carries a variety of imagery sensors and air-to-ground weapons. Each of these aircraft is controlled via remote split operations whereby a forward-located crew launches and recovers the vehicles. After launch and prior to

recovery, pilots and sensor operators—located in the United States—operate the aircraft. USAF, "Factsheets: MQ-1B Predator," 20 July 2010, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104469/mq-1b-predator.aspx; and USAF, "Factsheets: MQ-9 Reaper," 18 August 2010, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104470/mq-9-reaper.aspx.

46. David A. Deptula, "Unmanned Future," *Armed Forces Journal* 148, no. 10 (June 2011): 34; and Singer, *Wired for War*, 115–20, 126.

47. David A. Deptula, "Unmanned Aircraft Systems: Taking Strategy to Task," *Joint Force Quarterly* no. 49 (2nd Quarter 2008): 49–51.

48. JP 3-0, *Joint Operations*, 11 August 2011, III-35.

49. Bousquet, *Scientific Way of Warfare*, 69.

50. JP 3-0, *Joint Operations*, III-29.

51. Ibid., III-30.

52. See ibid., III-31–III-35, for a detailed listing of active and defensive protective measures.

53. "US Kicked Out of Kyrgyzstan Air Base," Military.com, February 2009, http://www.military.com/news/article/February-2009/us-kicked-out-of-kyrgyzstan-air-base.html; and "Kyrgyzstan Crisis: What You Need to Know," *Week*, 9 April 2010, http://theweek.com/article/index/201745/the-kyrgyzstan-crisis-what-you-need-to-know. Manas Air Base is an important supply base for air cargo and air-refueling aircraft supporting Afghanistan. Competition between political elements of the Kyrgyz government caused uncertainty over the US use of Manas. Moreover, the Kyrgyz parliament threatened to expel Russia and the United States from its territory in an effort to receive higher lease payments for use of its air bases. Shortly after Kyrgyzstan's temporary decision to expel US and Russian forces, Russia offered to pay more for its base and the use of Manas AB. This crisis was eventually resolved following higher lease payments by both states.

54. "Kyrgyzstan Extends US Lease on Manas Air Base," *BBC News*, 16 April 2010, http://news.bbc.co.uk/2/hi/8624723.stm.

55. JP 1, *Doctrine for the Armed Forces of the United States*, 20 March 2009, I-9.

56. JP 3-0, *Joint Operations*, I-3.

57. Chairman of the Joint Chiefs of Staff Instruction 2300.02F, *Coordination of Overseas Force Structure Changes and Host-Nation Notification*, 30 September 2009; and Air Force Instruction (AFI) 10-504, *Overseas Force Structure Changes and Host Nation Notification*, 21 October 2011.

Chapter 2

A Technologically Driven Paradigm of Overwhelming Force

Sound logistics forms the foundation for the development of strategic flexibility and mobility. If such flexibility is to be exercised and exploited, military command must have adequate control of its logistic support.

—RADM Henry E. Eccles, USN

For professional military organizations and officers almost everywhere, the decisive incentives accrued to the development of bigger institutional hierarchies and weapon systems, in eras when information and communications systems were improving but still remained quite slow, centralized, and cumbersome—all of which favored the continued development of mass and maneuver approaches to warfare.

—John Arquilla and David Ronfeldt

As noted, military strategy integrates war objectives, planning, and "series of actions" so that wartime operations mesh with politicians' grand strategy.[1] The planning process, however, must consider existing capabilities of fielded weapons. Development and production of new weapons and equipment takes time, and the constant state of readiness demanded of military forces does not support strategies built on unproven technologies. During a 2004 meeting with deployed military personnel in Kuwait, then–secretary of defense Donald Rumsfeld's comment "You go to war with the army you have, not the army you might want or wish to have at a later time" illustrated this reality.[2] Furthermore, within Colin Gray's 13 "Principles on Characteristics of Armed Forces for Guidance of Defense Planning," four of the first seven planning factors involve the evaluation of existing military forces. According to Gray, defense planners should evaluate whether existing military forces are "capable of winning," available in sufficient numbers, "applicable quickly," and "logistically supportable."[3] Similarly, airpower has contributed to a US military strategy based on its ability to speed victory, employ destructive force rapidly against adversaries, and sustain operations with adequate logistical support.[4]

These ideas have been central aspects of the US airpower paradigm. Thomas Kuhn revealed a groundbreaking way to study institutional thought processes when he stated that paradigms are "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners."[5] Scientists committed to a given paradigm engage in "normal science" and conduct "research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice." Kuhn adds that "men whose research is based on shared paradigms are committed to the same rules and standards for scientific practice."[6] Although there are many differences between the US Air Force and the scientific community, Kuhn's paradigm concept applies to the service.

In many respects, the Air Force has been committed to the idea that air-delivered kinetic effects prosecute war more rapidly and effectively than surface warfare.[7] Thomas Kane named this paradigm the "bombardment style of warfare," based on its emphasis on an alleged ability to deliver decisive kinetic effects from air vehicles.[8] Air Force normal science has focused its efforts toward improved weapon systems and employment methods that provide faster means to deploy violence against the enemy so that wars can be ended in the shortest amount of time. Even with improved weapons systems and employment, the Air Force has been heavily reliant on robust logistics systems. Similar to the scientific community's use of normal science, the Air Force's reinforcement of operational norms, rules, and standards within service regulations and doctrine has hardened support for the existing airpower paradigm.

US kinetic airpower doctrine has also been inextricably tied to the belief that airpower serves as a means of accelerating victory using the maneuver capabilities of aircraft. Manned aircraft, large foreign air bases, and robust logistical requirements have provided the means to satisfy maneuver warfare requirements. US airpower force structures provide "complex, synchronized, fast-tempo, multi-linear operations to surprise, penetrate [and] flank with mobile mass at [the] decisive point."[9] Moreover, the ability to maneuver air forces on a global scale has characterized US air operations and set the stage for how the United States developed and sustained its military force structure.

According to this line of argument, airpower's use of the third dimension has provided military strategists the ability to deliver reconnaissance and force with an incomparable maneuver capability, unlike slower and less maneuverable land and sea forces.[10] Although early airpower missions dealt primarily with reconnaissance, aircraft gained the ability to deliver destructive force directly against enemy assets.[11] Instead of supporting land forces or directing artillery, aircraft acquired the ability to conduct attacks themselves. In airpower's infancy, bombing attacks often took place in parallel with reconnaissance operations. For example, in 1911 the Italian army used reconnaissance aircraft to drop bombs against Libyan positions, and as early as 1912, "the offensive use of the dirigible and the airplane had begun to draw some interest among military authorities."[12] Moreover, by the end of World War I, aviation and weapons technologies advanced to such a degree that there was "a spreading conviction that if the airplane had not replaced the foot soldier or the artillery piece as the central cog in the military machine of 1918, its role could only continue to grow as it continued to evolve."[13]

Early airpower advocates Air Marshal Giulio Douhet in Italy and Brig Gen Billy Mitchell in the United States realized the potential importance of offensive airpower and focused on the merits of aerial bombing. From Douhet's perspective, aerial bombing had inherent measures of effectiveness that could increase strategic planners' ability to achieve decisive victory. He wrote that "the guiding principle of bombing actions should be this: *the objective must be destroyed completely in one attack, making further attack on the same target unnecessary . . . . The unit of bombardment must have the potentiality to destroy any target on a given surface*" (emphasis in original).[14] General Mitchell also believed that airpower could be decisive and argued that aerial bombing might be a revolutionary form of warfare:

> More than that, aerial torpedoes which are really airplanes kept on their course by gyroscopic instruments and wireless telegraphy, with no pilots on board, can be directed for over a hundred miles in a sufficiently accurate way to hit great cities. So that in [the] future the mere threat of bombing a town by an air force will cause it to be evacuated, and all work in munitions and supply factories to be stopped.
>
> A new set of rules for the conduct of war will have to be devised and a whole new set of ideas of strategy learned by those charged with the conduct of war. No longer is the making of war gauged merely by land and naval forces.[15]

Writings such as these provided added support for the use of aerial bombing and helped ensure that bomber aircraft held a central role within the force structure of the US Air Force.[16]

Even with the advent of modern precision-guided weapons, airpower historian Tami Biddle noted that current airpower debates have a "familiar ring," adding that

> since 1918 airmen have sought to find and destroy a critical Achilles' heel in an opposing society, polity, or economy so as to win wars without fighting one's way through the mass land armies of previous eras. Through more than eighty years and the experience of World War II, Korea, and Vietnam, the underlying philosophy and central implementing ideas of strategic bombing have changed remarkably little. The *tools* of air warfare have

> changed dramatically since the canvas and plywood planes of the First World War, but it is striking just how little the basic ideas behind the *use* of those tools have changed (emphasis in original).[17]

Biddle is correct that airpower ideas emphasizing the efficacy of bombing have been central and relatively continuous aspects of US airpower. Nonetheless, the airpower paradigm continues to hold that no other tool of warfare has the capability to deploy violence against enemy targets with the same degree of mobility and speed. Consequently, the tools of air warfare have improved in their ability to deliver powerful weapons. The community of airpower practitioners has advanced the efficacy of the air weapon but only within the regnant paradigm.

Modern aircraft are much more capable than their predecessors. Compared to World War II–era bombers, the B-52, B-1, and B-2 carry a load many times that of their propeller-driven ancestors. For example, the B-17 carried 9,600 pounds (lb.) of bombs, and the B-29 had a 20,000 lb. bomb load.[18] The B-52 and B-1 carry 70,000 lb. and 75,000 lb. bomb loads, respectively.[19] In fact, jet-powered attack aircraft flown in the Vietnam War and Operations Desert Storm and Iraqi Freedom carry payloads often exceeding those of World War II bombers.[20] Military aircraft have also become larger and faster because jet aircraft typically consume more fuel, require large fuel tanks, have heavy payloads, and require higher airspeeds or larger wings to deliver their weapons to the target. The development of large jet-powered aircraft such as Boeing 707 variants also led to the employment of large support aircraft such as the E-3 AWACS (Airborne Warning and Control System), RC-135 reconnaissance aircraft, and air-refueling tankers.[21] Although these aircraft have resulted in greatly increased airpower capabilities, their use has increased the logistical requirements of theater-level air operations.

Accordingly, geographic positioning, logistics, security, and politics drive the United States toward large air bases and robust logistics bases. During the Vietnam War, ODS, and OIF, a wide variety of airpower capabilities involving manned combat and combat support aircraft necessitated long runways, vast ramp space, and facilities for aircraft maintenance, weapon and fuel storage infrastructure, aircraft command and control, and aircrew ready areas. Air bases also included facilities capable of feeding and sheltering legions of aircrew, maintenance personnel, and support troops. The logistical aspects of air operations also required security from enemy attack and involved significant political negotiation with host countries.

Geographic Positioning

Consistent with the basic tenets of airpower outlined in AFDD 1, *Air Force Basic Doctrine, Organization, and Command*, theater air bases are important components of airpower because they provide geographic combatant commanders (GCC) strategic and operational flexibility and versatility, enhance persistence, and facilitate concentration of forces.[22] The location and presence of air bases in foreign countries provide GCCs options relative to the employment of airpower. Theater commanders may "shift from one campaign to another," operate at multiple levels of warfare, hold the ability to revisit targets, and "concentrate overwhelming power at the decisive time and place."[23] This process is not automatic. Selecting air bases and determining their suitability involves the careful evaluation of numerous factors, including geographic positioning, aircraft operating restrictions, and the logistical requirements of individual aircraft.

Geographic positioning of air bases is an important component of theater airpower regardless of the availability of air refueling. Colin Gray contends that range and reach are "advantages of airpower," often extended by air refueling.[24] Although air refueling greatly extends the reach of airpower, tanker aircraft are not a panacea for sustained long-distance air operations. Even during the Cold War, basing plans involving nuclear-armed bombers and tanker aircraft relied on a mix of air-refueling and ground-refueling bases.[25] Air-refueling aircraft carry a finite amount of fuel and have range limitations just as any other aircraft. Furthermore, because only a small proportion of the US tanker fleet can be refueled in the air, most tankers rely on ground refueling.[26] Regardless of their ability to extend the range of aircraft and increase loiter time, even air-refuelable tankers must eventually land for logistical support.[27] Similarly, the diverse array of attack, command-and-control, and reconnaissance aircraft requires ground-based logistical support.

Thus, tanker aircraft and air bases must be geographically dispersed throughout the theater of operations to enable airpower coverage. Due to the limited range of many Air Force offensive aircraft, they are normally based within the region where they conduct operations, usually within 500 miles of their target.[28] Moreover, "fighter aircraft tend to operate at much shorter ranges than bombers, and since they must operate in relatively large numbers, it is correspondingly more difficult to sustain them with aerial refueling."[29] Without a balanced air refueling and air base architecture, the GCC faces a difficult task in ensuring operational flexibility and versatility. This task is made even more difficult because each type of military aircraft has particular operating requirements.

Air bases do not have the universal capability to support every type of air asset in the theater of operations. Challenges involving large support and bomber aircraft, as well as smaller attack aircraft, require distinctive support infrastructures for continued wartime operations.[30] Basing of air-refueling, bomber, and cargo aircraft is especially challenging because they require long runways and large parking areas as well as immense amounts of fuel. As of 2002, the global inventory of airfields with runways exceeding 6,000 feet in length was only 2,011.[31] Consequently, basing options for aircraft such as KC-10 tankers may be significantly limited because they require runways of at least 7,000 feet, taxiways at least 75 feet wide, 34,800 square feet of parking area, and airfield surfaces capable of supporting their 593,000 lb. maximum takeoff weight.[32] Large aircraft such as B-1B and B-52 bombers, as well as C-17 cargo aircraft, have similar airfield requirements.[33] Smaller aircraft like F-16, F-15E, and A-10 attack aircraft require less runway and parking space but require dedicated weapon storage and loading areas.[34] Consequently, selection of individual bases and the theater air order of battle may have more to do with a base's infrastructure compatibility with specific types of aircraft than with its geographic location.

In the early days of the Vietnam War, airfields were in short supply. According to aviation historian Bill Yenne, at the beginning of the war "the only jet-serviceable air bases available were Da Nang, Bien Hoa, and Tan Son Nhut."[35] Few airfields could support jet operations, and existing ones were often geographically removed from target areas (see fig. 1).

The lack of suitable airfields caused US air assets to be spread throughout Southeast Asia and often forced war planners to base aircraft in friendly states such as Thailand. The dispersal of air assets required extensive use of air-refueling tankers to extend the range of all types of combat and support aircraft. According to Wayne Thompson, "One of the characteristics of air warfare introduced during the Vietnam War was the routine use of air-refueling in combat operations. By the end of Rolling Thunder in 1968, 90 KC-135 air-refueling tankers made possible not only B-52 operations from Guam, but also fighter operations from Thailand."[36] Regardless of the range extension that air refueling provided, the limited number of airfields made mixed basing of cargo, fighter, tanker, and bomber aircraft a necessity.[37] By 1968, efforts to relieve air base shortages resulted in the construction of eight major bases with 15 runways, and by the end of the war, "200 additional airfields were also built and at least that many heliports."[38] These developments demonstrate the important relationship between aircraft range, the location of air bases, and the availability of theater air-refueling assets.

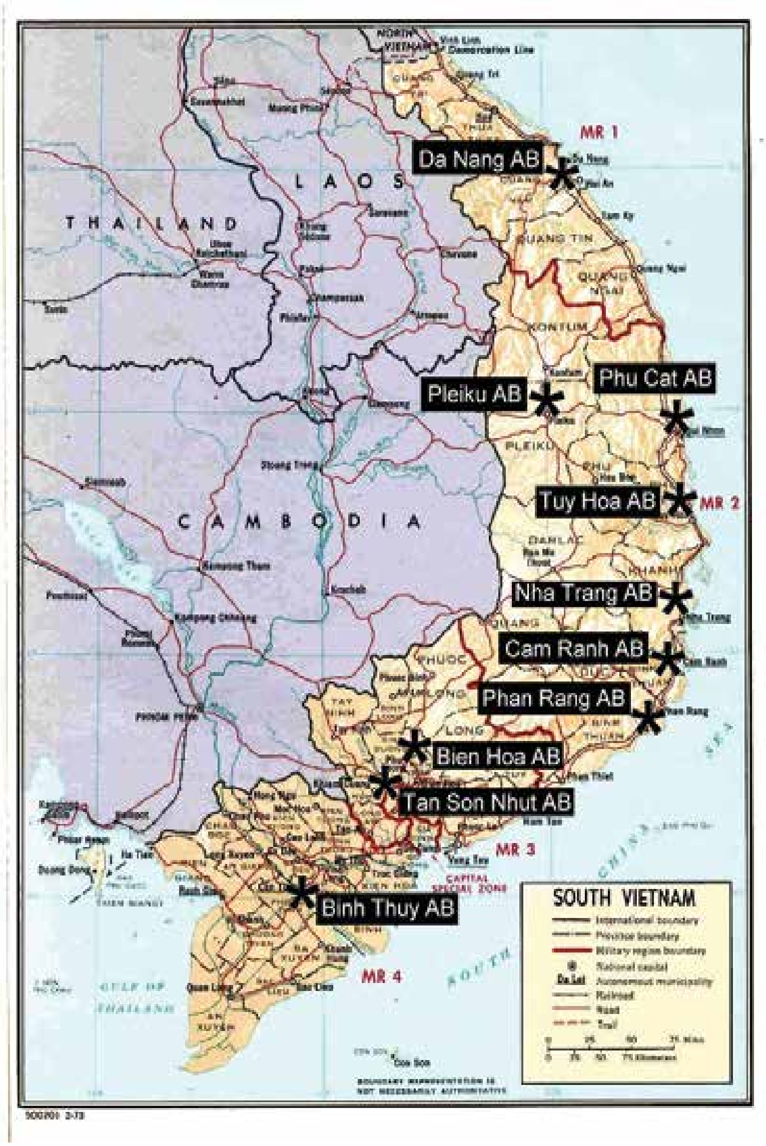

Figure 1. US air bases of the Vietnam War
(Reprinted from: *Wikipedia*, http://upload.wikimedia.org/wikipedia/en/f/fe/Usaf-vietnam-map.jpg.)

A quarter-century later, Operation Desert Storm's war planners were challenged by the Persian Gulf region's limited number of airfields. They had to base 2,430 fixed-wing aircraft at approximately 25 airfields located in multiple

Middle Eastern countries.[39] Although Benjamin Lambeth noted that "the coalition enjoyed a basing infrastructure in the Gulf region that left almost nothing to be desired, largely owing to the military assistance that the United States had provided Saudi Arabia over the preceding four decades," the scope of operations made airfields a valuable commodity.[40] As in the Vietnam War, a relative shortage of airfields resulted in additional construction and the mixed basing of different types of aircraft at common airfields.[41] Air bases were a critical enabler for the US-led coalition against Iraq, and the DOD's *Conduct of the Persian Gulf War* report illustrated the importance of "staging bases and a well-developed infrastructure, especially airfields and ports."[42] Similar to the US experience in Vietnam, the geographic positioning of air assets during ODS was primarily dependent on airfield ramp space, support capabilities, and air refueling.

The same trends influenced air operations during Operation Enduring Freedom. Afghanistan had few air bases capable of supporting US combat aircraft, and neighboring countries such as Pakistan did not allow large-scale air operations from their airfields.[43] Therefore, the majority of air assets were based at geographically distant airfields such as Al-Dhafra and Al-Udeid. Air expeditionary wings such as the 380 AEW and 379 AEW were responsible for supporting a wide variety of aircraft, including tanker, reconnaissance, and strike platforms.[44]

Geographically displaced airfields and the basing of strike aircraft at multiple locations made air refueling essential for continued operations. Lambeth explained the impact of range-extending air refueling support during OEF: "Yet another operational trend that continued in Enduring Freedom had to do with extended-range operations. In Desert Storm, the proportion of tanker sorties among the total number of air sorties flown was 12 percent. . . . In Enduring Freedom, it was 27 percent. By the same token, long-range bombers have delivered a steadily increasing percentage of the overall numbers of weapons expended throughout the succession of U.S. combat engagements since 1991. In Desert Storm, it was 32 percent. . . . In Enduring Freedom, it was about 70 percent."[45]

Ideally, future operations will involve theater basing within range of air bases so that the success or failure of air operations will be less dependent on air refueling. Nonetheless, air refueling provides an extension of ground logistics bases and mitigates some of the challenges involved with disparate geographic basing. But airfields and tankers can only support theater military operations as long as they receive the logistics (and protection) they require. Consequently, the long-term sustainment of air bases may be just as critical as aircraft range or the range-extension capabilities of air-refueling tankers.

According to AFDD 2-4, *Combat Support*, marrying the logistical needs of airpower assets with suitable airfields is an issue of agile combat support (ACS) which is defined as "the ability to create, protect, and sustain air and space forces across the full range of military operations."[46] The goal of ACS is to "generate combat capability by creating, posturing, bedding down, protecting, servicing, maintaining, and sustaining support and operational forces."[47] AFDD 2-4 provides a basic framework for assessing logistical support and available infrastructure to achieve ACS. For example, theater assessment of airfields should include an intelligence review, expeditionary site surveys, logistical sustainability evaluations, and crisis action planning. This process ensures that theater airfields are suitable for use, sustainable, and provide adequate options to the GCC in the case of emergencies or enemy action.[48] When airfields have been deemed suitable and sustainable, they can begin to accept the myriad of support personnel necessary to sustain theater airpower. Thus, the influx of logistics and support personnel quickly expands the force footprint of operational bases.

Tooth to Tail

Even Prussian military theorist Carl von Clausewitz lamented the requirements of maintenance and supply. During the revolutionary Napoleonic era, armies increased dramatically in size and were becoming both expensive and complicated to maintain.[49] Thus, nineteenth-century commanders were constantly faced with challenges involving the acquisition of military supplies and the need to keep units at a high state of readiness. Today's air operations face the same challenges; however, logistics have become more difficult because modern military operations require an immense variety of equipment, supplies, and expertise for each weapon system and mission. Moreover, complex logistics requirements exist throughout the initial deployment and sustainment phases of military operations.

Manpower requirements begin with the initial deployment of forces. According to Christopher Bowie, depending on the "type of aircraft, for a squadron of 24 operational combat aircraft, an average of about 500 personnel and 350 tons of equipment are needed" to deploy into theater.[50] Upon arrival at forward operating locations (FOL), they require large numbers of personnel for aircraft and vehicle maintenance, base operations, civil engineering, equipment supply, billeting, and food preparation, to name a few tasks.[51] Moreover, air base personnel are vital for processing the 100–200 tons of ammunition and 3,500 tons of fuel typically required by Air Force combat wings.[52] Figure 2 provides perspective relating to the logistics requirements of modern air operations such as Enduring Freedom. It demonstrates that support elements often require more supplies than the combat forces they support.

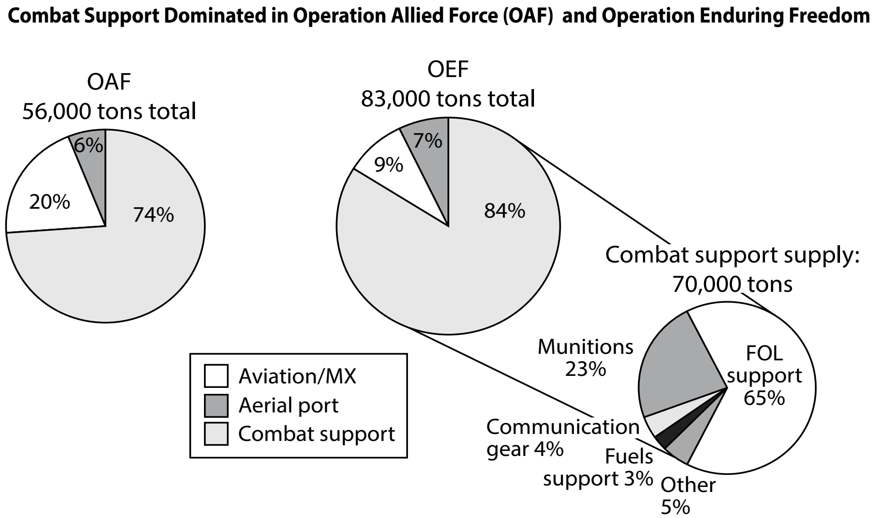

Figure 2. Logistics in Operations Allied Force and Enduring Freedom
(Adapted from: Mahyar A. Amouzegar et al., *Analysis of Combat Support Basing Options* [Santa Monica, CA: RAND, 2004], 5.)

Supplies processed by support personnel are delivered via lines of communication involving vast interconnected land, sea, and air transportation networks. The essential reliance on transportation of supplies is not a new phenomenon. John Lynn notes that "while logistic needs have changed over the centuries, logistics have always exerted tremendous influence on strategy and operations."[53] Martin van Creveld reinforced this idea with this observation:

> Strategy, like politics, is said to be the art of the possible; but surely what is possible is determined not merely by numerical strengths, doctrine, intelligence, arms and tactics, but, in the first place, by the hardest facts of all: those concerning requirements, supplies available and expected, organization and administration, transportation and arteries of communication. Before a commander can even start thinking of maneuvering or giving battle, of marching this way and that, of penetrating, enveloping, encircling or annihilating or wearing down, in short of putting into practice the whole rigmarole of strategy, he has—or ought—to make sure of his ability to supply his soldiers with those 3,000 calories a day without which they will very soon cease to be of any use as soldiers; that roads to carry them to the right place at the right time are available, and that movement along these roads will not be impeded by either a shortage or a superabundance of transport.[54]

US military operations in Vietnam, ODS, and OEF were not exceptions. The global LOCs involved in each of these major force deployments required extensive logistical support and intercontinental transportation networks.

During the early stages of the Vietnam War, the vast majority of supplies were pre-positioned at forward support locations (FSL) such as Okinawa, Japan; Subic Bay, Philippines; and Korat and Udorn, Thailand.[55] As the conflict progressed, Vietnamese seaports were expanded to increase US supply operations. The US supply system in Vietnam relied on a constant stream of transport ships to maintain a 20-day supply of petroleum products and a large arsenal of munitions at coastal ports. It also relied on land vehicles and aircraft to transport fuel and other supplies inland to FOLs scattered throughout South Vietnam.[56] Even after additional supply bases were constructed, "there was no front and no rear in the conventional sense. There were no advances and withdrawals on linear axes, along which the sinews of war could flow."[57]

While disjointed LOCs made operations difficult, ineffective inventory control of relatively plentiful means of transportation and war materials caused extensive waste. For example, "depot operations in 1968 processed about two million tons of materiel, but only about one-third were available for issue. The majority was *lost* and not on existing, usable supply records."[58] Consequently, the disorganized nature of the US logistics system caused periodic shortages of munitions and other supplies because of poor logistics policies using the World War II–era "push" system that "netted pretty much the same results: inadequate support of critical items, far too much of the unnecessary, and no means for becoming more sensitive and responsive to combat and support needs."[59] Fortunately for the United States, Vietnam offered numerous ports that provided direct access to the war zone, and the steady stream of materiel shipments overcame uncoordinated attempts to manage obsolete brute force methods of supply.

In many respects, the logistics of ODS bear many similarities to US supply operations in the Vietnam War. The majority of supplies were transported by sea, offloaded at one of many ports, and then delivered by truck and rail to FOLs. In Desert Storm, pre-positioned and contracted supply ships delivered four-fifths of initial supplies.[60] US forward air bases relied on the constant supply of Saudi fuel trucks that transported petroleum products from Saudi Arabian refineries to US-operated airfields.[61] This effort allowed approximately 300 US air tankers to provide 178 million gallons of fuel to coalition aircraft.[62] Ground vehicles also transported the vast majority of munitions to air bases; however, delivery of aircraft munitions was delayed at times due to a shortage of munitions-handling equipment.[63] When combat operations used munitions faster than expected, airlift aircraft mitigated shortages by transporting more than 3,600 tons of bombs to Saudi Arabian airfields.[64]

Although Desert Storm's general method of logistics supply was similar to that of the Vietnam War, the first Persian Gulf conflict's extensive use of computerized logistics networks dramatically improved the management of theater supply inventories.[65] According to van Creveld, "What made this war unique was the fact that, after it ended, every single item not consumed or expended had to be accounted for, restored to a pristine condition and evacuated. The days when American forces leaving a theater of war would leave behind vast junkyards for the locals to plunder were over."[66] Without a doubt, logistics improvements since Vietnam and increased host-nation cooperation contributed to the operational successes of ODS, yet the conflict represented an iterative improvement in the sustainment of maneuver warfare logistics that has become an essential part of the USAF's airpower paradigm.

Operation Enduring Freedom is the latest example of maneuver-warfare logistics. As in Vietnam and ODS, the majority of OEF supplies are delivered by seagoing cargo vessels and then transported by ground vehicles or rail transport to various bases scattered throughout Afghanistan (see fig. 3).[67]

Although Enduring Freedom has involved fewer aircraft—approximately 200—air operations have relied heavily on tanker and bomber support from dispersed bases.[68] Furthermore, tanker sorties and cargo airlift missions comprised the majority of missions flown to and from Afghanistan. From 2001 to 2004, "of the 11,000 sorties flown in support of OEF, only approximately 3,400 were combat, command and control, intelligence, surveillance, and reconnaissance (C2ISR), or Special Operations Forces (SOF)/combat support and rescue sorties."[69] The rest were cargo and air-refueling sorties. Nonetheless, supply operations were put in place for the long haul rather than being designed for quick victory, as in Desert Storm, and enabled a continued airpower presence against enemy forces in Afghanistan.[70] Moreover, US Transportation Command's use of information technologies and "data transparency" indicates a DOD effort to improve combat logistics and delivery of supplies.[71] However, information technologies may only provide a method to cope with the increasing complexity of ACS operations.

Logistics requirements in Vietnam, ODS, and OEF increased with the complexity of operations. More advanced aircraft demanded more complex logistics infrastructures and vast amounts of fuel and munitions. Furthermore, complex lines of communication made the supply of geographically separated FOLs difficult to sustain. Even with improved information systems and logistics management, supply remained dependent on seaports, land transportation, and stopgap airlift operations. As van Creveld sagely noted, "One thing seems certain: in the future, logistics will become even more complex than they already are. In part, this is because they really *are* becoming more complex, what with the introduction of countless new machines and the vast amount of coordination those machines require to keep functioning and fighting."[72] Nonetheless, people instead of machines are ultimately responsible for the conduct of warfare and provide additional options relative to the equipment at hand. Unfortunately, enemy personnel have the option to exploit US lines of communication, and foreign heads of state have the power to invite or deny access to their facilities and national infrastructure.

Figure 3. Operation Enduring Freedom supply routes
(Reproduced from Tom Gjelten, "U.S. Now Relies on Alternate Afghan Supply Routes," National Public Radio, http://www.npr.org /2011/09/16/140510790/u-s-now-relies-on-alternate-afghan-supply-routes. Used with permission.)

Security

Security of air bases and supply lines is critical to the support of air operations. Logistical shortages may halt operations. The destruction of base infrastructure and/or aircraft, theft of supply items, or attacks against supply convoys have the potential to degrade the sustainment of regional airpower capabilities.

Security against enemy attacks and theft was a major concern during the Vietnam War. Alan Vick described the adverse effects of enemy attacks on US FOLs:

> More ground attacks on air bases were recorded in Vietnam than in any other conflict. VC [Viet Cong] and NVA [North Vietnam Army] forces attacked USAF main operating bases 475 times between 1964 and 1973. Those attacks destroyed 99 U.S. and Vietnamese aircraft and damaged another 1,170. Additional attacks against other USAF, Army, Marine Corps, and Republic of Vietnam Air Force (RVNAF) facilities in Vietnam and against USAF bases in Thailand raised the total destroyed to 375, roughly 4 percent of all aircraft losses. Although this is a relatively small percentage of the total losses, it is interesting that more U.S. Air Force fixed-wing aircraft were destroyed by ground action than were downed by MiGs (99 versus 62).[73]

Vick also noted that while enemy attacks caused significant aircraft losses, "high-value aircraft, such as KC-135s, B-52s, AC-130s, and F-105Gs were based in Thailand and Guam, where the ground threat was lower or nonexistent."[74] Convoys and supply lines were also constantly under threat of enemy attack and theft. Truck convoys faced frequent attacks. And by the end of the war, former commander of the 1st Logistics Command, LTG Joseph M. Heiser Jr., estimated that 250 million gallons of petroleum were lost to pilferage.[75] Fortunately for US air operations, the sheer volume of supplies sent to Southeast Asia limited the adverse effects of security vulnerabilities.

The most significant security concerns during Operation Desert Storm involved SCUD theater ballistic missile attacks against coalition facilities. According to Lambeth, "base vulnerability was generally not a problem," the threat of terrorism was only a "low-key" threat, and most coalition bases had few passive defenses.[76] Nonetheless, the danger posed by Iraq's SCUDs led the United States to deploy Patriot batteries throughout the region to protect coalition facilities and dissuade Israel from entering the conflict.[77] Most Iraqi SCUDs failed due to structural failures or guidance problems or were shot down by US-made Patriot missiles.[78] Although the coalition feared its forces were vulnerable following a SCUD missile hit on a US base in Dhahran, Saudi Arabia, in which 27 US personnel were killed, rear area security was not a significant problem compared with the Vietnam War and Operation Enduring Freedom.[79]

Similar to the Vietnam War, US FOLs and supply convoys have been under constant threat of attack in OEF. US-operated air bases at Bagram and Kandahar, Afghanistan, deal with elusive threats such as car bombs, mortar fire, and "small-team assaults" but must also "be wary of the occasional large strike with heavy weapons."[80] Taliban forces recognize the value of US airpower and seek to impede air operations.[81] Enemy forces have also impacted NATO supply lines throughout Afghanistan. Tim McGirk wrote in 2009 that the Taliban widened the "scope of their attacks so that convoys rumbling across two-thirds of the country are now prey to attack, usually by roadside bombs or a well-laid ambush in which rocket-propelled grenades are fired at the lead vehicle, forcing the convoy to a deadly standstill." He also noted that "from June to September [2009], more than 145 truck drivers and guards were killed in attacks on convoys and 123 vehicles were destroyed."[82] Pakistani Taliban forces have restricted the flow of fuel supplies into Afghanistan with multiple attacks against coalition fuel convoys traveling through Pakistan.[83] The Pakistani government has also halted such transfers several times.[84] Attacks on fuel convoys traversing Pakistan have been one of the major reasons that the Department of Defense has opened multiple northern supply routes into Afghanistan. Despite these obstacles, military leaders worked to ensure a constant supply of war materiel to Enduring Freedom's multiple FOLs. Brig Gen Jimmy McMillian's 2010 statement that "our objective, in all cases, is uninterrupted operations . . . and in some locations, this means uninterrupted aircraft sortie generation, in others, uninterrupted training activity" demonstrates the Air Force leadership's commitment to US supply operations.[85]

The US experiences during the Vietnam War, ODS, and OEF indicate that the operational environment determines the context of supply-line security. Vietnam and the current war in Afghanistan demonstrate that extended LOCs through hostile territory invite enemy action against supply convoys. Furthermore, FOLs are vulnerable to attacks that can destroy or damage deployed aircraft. Ultimately, large-scale logistics have provided the United States the ability to overcome enemy attacks and pilferage; however, these methods owe some of their success to their favorable political environment.

Politics

During the Vietnam War, the United States endured few political restrictions to its use of South Vietnamese territory and facilities. The Saigon government was frequently not taken seriously. In 1965, the US ambassador to South Vietnam, Henry Cabot Lodge, said: "There is no tradition of a national government in Saigon. . . . I don't think we should take this government seriously. There is no one who can do anything. We have to do what we think we ought to do regardless of what the Saigon government does."[86] The Johnson administration took the position that the local government's lack of legitimacy meant that the United States was primarily responsible for South Vietnam's security.[87] Saigon's political input was rarely accepted or considered during US military planning actions.[88] Consequently, the relatively unrestricted access and ubiquitous presence of US forces in South Vietnam meant that supply operations were not restricted by host-nation political concerns.

Compared with the US experience in Vietnam, more recent political discourse with host nations has had a significant impact on supply and air operations. During ODS, the US buildup of military forces was initially restricted by King Fahd's reluctance to allow Western military forces into Saudi Arabia.[89] But, after considerable diplomacy, the monarch approved US use of Saudi facilities.[90] Furthermore, the US-led coalition was threatened by the possibility Israel would retaliate against Iraqi SCUD attacks. The George H. W. Bush administration feared if Israel became involved, the Saudis would no longer allow the use of their country for ODS.[91] Ultimately, Israel did not enter the war, the United States was able to use Saudi facilities, and the Saudis supported operations to such a degree that they "provided approximately 4,800 tents; 1.7 million gallons of packaged petroleum, oil and lubricants; more than 300 heavy equipment transporters (HET); about 20 million meals; on average more than 20.5 million gallons of fuel a day; and bottled water for the entire theater."[92] Nonetheless, throughout the first Persian Gulf War, host-nation states such as Saudi Arabia held significant power to affect air operations to a greater degree than enemy action could have accomplished.

Politics and diplomacy have also played a major role in Operation Enduring Freedom. The George W. Bush and Obama administrations have had to acknowledge the demands of Afghan president Hamid Karzai, negotiate safe passage of coalition aircraft and supply convoys through Pakistan, and coordinate supply routes with Afghanistan's northern neighbors.[93] Although Afghanistan does not possess the military strength to expel US forces, it could exert its national will against the United States if it desired their removal. Pakistan holds more political leverage than Afghanistan because it controls major lines of communication to and from Afghanistan. Although northern routes provide theater commanders additional supply options, Pakistan controls critical air and ground supply routes. Consequently, its political power over the United States is significant in that it has the ability to isolate US air operations over Afghanistan from tanker, ISR, and cargo aircraft located at Al-Udeid, Al-Dhafra, and elsewhere in the Persian Gulf. Such actions are unlikely; if they did occur, however, they would severely restrict the United States' ability to conduct air operations in Afghanistan.

Conclusions about an Overwhelming Force Paradigm

Secretary Rumsfeld was correct in his assertion that the United States goes to war with the equipment it has in its inventory. It also goes to war with the prevalent ideas commanders hold in their collective knowledge base. Airpower's ability to provide a relatively fast, massive, and cost-effective destructive force is a manifestation of the idea that the "American way of war" involves overwhelming the enemy.[94] According to Russell Weigley, "Air power is especially suitable for a war of destruction, annihilation, elimination" and may answer "the problem of how to secure victory in its desired fullness without paying a cost so high that the cost would mock the very enterprise of waging war."[95] The US military paradigm has been one of overwhelming military force, and airpower has been one of many means to sustain this paradigm. Thus, technological innovation and employment concepts have continuously increased the destructive prowess of US airpower in support of overwhelming force. Air weapons, and their associated employment methods, often provided the means to maneuver in multilinear, fast-tempo, and potentially decisive ways so victory could be achieved at minimum cost. Although seemingly contradictory, maneuver warfare concepts have also been compatible with existing technologies and have facilitated what Thomas Kane called "the bombardment style of warfare."[96] Aircraft, communications, logistics, and organizational structures made multilinear, high-tempo bombing possible while other potentially more-effective means remained unfeasible. Although Kane's analysis is perhaps overly simplified, it does convey many of the general themes Biddle, Richard Overy, and others explored. Each of these authors examined how institutional thought, available technology, and industrial means produced a bombardment force that was overwhelming but not necessarily the most effective means of force projection.[97] Moreover, as airpower technologies evolved into larger, faster, and more powerful aircraft, their employment constructs became increasingly complex and often required in-depth assessments concerning geographic positioning, logistics, security of LOCs, and politics.

As illustrated by the three case studies in this chapter, shortfalls involving geographic positioning and logistics were often overcome by technological capabilities such as air refueling and cargo airlift; however, long-term sustainment remained constrained by supply LOCs, security, and politics. Combat operations can continue only as long as FOLs retain their access to supplies. Such access is dependent upon other factors, such as the location of air bases, security, and politics, which may also determine whether an operation is feasible and/or sustainable.

The US strategic infrastructure involves weapon systems, bases, and supply lines intended to provide decisiveness, speed, and overwhelming force. Whether it is bombs, fuel, or supplies, US airpower involves the delivery of assets from point A to point B as rapidly as possible. In each of these scenarios, large quantities of firepower and supplies have been important to the conduct of operations. Because of restrictions and technological limitations, US forces were large and were not organized for continuous convergent attacks against the enemy. In their current form, modern military forces still require vast quantities of supplies. The enormous volume of supplies required for military operations, however, has made it very difficult for global LOCs to facilitate fast delivery. Until it becomes technologically feasible for aircraft to operate with less infrastructure and logistics support, it is unlikely that the effective and efficient sustainment of a persistent, flexible, and overwhelming swarming capability will be possible.

Although forces deployed as part of OEF include improved weapon systems involving advanced computer systems and information technologies, they are not organized for strategic swarming operations. Forward operating locations require large quantities of daily supplies, and delivery of materiel incurs significant security risks. Even if airpower forces were able to sustain autonomous or semiautonomous swarming operations, they would quickly consume existing inventories and would have to cease operations until supplies were replenished. Moreover, in OEF a large proportion of combat and combat support aircraft are geographically distant from Afghanistan. The dispersed nature of air bases and airpower capabilities significantly limits opportunities for concentration of assets over the target area. In many respects, the United States is bound to its maneuver warfare construct because of the aircraft and associated organization schemes it employs. More importantly, technology has not demonstrated alternative airpower capabilities and employment concepts that are capable of comparable force. However, if future swarm-capable aircraft and employment concepts provide the means to reshape the existing maneuver warfare construct, they might enable a new form of power projection that releases US airpower from the hold of logistics-intensive maneuver warfare concepts.

Notes

1. Clausewitz, *On War*, 177.

2. Eric Schmitt, "Iraq-Bound Troops Confront Rumsfeld over Lack of Armor," *New York Times*, 8 December 2004, http://www.nytimes.com/2004/12/08/international/middleeast/08cnd-rumsfeld.html. Rumsfeld made the comment in response to questions and comments regarding the Army's lack of availability of "up-armored" Humvees and improved body armor.

3. Gray, *Explorations in Strategy*, 124.

4. AFDD 1, *Air Force Basic Doctrine, Organization, and Command*, 14 October 2011, 11. "Airpower is the ability to project military power or influence through the control and exploitation of air, space, and cyberspace to achieve strategic, operational, or tactical objectives." Although the Air Force's definition includes multiple domains, this chapter concentrates solely on the air domain.

5. Thomas S. Kuhn, *Structure of Scientific Revolutions*, 3rd ed. (Chicago: University of Chicago Press, 1996), x.

6. Ibid., 10–11.

7. Benjamin S. Lambeth, *Transformation of American Air Power* (Ithaca, NY: Cornell University Press, 2000), 289.

8. Thomas M. Kane, *Military Logistics and Strategic Performance* (Portland, OR: Frank Cass, 2001), 160–63.

9. Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, 17.

10. J. C. Slessor, *Air Power and Armies* (1936; repr., Tuscaloosa: University of Alabama Press, 2009), 8–9; Giulio Douhet, *Command of the Air*, trans. Dino Ferrari, (1921; repr., Tuscaloosa: University of Alabama Press, 2009), 9; and Mitchell, *Winged Defense*, 8–9.

11. Slessor, *Air Power and Armies*, 89.

12. Lee Kennett, *First Air War* (New York: Free Press, 1991), 18, 43.

13. Ibid., 226.

14. Douhet, *Command of the Air*, 20–21.

15. Mitchell, *Winged Defense*, 6.

16. Overy, "Air War in Europe, 1939–1945," 12; and Tami Davis Biddle, *Rhetoric and Reality in Air Warfare: The Evolution of British and American Ideas about Strategic Bombing, 1914-1945* (Princeton, NJ: Princeton University Press, 2002), 107, 132. Douhet's writings were not available outside of Italy until the 1930s. His influence is primarily associated with strategic bombing.

17. Biddle, *Rhetoric and Reality in Air Warfare*, 300.

18. Roger Freeman, "B-17 Flying Fortress," in *Great Book of World War II Airplanes*, Jeffrey Ethell et al. eds. (New York: Bonanza Books, 1983), 129; and Michael S. Neiberg, *Warfare in World History* (New York: Routledge, 2001), 77.

19. USAF, "Factsheets: B-52 Stratofortress," 20 September 2005, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104465/b-52-stratofortress.aspx; and USAF, "Factsheets: B-1B Lancer," 15 May 2005, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104500/b-1b-lancer.aspx.

20. Enzo Angelucci and Peter Bowers, *American Fighter* (New York: Orion Books, 1985), 315; and Boeing Company, "F-15E Strike Eagle," http://www.boeing.com/defense-space/military/f15/index.htm (accessed 19 February 2012). For example, the Vietnam-era F-4E Phantom had a 16,000 lb. payload, and the modern F-15E Strike Eagle has a 23,000 lb. payload.

21. Boeing Company, "Commercial Airplanes: 707 Family," http://www.boeing.com/commercial/707family/index.html (accessed 19 February 2012).

22. AFDD 1, *Air Force Basic Doctrine, Organization, and Command*, 37. The "Tenets of Airpower" are centralized control and decentralized execution, flexibility and versatility, synergistic effects, persistence, concentration, priority, and balance. See AFDD 1 for a detailed explanation of each tenet.

23. Ibid., 39–41.

24. Gray, *Explorations in Strategy*, 67–68.

25. A. J. Wohlstetter et al., *Selection and Use of Strategic Air Bases* (Santa Monica, CA: RAND, 1954), 10–12.

26. Mahyar A. Amouzegar et al., *Evaluation of Options for Overseas Combat Support Basing* (Santa Monica, CA: RAND, 2006), 90.

27. Air Force Pamphlet (AFP)10-1403, *Air Mobility Planning Factors*, 12 December 2011, 17–19; and USAF, "Factsheets: KC-135 Stratotanker," 15 September 2004, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104524/kc-135-stratotanker.aspx.

28. O'Hanlon, *Science of War*, 158.

29. Kane, *Military Logistics and Strategic Performance*, 163.

30. Martin van Creveld, *Supplying War: Logistics from Wallenstein to Patton*, 2nd ed. (Cambridge, UK: Cambridge University Press, 2004), 254. Van Creveld wrote, "Take the First Gulf War 1991. At the strategic level, the logisticians of Central Command availed themselves of much larger aircraft requiring much larger airports and much larger ships requiring much larger docking facilities."

31. Christopher J. Bowie, *Anti-Access Threat and Theater Air Bases* (Washington, DC: Center for Strategic and Budgetary Assessments, 2002), 20.

32. AFP 10-1403, *Air Mobility Planning Factors*, 17–19; and Mahyar A. Amouzegar et al., *Analysis of Combat Support Basing Options* (Santa Monica, CA: RAND, 2004), 18.

33. USAF, "Factsheets: B-52 Stratofortress"; USAF, "Factsheets: B-1B Lancer"; and AFP 10-1403, *Air Mobility Planning Factors*, 17–19.

34. See Air Force Handbook (AFH) 32-1084, *Facility Requirements*, 1 September 1996, for specific facility requirements; and Bowie, *Anti-Access Threat and Theater Air Bases*, 20.

35. Bill Yenne, *History of the U.S. Air Force*, rev. ed. (Stamford, CT: Longmeadow Press, 1992), 83.

36. Wayne Thompson, "Operations over North Vietnam, 1965–1973," in *History of Air Warfare*, ed. John Andreas Olsen (Washington, DC: Potomac Books, 2010)," 112.

37. Yenne, *History of the U.S. Air Force*, 69, 83.

38. Kane, *Military Logistics and Strategic Performance*, 161; and Beth F. Scott, James C. Rainey, and Andrew W. Hunt, eds., *Logistics of Waging War: A Historical Perspective* (Maxwell AFB, AL: Air Force Logistics Management Agency, 2000), 133, 353.

39. Department of Defense (DOD), *Conduct of the Persian Gulf War: Final Report to Congress* (Washington, DC: DOD, 1992), 160, 162.

40. Lambeth, *Transformation of American Air Power*, 107.

41. DOD, *Conduct of the Persian Gulf War*, 160, 162, 517, 518. Air Force and Navy Seabee teams constructed bare-base airfields at Al-Kharj and Al-Kibrit.

42. Ibid., 138.

43. Ariel Zirulnick, "Obama Admits 'Worst-Kept Secret': US Flies Drones over Pakistan," *CSMonitor.com*, 31 January 2012, http://www.csmonitor.com/World/terrorism-security/2012/0131/Obama-admits-worst-kept-secret-US-flies-drones-over-Pakistan. Iran is considered an enemy of the United States, and Pakistan has allowed RPA operations from only a select few of its airfields.

44. AFCENT, "Factsheets: 380th Air Expeditionary Wing History"; and AFCENT, "Units: 379th Air Expeditionary Wing."

45. Lambeth, "Operation Enduring Freedom, 2001," 271.

46. AFDD 2-4, *Combat Support*, 23 March 2005, 1.

47. Ibid., 4.

48. Ibid., 21–25.

49. Clausewitz, *On War*, 330.

50. Bowie, *Anti-Access Threat and Theater Air Bases*, 15.

51. James C. Rainey et al., eds., *Combat Support: Shaping Air Force Logistics for the 21st Century* (Maxwell AFB, AL: Air Force Logistics Management Agency, 2003), 10. As defined in *Combat Support*, "FOLs [forward operating locations] are sites in a theater, out of which tactical forces operate. FOLs can have differing levels of CS [combat support] resources to support a variety of employment time lines. Some FOLs in critical areas under high threat should have equipment pre-positioned to enable aerospace packages designed for heavy combat to deploy rapidly. These FOLs might be augmented by other, more austere FOLs that would take longer to spin up. In parts of the world, where conflict is less likely or humanitarian missions are the norm, all FOLs might be austere."

52. O'Hanlon, *Science of War*, 147.

53. John A. Lynn, ed., *Feeding Mars: Logistics in Western Warfare from the Middle Ages to the Present* (Boulder, CO: Westview Press, 1993), ix.

54. Creveld, *Supplying War*, 1. See *Supplying War* for a detailed examination of 17th through 21st century logistics.

55. Joel D. Meyerson, "War Plans and Politics: Origins of the American Base of Supply in Vietnam," in Lynn, *Feeding Mars*, 274; and Rainey et al., *Combat Support,* 10. As defined in *Combat Support*, "FSLs are sites near or within the theater of operations for storage of heavy combat support resources, such as munitions or war reserve materiel, or sites for consolidated maintenance and other support activities. The configuration and specific functions of FSLs depend on their geographic location, the threat level, steady-state and potential wartime requirements, and costs and benefits associated with using these facilities."

56. Scott, Rainey, and Hunt, *Logistics of Waging War*, 348–50.

57. Julian Thompson, *Lifeblood of War: Logistics in Armed Conflict* (London: Brassey's, 1991), 193.

58. Scott, Rainey, and Hunt, *Logistics of Waging War*, 346.

59. Ibid., 347, 349; and Craig M. Brandt, ed., *Fundamentals of Military Logistics: A Primer of the Logistics Infrastructure* (Dayton, OH: Defense Institute of Security Assistance Management, 2005), 175–76. "Push" logistical supply methods involve standard shipments of supplies by logistical planners based on preplanned requirements regardless of the real-time supply needs of field units. "Pull" logistical supply requires robust communications with logistics C2 elements and involves supply based on field units' real-time logistical requirements. Instead of headquarters dictating supply requirements and inventory levels, "pulling" field units have decentralized authority to manage their own logistics inventories.

60. Creveld, *Supplying War*, 255; and Congressional Budget Office (CBO), *Options for Strategic Military Transportation Systems* (Washington, DC: CBO, 2005), 5–6.

61. DOD, *Conduct of the Persian Gulf War*, 472.

62. Michael Self and Edward Kozlowski, "Air Force Logistics Command Operations in Desert Storm," White Paper (Wright Patterson AFB, OH: Air Force Logistics Command, July 1991), 12.

63. DOD, *Conduct of the Persian Gulf War*, 476–77.

64. Self and Kozlowski, "Air Force Logistics Command Operations in Desert Storm," 14.

65. DOD, *Conduct of the Persian Gulf War*, 466.

66. Creveld, *Supplying War*, 256.

67. Tom Gjelten, "U.S. Now Relies on Alternate Afghan Supply Routes," *National Public Radio*, 16 September 2011, http://www.npr.org/2011/09/16/140510790/u-s-now-relies-on-alternate-afghan-supply-routes.

68. Robert S. Tripp et al., *Supporting Air and Space Expeditionary Forces: Lessons from Operation Enduring Freedom* (Santa Monica, CA: RAND, 2004).

69. Ibid., 13.

70. DOD, *National Military Strategy of the United States of America* (Washington, DC: DOD, 2011), 5–6.

71. US Transportation Command, *USTRANSCOM 2011 Annual Report* (Scott AFB, IL: USTRANSCOM, 2011), 10, http://www.transcom.mil/documents/annual_reports/FY2011_USTRANSCOM_Annual_Report.pdf.

72. Creveld, *Supplying War*, 260.

73. Alan Vick, *Snakes in the Eagle's Nest: A History of Ground Attacks on Air Bases* (Santa Monica, CA: RAND, 1995).

74. Ibid., 72.

75. Scott, Rainey, and Hunt, *Logistics of Waging War*, 355–56, 362.

76. Lambeth, *Transformation of American Air Power*, 141.

77. Lawrence Freedman and Efraim Karsh, *Gulf Conflict 1990–1991: Diplomacy and War in the New World Order* (Princeton, NJ: Princeton University Press, 1993), 102–7. According to Freedman, Israel's entrance into military operations against Iraq would have fragmented the US-led coalition and threatened use of many Middle Eastern states' staging areas and bases of operation.

78. Ibid., 310.

79. Michael A. Palmer, *Guardians of the Gulf: A History of America's Expanding Role in the Persian Gulf, 1833–1992* (New York: Free Press, 1992), 220.

80. Marc V. Schanz, "New Look of Base Defense," *Air Force Magazine*, 93, no. 10 (October 2010): 59.

81. Ibid., 60.

82. Tim McGirk, "Taliban Attacks on NATO Convoys Increase," *Time*, 7 October 2009, http://www.time.com/time/world/article/0,8599,1928899,00.html.

83. Fred Pleitgen, "Attackers in Pakistan Hit Another Convoy Carrying Fuel for NATO Troops," CNN.com, 4 October 2010, http://articles.cnn.com/2010-10-04/world/pakistan.supply.route_1_convoy-nato-supply-pakistani-taliban-spokesman?_s=PM:WORLD; and "Rocket Attack on NATO Fuel Supply Convoy in Pakistan," *Guardian*, 8 December 2011, http://www.guardian.co.uk/world/2011/dec/08/rocket-attack-nato-pakistan.

84. Scott Baldauf, "Pakistan Cuts Supply Lines, but US Has Options," *Christian Science Monitor*, 29 November 2011, http://www.csmonitor.com/World/Asia-South-Central/2011/1129/Pakistan-cuts-supply-lines-but-US-has-options.

85. Schanz, *New Look of Base Defense*, 59. Brigadier General McMillian was the director of security forces in the Air Staff's logistics, installations, and mission support division at the time of his statement.

86. Gordon M. Goldstein, *Lessons in Disaster: McGeorge Bundy and the Path to War in Vietnam* (New York: Henry Holt and Co., 2008), 211.

87. H. R. McMaster, *Dereliction of Duty* (New York: Harper Perennial, 1997), 190.

88. Ibid., 180–88.

89. Scott W. Conrad, *Moving the Force: Desert Storm and Beyond* (Washington, DC: National Defense University, 1994), 17.

90. Freedman and Karsh, *Gulf Conflict 1990–1991*, 86–95.

91. Ibid., 86–95, 102–7; and DOD, *Conduct of the Persian Gulf War*, 26, 66.

92. DOD, *Conduct of the Persian Gulf War*, 127.

93. Bob Woodward, *Obama's Wars* (New York: Simon & Schuster, 2010), 8, 66–67, 147–48, 284–85; and Gjelten, "U.S. Now Relies on Alternate Afghan Supply Routes."

94. Russell F. Weigley, *American Way of War: A History of United States Military Strategy and Policy* (New York: Macmillan, 1973), 239.

95. Ibid., 239, xxii.

96. Kane, *Military Logistics and Strategic Performance*, 160–61.

97. Idid.; Overy, *Air War: 1939–1945*; and Biddle, *Rhetoric and Reality in Air Warfare*.

Chapter 3

Remotely Piloted Aircraft, Swarms, and Instant Basing

I warn you, tomorrow I will bring locusts into your country.

—Exodus 10:4

There is a long journey to be made between the discoveries of basic science and the appearance of new weaponry in sufficient numbers to make a difference. Further, it is also unrecognized that the real success of new weapons usually comes in areas that were unimagined by the scientists and developers. Rather once the device is fielded it very often happens that it is combined with other mature technologies and put to purposes altogether different from those imagined by the originators. All these things take time.

—David R. Mets

In the 1990s, Martin Libicki proposed that the future of warfare might include a "mesh" of highly integrated sensors, weapons, and information technologies capable of immediately finding, identifying, and targeting adversaries.[1] He argued that the miniaturization of military equipment and weapons and their integration with advanced computer technologies would create an environment where "the large, the complex, and the few will have to yield to the small and the many."[2] Beyond his emphasis on information technologies and the networked employment of joint military forces, Libicki's ideas are especially important to the future of airpower because they emphasize the combined capability of small, inexpensive weapon systems. Accordingly, small remotely piloted aircraft that do not require airfields or robust logistics may foster changes within the existing industrial maneuver warfare paradigm. As noted in chapter 2, aerospace technologies have been continuously applied to military aircraft and their supporting infrastructures and have enabled modifications to existing concepts of operation. Nonetheless, RPAs may provide an important opportunity for the US Air Force and its sister services. Swarm technology involving small, inexpensive aircraft might serve as a vanguard for a new airpower paradigm. This chapter explores the prospect of an RPA-driven vanguard by surveying three topics: (1) presently employed RPAs and their CONOPS, (2) developmental RPA technologies necessary for swarming operations, and (3) the Instant Basing construct of logistics; its impact on the geographic positioning of forces, logistics, force protection, and politics; and how it may provide grand strategic utility.

Remotely Piloted Aircraft and Their Concepts of Operation

Military unmanned aerial vehicles (UAV) are not a new phenomenon. Their origins trace to 1918, but they retained a largely experimental nature in subsequent decades.[3] Since the 1950s, RPAs have been employed in covert national security missions involving intelligence, surveillance, and reconnaissance (ISR). In recent decades they have demonstrated their utility in overt military operations and have become an important aspect of contemporary combat operations.[4] According to airpower scholar Tony Mason, the importance of RPAs was elevated in 1999 during Operation Allied Force. As part of the 1999 Balkan conflict, "USAF RQ-1 Predators, USN RQ-2 Pioneers, and U.S. Army RQ-5 Hunters . . . provided target information and verification, battle damage assessment, and refugee monitoring" for a fraction of the cost of manned aircraft.[5]

The utility of RPAs grew so much that in the five years following Allied Force they provided a significant portion of ISR during air and ground operations in Afghanistan and Iraq.[6] Furthermore, theater-level RPAs, such as the MQ-1 Predator, were modified to employ air-to-ground weapons. They provided an additional precision-strike capability, and later systems such as the MQ-9 Reaper were deployed with ground-strike capabilities.[7] RPAs were used extensively during Enduring Freedom and Iraqi Freedom, and their effectiveness catalyzed an exponential increase in demand for additional support.[8] The utility of their fused ISR and strike capabilities led the Air Force to increase its RPA operational capacity to 65 combat air patrols (CAP).[9] According to one observer, "the Air Force measures its RPA presence in-theater with the term 'CAP,' which equals a 24-hour presence over a given geographical area. A single combat air patrol translates to about four aircraft: three in-theater and one at home base for training."[10] Large and medium theater-level remotely piloted aircraft such as the RQ-4 Global Hawk, MQ-1 Predator, and MQ-9 Reaper have been the most acclaimed segment of the Air Force's RPA fleet because of their ability to find, fix, target, and potentially destroy enemy targets without risking the lives of pilots.[11] However, they are a small segment of the DOD arsenal of unmanned aircraft.

According to the U*nmanned Systems Integrated Roadmap FY2011–2036*, the DOD employs a large array of remotely piloted vehicles ranging widely in size and capability (see table 1).[12]

General Groupings	Name	Vehicles	Ground Control Stations	Employing Service(s)	Capability/Mission
Group 5 >1,320 lbs >18,000 alt	RQ-4A Global Hawk/BAM S-D Block 10	9	3	USAF/Navy	ISR/Maritime Domain Awareness (Navy)
	RQ-4B Global Hawk Block 20/30	15	3	USAF	ISR
	RQ-4B Global Hawk Block 40	1	1	USAF	ISR/Battle Management Command and Control
	MQ-9 Reaper	54	61a	USAF	ISR/Reconnaissance, Surveillance, and Target Acquisition (RSTA)/electronic warfare/Precision Strike (PS)/Force Protection (FP)
Group 4 >1,320 lbs <18,000 alt	MQ-1A/B Predator	161	61a	USAF	ISR/RSTA/PS/FP
	MQ-1 Warrior/ MQ-1C Gray Eagle	26	24	Army	ISR/RSTA/PS/FP
	UCAS-D	2	0	Navy	Demonstration Only
	MQ-8B Fire Scout	9	7	Navy	ISR/RSTA/antisubmarine warfare/antisurface warfare/mine warfare
Group 3 <1,320 lbs <18,000 alt	MQ-5 Hunter	25	16	Army	ISR/RSTA/Battle Damage Assessment (BDA)
	RQ-7 Shadow	364	262	Army/USMC/SOCOM	ISR/RSTA/BDA
	A160T Hummingbird	8	3	SOCOM/DARPA/Army	Demonstration
	Small Tactical Unmanned Aircraft Systems (STUAS)S	0	0	Navy/USMC	ISR/Explosive Ordnance Disposal (EOD)/FP
Group 2 21–55 lbs <3,500 alt <250 knts	ScanEagle	122	39	Navy /SOCOM	ISR/RSTA/FP
Group 1 0–20 lbs <1,200 alt <100 knts	RQ-11 Raven	5,346	3,291	Army/Navy/SOCOM	ISR/RSTA
	Wasp	916	323	USMC/SOCOM	ISR/RSTA
	SUAS Puma	39	26	SOCOM	ISR/RSTA
	gMAV/T-Hawk	377	194	Army (gMAV) Navy (T-Hawk)	ISR/RSTA/EOD

Table 1. Department of Defense remotely piloted aircraft
(Adapted from DOD, *Unmanned Systems Integrated Roadmap FY2011–2036* [Washington, DC: DOD, 2011].)

Remotely piloted aircraft in Groups 1–3 are generally small, deployed by field units, and have limited capabilities beyond providing local ISR support to tactical forces. Many RPAs in these categories operate autonomously and can be recovered by their operators in austere locations.[13] Micro-RPAs in Group 1 "are used for individual situation awareness, have a range of 1 to 3 nautical miles (nm), can only be used in daylight with fair weather conditions, and carry payloads weighing less than 0.5 lb."[14] Group 2 RPAs are called mini-RPAs because they are "designed to be man-portable, launched and flown by either a single soldier, or by a handful of troops."[15]

Air vehicles in Group 3 are commonly referred to as small RPAs since their operational capabilities and increased size, weight, and logistics requirements are greater than mini-RPAs but less than their larger counterparts in Groups 4 and 5.[16] Figure 4 illustrates the size difference between small, medium, and large RPAs. Small RPAs are capable of supporting a multitude of missions including "operational and intelligence support, psychological operations, resupply, ISR, and sensor deployment; have an endurance of 10 to 12 hours; and typically carry payloads weighing 50 to 250 lbs."[17]

Aircraft in Group 4 are called medium RPAs, and those in Group 5 are referred to as large remotely piloted aircraft.[18] Similar to small RPAs, medium and large RPAs can accomplish a range of intelligence-related missions. Those missions support theater-level objectives at much greater range than those in the first three groups, and when medium and large RPAs are operationally deployed, they are dependent on expeditionary air bases due to their size, operational requirements, C2 infrastructure, and logistics needs.[19] Thus, it is important to understand that the theater-level capabilities furnished by the current generation of medium and large RPAs come at the expense of operational and logistical simplicity.

From an operational perspective, the Predator, Reaper, and Global Hawk rely on complex architectures involving US-based ground stations (GS), satellite communications relays, and forward-deployed ground control stations (GCS). These RPAs operate under a "remote split" concept of operations that reduces each platform's deployed footprint by keeping the majority of mission personnel and equipment in the continental United States (CONUS) rather than the war zone.[20] Satellite connectivity allows remote split operations in any geographic combatant command and thus reduces the logistical support and force protection assets inherent to manned aircraft.[21] However, unlike sorties using traditionally piloted aircraft, the success of Predator, Reaper, and Global Hawk missions depends on reliable satellite and line-of-sight communication links. According to an experienced RPA operator, MQ-1/9 pilots rely on "a C-band line-of-sight (LOS) link or Ku-band beyond line-of-sight

(BLOS) satellite link" to maintain control of their aircraft through all phases of flight (see fig. 5).[22]

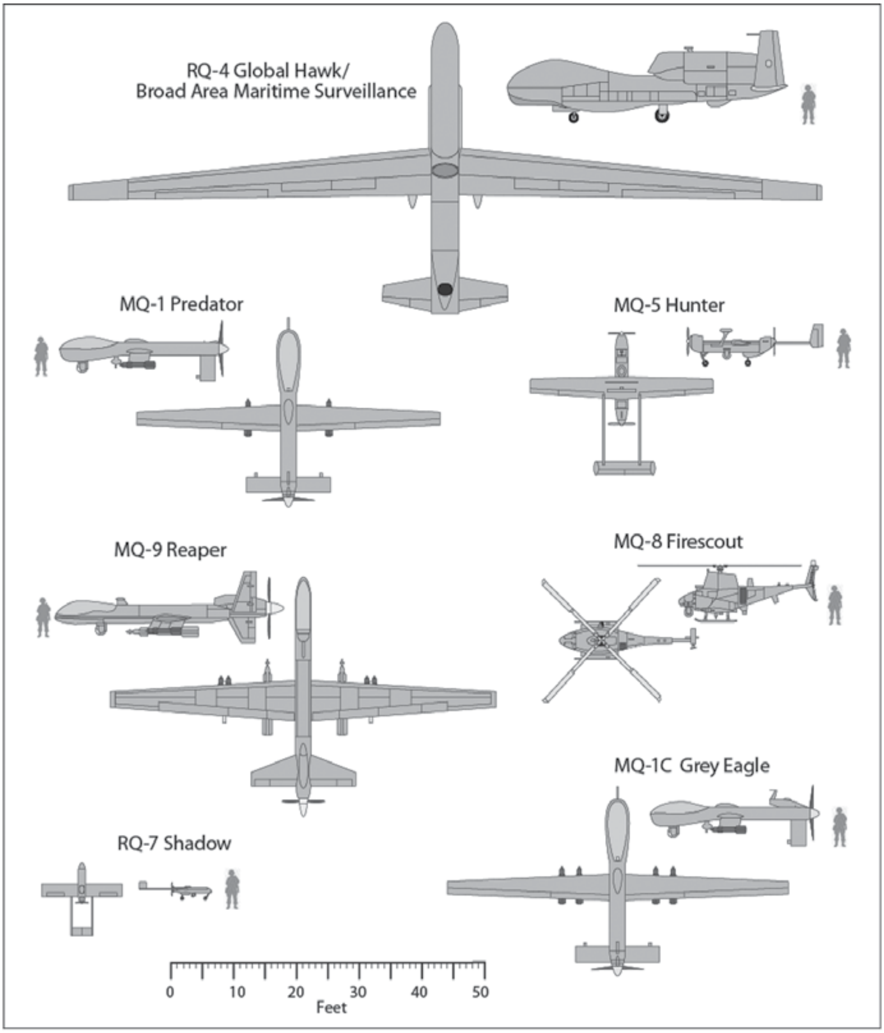

Figure 4. Selected Department of Defense RPAs from Groups 3–5
(Reproduced from Congressional Budget Office [CBO], *Policy Options for Unmanned Aircraft Systems*, Publication 4083 [Washington, DC: CBO, June 2011].)

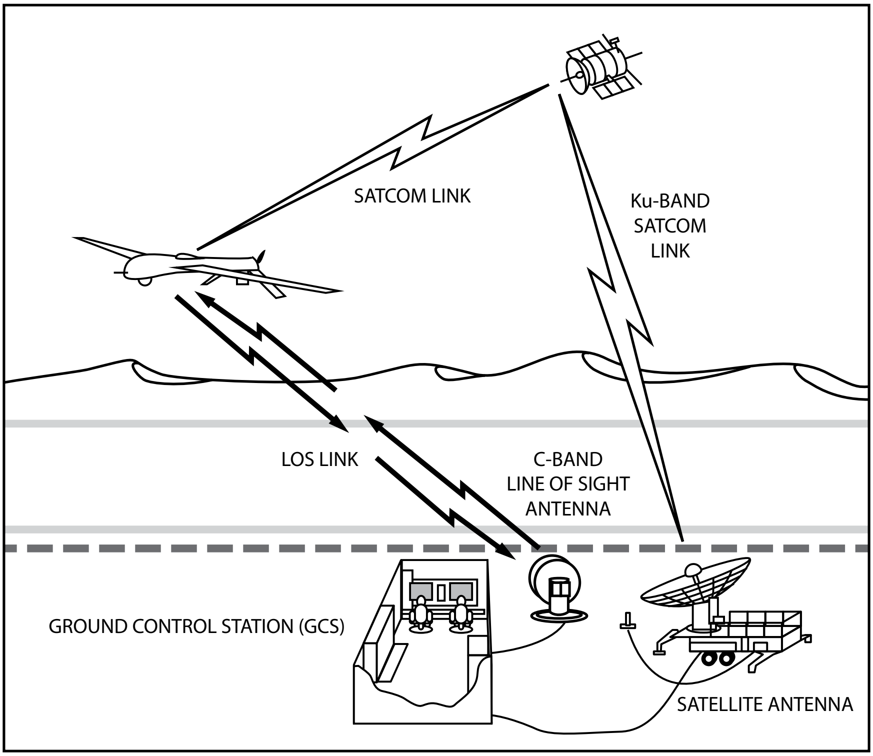

Figure 5. MQ-1 and MQ-9 LOS and BLOS configuration
Reproduced from Technical Order 1Q-1[M]b-1, *MQ-1B and RQ-1B Flight Manual*, Change 11, 14 January 2008.

Although the Global Hawk's architecture is similar to the Predator and Reaper, it requires two satellites to conduct its mission instead of the single satellite required for MQ-1/9 operations. Within the RQ-4 construct, one satellite provides mission control element (MCE) pilots oversight of the aircraft's flight parameters, while a second satellite transfers intelligence and sensor control data to intelligence specialists (see fig. 6).[23] Although the RQ-4 is largely reliant on satellite connectivity, it can continue its mission autonomously if it loses its communication links.

Unlike the MQ-1/9, the RQ-4 is highly automated. Almost all aspects of the Global Hawk's flight profile are preprogrammed. During takeoff and landing, the aircraft flies an autonomous sequence in which the launch and recovery

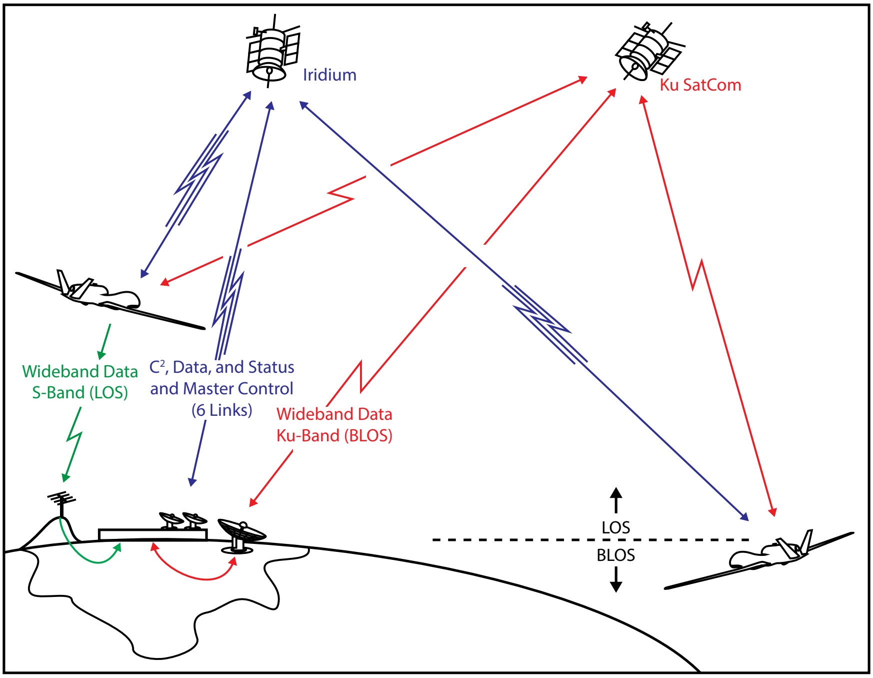

Figure 6. RQ-4 Global Hawk system architecture
(Reproduced from Herbert J. Kramer, "Global Hawk UAS [Unmanned Aerial System] of NASA," https://directory.eoportal.org Image credit: NASA/DFRC.)

element (LRE) pilot monitors critical phases of flight via LOS equipment but has few options to change the profile if an emergency occurs.[24] It is important to note that most medium and large RPAs cannot perform autonomous take-offs and landings, and remote operation during critical phases of flight is problematic due to multiple-second delays in satellite communications.[25] As a result, LRE personnel and their LOS communications equipment will likely remain essential aspects of medium and large RPA operations.[26] Furthermore, automation does not alleviate their requirement for relatively long runways.

Due to their weight and dimensions, MQ-1/9s and RQ-4s require airfields with 5,000- and 8,000-foot runways, respectively, and are often collocated with manned aircraft.[27] Similar to the manned aircraft requirements discussed in the previous chapter, medium and large RPAs must be positioned at bases within range of their target area. MQ-1s and MQ-9s are typically based at forward expeditionary bases because their combat radius is only 400 nm.[28] The RQ-4 has a maximum combat radius of 5,400 nm and can be based farther from the area of operations.[29] Its transit time, however, decreases its persistence over the target area. In many cases, RPA airfield compatibility and range considerations are more critical than those of contemporary manned aircraft because they lack the ability to conduct air refueling.[30] Because of these considerations, Predators, Reapers, and Global Hawks were based with manned aircraft at expeditionary bases in Afghanistan and Iraq during Operations Enduring Freedom and Iraqi Freedom. MQ-1s were positioned with C-130s at Ali Air Base, Iraq, in 2004, and MQ-1s and MQ-9s were based with a variety of manned combat aircraft at the Kandahar airfield and Bagram Air Base, Afghanistan.[31] The 380th AEW operated RQ-4s, KC-10 tankers, and AWACS aircraft from its location during both operations.[32]

Given their basing requirements, CONOPS for RPAs in Groups 4 and 5 are often similar to the operational concepts of manned aircraft, as discussed in the previous chapter. One exception is that RPA control systems are divided among LREs, satellite relays, and stateside facilities instead of being resident in the aircraft itself. In addition, their operational requirements and their likely stationing at airfields operating manned aircraft make them subject to the logistical considerations inherent with forward-employed manned aircraft.

Like manned aircraft operating from expeditionary bases, Predator, Reaper, and Global Hawk RPAs are dependent on agile combat support.[33] Following their deployment to a given theater of operations, MQ-1/9s and RQ-4s require hangars, maintenance facilities, force protection, food and shelter for their associated personnel, munitions (in the case of the MQ-1/9), and a steady supply of fuel.

Interruption of theater ACS may affect RPAs more than manned aircraft because they are more heavily dependent on airlift. For example, because Predators and Reapers have limited range and lack an autonomous landing capability, they cannot fly into theater and instead must be disassembled and packed into specialized containers for shipment to forward locations.[34] The same is true when they are redeployed. Consequently, MQ-1/9s are heavily dependent on military and commercial airlift for intertheater transport.

Although continued expeditionary operations require the forward deployment of LREs, the RQ-4 does not have the same transport problems as Predator and Reaper systems because its intercontinental range allows it to deploy and redeploy without airlift. Nonetheless, because Global Hawks transit civilian airspace during such flights, advance coordination and approval are required. Even within the United States, the Federal Aviation Administration requires RPAs to have a special flight certificate to transit controlled airspace.[35] Like all forward-deployed aircraft, RQ-4 and MQ-1/9 support equipment and personnel are typically airlifted to and from the theater of operations.[36] Although remote split operations decrease the number of forward-deployed personnel and the scale of ACS for medium and large RPAs, these requirements are not significantly less than those for traditional manned aircraft.

Host nations also have the authority to regulate the use of RPA airfields. Because the operational concepts of medium and large RPAs are tied to robust airfields sustained by external lines of supply, host nations hold significant political influence over US employment of its largest RPAs.[37] Host nations may allow near unrestricted access to their facilities, as Saudi Arabia did during Desert Storm. Alternatively, nations such as Pakistan may heavily restrict and ultimately evict US forces from their air bases. In the first Persian Gulf War, Saudi Arabia allowed the United States to use its airfields with few restrictions and supplied fuel to all of coalition aircraft operating from Saudi bases.[38] More recently, Pakistan expelled MQ-1/9 aircraft from its bases following internal opposition to US drone strikes against targets within Pakistani territory.[39] The Pakistani example demonstrates that RPAs may be just as vulnerable to host-nation restrictions as manned aircraft.

Developmental RPA Technologies Necessary for Swarming

The MQ-1 Predator, MQ-9 Reaper, and the RQ-4 Global Hawk have served important roles in the overall development of RPAs. They demonstrated that remote split operations could reduce US airpower's forward footprint with a networked arrangement of ground stations, satellites, and expeditionary bases. Their operational and logistical requirements, however, required that they be employed much like manned aircraft. Furthermore, the use of foreign airfields has meant that medium and large RPAs are subject to host-nation oversight. However, swarms of micro, mini, and small RPAs might operate free of airfields and thus significantly reduce the logistical footprint of US air forces. Command and control of future RPAs, or swarms of RPAs, will also be important. The MQ-1/9's single-satellite remote split architecture may serve as an excellent model for the development of future generations of globally deployed RPAs. Regardless, RPA technology is still in its larval phase of development.

At the turn of the twenty-first century, the demand for ISR support at the tactical, operational, and strategic levels of war accelerated service-specific RPA development and procurement programs so much that each of the armed services deployed air vehicles specifically suited to its own battlefield needs.[40] During Iraqi Freedom more than 10 different types of remotely piloted aircraft operated independently without the ability to exchange information between military services or other aircraft.[41] As a result of this uncoordinated development and procurement of RPAs, the Department of Defense released the *Unmanned Aircraft Systems Roadmap 2005–2030* and has since published frequent updates.[42] The 2005 document was intended "to assist DoD decision makers in developing a long-range strategy for UA [unmanned aircraft] development and acquisition in future Quadrennial Defense Reviews (QDR) and other planning efforts, as well as to guide industry in developing UA-related technology."[43] The document also alluded to the future utility of swarming RPAs on the battlefield:

> Combining sensor products in novel ways using advanced processing systems on board the aircraft will help solve the sensor autonomy problem as well. Smaller UA operating with minimal data links, or in swarms, need this ability even more. The ability to flood a battlespace with unmanned collection systems demands autonomous sensor operation to be feasible. While the carriage of multiple sensors on a single, small UA is problematic, networks of independent sensors on separate platforms that can determine the most efficient allocation of targets need to be able to find, provisionally identify, and then collect definitive images to alert exploiters when a target has been found with minimal if any human initiative.[44]

Although this mention of swarming was meant to spur an additional method of collecting intelligence during wartime, it paralleled many of Arquilla and Ronfeldt's characteristics of swarming. They claim swarms will involve a high degree of autonomy; "small, dispersed, internetted maneuver units"; "integrated surveillance, sensors, and C4I [command, control, communications, computers, and intelligence] for topsight"; and should have "stand-off and close-in capabilities."[45] Simplified, future RPA swarms may require micro, mini, or small air vehicles with few logistics requirements; a high degree of aircraft and swarm autonomy; robust communications capability between swarming aircraft; sufficient payload capacity; and C4I [command, control, communications, computers, intelligence, surveillance, and reconnaissance] connectivity.[46]

Micro, mini, and small RPAs have already been marketed for commercial and military missions. Micro and mini RPAs are "optionally expendable, can be carried by individual personnel, and generally operate within line-of-sight range of the units they support." According to *Defense Update*, many fixed-wing micro and mini unmanned air vehicles may "represent a new concept of an 'always ready' UAV carried in a tube, with wings wrapped around the fuselage. When needed, the UAV is pulled out of its tube, the wings automatically snapping into position making the UAV ready to launch."[47] Although micro and mini RPAs (Groups 1–2) provide small units significant utility with minimal logistics support, small (Group 3) RPAs demonstrate exceptional promise for theater-level applications. Small unmanned aircraft, such as the jointly produced INSITU/Boeing ScanEagle and Integrator systems, use autonomous navigation, have a 50-mile range limited only by their communications equipment, and stay aloft up to 24 hours.[48] The Integrator also has multiple payload bays and hard-points, or attachment sites, capable of carrying up to 37.5 lb. of equipment and, potentially, weapons (see fig. 7).[49]

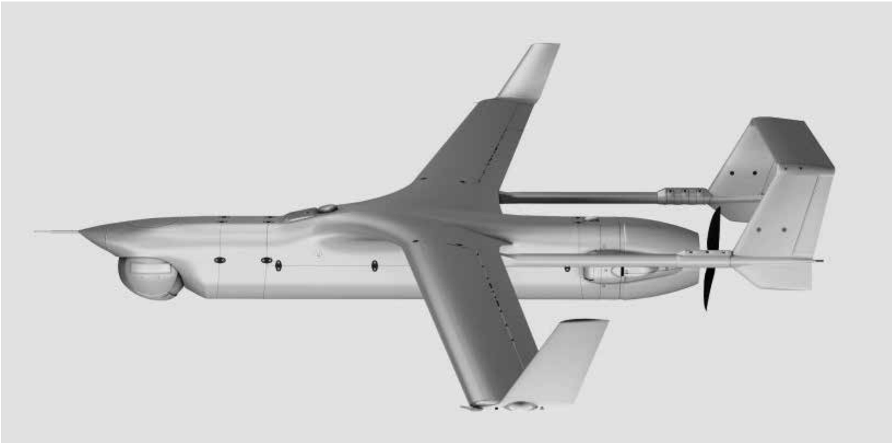

Figure 7. INSITU Integrator
(Photograph courtesy of INSITU.)

Furthermore, companies such as INSITU, Boeing, and SAIC developed small RPAs that can be inserted into target areas by larger aircraft. Examples of air-insertable RPAs include the SAIC Finder and Boeing SECC.[50] During operational testing, the Finder was carried by MQ-1/9 aircraft and controlled using the Predator/Reaper's satellite relay.[51] Each of these aircraft has demonstrated the reality of micro, mini, and small RPAs operating with minimal logistics and without the need of airfields.

Beyond micro and mini RPAs that can be launched and recovered by individual personnel, small RPAs such as the ScanEagle, Integrator, and Finder are launched and recovered with minimal support equipment and manpower. ScanEagles and Integrators are launched with a pneumatic catapult and recovered by a crane-type recovery system (see fig. 8).[52]

The launch catapult and recovery crane are relatively compact and can be transported by a common ground vehicle.[53] The Finder can also be catapult launched and may be recovered using minimal equipment.[54] Furthermore, these systems use readily available fuels such as gasoline, diesel, and jet fuel and require as few as four people to launch, operate, and recover their respective vehicle.[55] In 2004 the Marine Corps flew early variants of the ScanEagle for 456,000 combat hours in OEF and OIF, and in early 2012 the Navy's Integrator RQ-21 variant achieved early operational capability (EOC) for use in land-based and maritime missions.[56] Although mini, micro, and small RPAs may provide significant utility with minimal logistics, they will require more advanced automation and communications technologies to allow them to operate collectively within swarms.

Figure 8. INSITU ScanEagle/Integrator launch and recovery system
(Photograph courtesy of INSITU.)

Swarming weapon systems will require "complex organizational innovations and more information structuring and processing capabilities" than are possible with the current generation of manned and unmanned aircraft.[57] Not only will swarming aircraft be sharing information with other members of the swarm, they will be operating autonomously within a system of autonomous aircraft. Their guidance systems must have sufficient processing power to maintain position within the dynamic swarm environment and also accomplish their mission objectives. According to the *Unmanned Systems Integrated Roadmap FY2011–2036*, "The special feature of an autonomous system is its ability to be goal-directed in unpredictable situations. . . . An autonomous system is able to make a decision based on a set of rules and/or limitations. It is able to determine what information is important in making a decision."[58] Although decisions by humans are free, a cost is incurred when they are made by machines.

According to Rafael Yanushevsky, "The more autonomous ability a UAV has, the more complex its guidance and control system is and, as a result, the higher is its size and weight, the less . . . its endurance, combat radius, and/or speed. Payload capacity and endurance (fuel capacity) are inversely related."[59] Emerging technology will address a large part of this problem. For example, innovations in complementary metal-oxide semiconductors (CMOS), essentially the microchips in computers, have resulted in smaller, more-powerful guidance and control systems. Breakthroughs in nanoprocessor technologies, like those recently tested at Harvard University, could also decrease size and weight while increasing the processing power of electronic guidance equipment on board future generations of swarming RPAs.[60] Small RPAs such as the ScanEagle, Integrator, and Finder are particularly sensitive to weight and use relatively simple guidance systems. Therefore, fully autonomous guidance equipment on small RPAs will likely involve miniaturized electronic components.

In situations where full autonomy is not technologically feasible or acceptable to military commanders, operators may adjust a swarm's level of autonomy. This concept is often called "sliding autonomy" or "flexible autonomy" (see table 2).[61]

Table 2. The four levels of autonomy

(Reproduced from DOD, *Unmanned Systems Integrated Roadmap FY2011–2036* [Washington, DC: DOD, 2011].)

Level	Name	Description
1	Human Operated	A human operator makes all decisions. The system has no autonomous control of its environment although it may have information-only responses to sensed data.
2	Human Delegated	The vehicle can perform many functions independently of human control when delegated to do so. This level encompasses automatic controls, engine controls, and other low-level automation that must be activated or deactivated by human input and must act in mutual exclusion of human operation.
3	Human Supervised	The system can perform a wide variety of activities when given top-level permissions or directions by a human. Both the human and the system can initiate behaviors based on sensed data, but the system can do so only if within the scope of its currently directed tasks.
4	Fully Autonomous	The system receives goals from humans and translates them into tasks to be performed without human interaction. A human could still enter the loop in an emergency or changes the goals, although in practice there may be significant time delays before human intervention occurs.

For example, if commanders choose not to use fully autonomous swarms, they may use hierarchical command and control to achieve human supervised autonomy. According to Yanushevsky,

> UAVs require human guidance to varying degrees and often through several operators, which is what essentially defines an unmanned aerial system (UAS). . . . A hierarchical control system, where a local operator controls a group of UAVs and an operator-manager controls the actions of local operators, can provide the best solution of the coordinated control of the fleet of UAVs. Moreover, the use of a manned aerial vehicle with an operator as the leader of a local UAV group, instead of using a ground-based operator, can significantly reduce the UAV's payload and increase their performance.[62]

Regardless of guidance system and performance tradeoffs, the willingness of civilian leaders and military commanders to accept the risk of unintended effects such as collateral damage will also shape their decisions to allow fully autonomous RPA swarms. The DOD notes, "Robust safeties and control measures will be required for commanders to trust that autonomous systems will not behave in a manner other than what is intended on the battlefield."[63] Consequently, computer algorithms that define RPA swarm flight parameters, mission objectives, and communication protocols will be some of the most important factors affecting leaders' willingness to unleash their swarms.

Algorithms programmed into autonomous RPAs can be thought of as premade decisions. For a given situation, a fully autonomous RPA will fly according to the rule structures and parameters programmed into its software. This process will repeat itself as long as the aircraft is in operation, and the fidelity of the process will depend on the sampling rate of its guidance system.[64] Swarm guidance algorithms are exponentially more complex than individual RPA algorithms because they must account for the flight dynamics of individual as well as neighboring aircraft and essentially make decisions for the swarm.[65]

These factors explain why major advances in RPA swarming have involved algorithm research, development, test, and evaluation (RDT&E). University of Pennsylvania researcher Vijay Kumar and his team of scientists gained notoriety for their swarm-enabling algorithms. As demonstrated in a recent video, their algorithms enabled formations of quad-rotor helicopters to accomplish multiple cooperative tasks, including advanced formation flight maneuvers.[66] Other scientists, such as Dong You and David Shim, developed algorithms that maximize the fuel capacity of RPAs by flocking vehicles in formation like migratory birds.[67] Flying in tight formations could save 12–20 percent in fuel costs.[68] Furthermore, German scientists Alex Bürkle, Florian Segor, and Matthias Kollman created sets of computer rules for collaborative micro RPA swarms, ground-based sensors, vehicles, and ground control stations.[69] Their work also involved a communications infrastructure that may apply to future military swarming applications.[70] Other scientists and defense firms have also developed algorithms for RPA search-and-destroy missions, automated ground fueling stations for RPAs, and air refueling.[71] Regardless of algorithm success in achieving specialized tasks that might contribute additional capabilities to RPA swarms, the defense industry measure of success will be its ability to integrate the plethora of disassociated algorithms and technologies into an overall architecture that enables swarming CONOPS.

RPA swarms will rely heavily on the integration of software, aircraft capabilities, computer guidance systems, sensor and weapons payloads, and C2 networks. Autonomous swarming aircraft will require sufficient flight performance and equipment payload capacity so they can translate their algorithms into effects desired by political and military leaders. Furthermore, they will require C2 interfaces that allow commanders to use sliding autonomy according to political aims or technological limitations. Bandwidth limitations involving satellite communications will also impact the remote operation and C2 of swarms.[72] However, existing C2 aircraft such as the E-3 Sentry and E-2 Hawkeye might facilitate theater-level command and control of RPA swarms if they are retrofitted with appropriate technologies. According to the *Unmanned Systems Integrated Roadmap*, human-supervised autonomous systems may be possible as early as 2018, and swarms of fully autonomous systems may pass RDT&E stages between 2020 and 2036.[73] Nonetheless, when the DOD finally acquires the capability to conduct RPA swarming operations, the Instant Basing concept of logistics might increase swarming effects while minimizing the logistical footprint of future airpower operations. Moreover, RPA swarms linked to a concept of Instant Basing may provide such uniquely capable ways and means of power projection that the US military paradigm of overwhelming force could be transformed to one of precise proportionality.

Instant Basing

A significant portion of US land-based airpower CONOPS is contingent upon access to forward airfields. The deployment of land-based airpower involves the geographic positioning of forces and subsequent sustainment of forces by lines of supply, force protection (security), and diplomacy with host nations. The basing of manned aircraft and existing theater-level unmanned aircraft is dictated by the availability of compatible airfields and their ability to provide sustained logistical support for continued operations. Furthermore, because combat and support aircraft are often concentrated at large air bases, forward airfields serve as lucrative targets for enemy attacks and afford host nations significant political leverage. Consequently, the existing airpower CONOPS involving manned aircraft and medium/large RPA equivalents costs the United States considerable operational and strategic flexibility.

Instant Basing is a proposed logistical concept that increases joint force operational flexibility by significantly reducing the deployment and sustainment requirements of US airpower. Further, Instant Basing generates airpower with minimal risk to US personnel because most Airmen, Soldiers, Sailors, and Marines associated with this concept will deploy, generate their RPA swarms, and redeploy to a different location before their presence becomes obvious to the enemy. The Instant Basing concept also relies on global commercial lines of supply, communications, and commerce to ensure that RPA swarms, their support equipment, and associated personnel are available for deployment in minimum time. The assumptions of this concept are (1) swarms of small RPAs provide satisfactory theater-level effects, (2) the Department of Defense works with the Department of State to gain use of swarm launch sites within host nations, (3) commercial and military airlift are available, (4) personnel responsible for launching and recovering swarming RPAs are positioned in the theater shortly before an execution order, (5) force protection is provided by small US military elements or by host nations, (6) host nations allow the entry and exit of US personnel, and (7) joint forces provide security for Instant Basing personnel during operations in hostile territory. Clausewitz wrote that "everything in war is very simple, but the simplest thing is difficult" and emphasized that "friction" was the distinguishing factor between "real war" and "war on paper."[74] At this stage in its development, the idea of Instant Basing is significantly simplified and resides on paper for the purpose of sparking new thinking about alternative means of power projection that exploit airpower principles and modern technological developments. The author acknowledges that no plan is easy, even if it involves Instant Basing.

The first stage of Instant Basing is the transportation of equipment and personnel into theater. Notionally, teams of six people will be responsible for launching 15-aircraft swarms of small RPAs.[75] Three probable transportation options exist for this ensemble. First, swarm-capable unmanned aircraft and support equipment may be pre-positioned within areas of operation. Second, swarming air assets and supporting persons may be directly transported to their deployment site using commercial cargo carriers, passenger airlines, and/or military means. Third, crated RPAs and associated equipment may be deliberately kept in a state of transit within commercial carrier shipment systems. Future operations will likely involve a combination of these options and may also include RPA swarms dispatched from US Navy warships and submarines.[76] Nonetheless, Instant Basing primarily focuses on the rapid and safe deployment of land-based airpower.

The first method of positioning swarm-capable RPAs in a theater using Instant Basing involves pre-positioned US Military Sealift Command (MSC) ships and/or terrestrial storage facilities. The MSC currently manages a fleet of 30 pre-positioned maritime vessels loaded with military equipment for rapid response to global conflicts and could provide a flexible response option for contingencies requiring swarming operations.[77] One drawback, however, is time lost moving pre-positioned ships into port, finding and offloading assets, and then arranging subsequent transportation to specific launch sites. Furthermore, not all locations will have ports capable of handling large cargo ships. If supply ships are able to dock, force protection will be a major concern while in port. Additional personnel will be required to handle bulk supplies of RPAs and launch/recovery equipment, and during that time, supply ships and their personnel will be vulnerable to attack without host-nation force protection and/or US military security personnel.

Another pre-positioning option may involve contracted or US-owned storage facilities within allied countries. Just as stocks of RPAs could be stored on MSC ships, the US military might store crates of RPAs and support equipment in warehouses throughout geographic combatant commands.[78] However, this option would also require significant security. Swarming RPAs will likely involve classified and proprietary technology that will require continuous protection and frequent software and hardware upgrades. Furthermore, if they serve as a key air asset for regional conflicts, GCCs may demand that they are always available for rapid deployment. Unfortunately, even if storage sites are secured on host-nation government bases, it may be difficult to maintain secrecy if local military, civilian populations, or enemy elements monitor US storage facilities. Whether originating from seaports or terrestrial warehouses, air weapons will be concentrated and likely require convoy transportation to dispersed sites. Large convoys could introduce operational supply vulnerabilities similar to those encountered by NATO convoys traversing Pakistan during OEF.[79] Given the drawbacks of pre-positioned forces, commercial and military airlift may provide a better means of transportation for swarm assets.

A second force-delivery method makes extensive use of commercial logistics firms, military airlift, and local transportation companies. Once RPA swarm-force personnel are notified that they will be needed in a given theater of operations, their aircraft and equipment will be packaged and palletized for shipment. USTRANSCOM will coordinate shipments via commercial logistics firms such as FedEx, UPS, or DHL to locations as close as possible to designated launch sites in host nations.[80] Since commercial shippers require physical addresses, RPA swarms and their equipment may be shipped to host-nation-approved soccer stadiums, racetracks, or government facilities near optimal launch locations.[81] If commercial airfreight companies are used, maximum consideration should be provided to door-to-door delivery, shipment insurance, 24/7 surveillance of shipments, and expedited delivery.[82] Furthermore, the impact of stolen shipments could be reduced if physical keys, access codes, or insertable critical components are personally carried by launch and recovery teams. When the commercial cargo company provides an estimated arrival date and tracking number, local defense travel offices will provide launch teams airline tickets to locations closest to their planned launch site.[83] RPA launch and recovery team leaders should have sufficient authority to use government funds for costs associated with accessing equipment, expediting customs processing, and related expenses.[84] Ideally, swarm personnel will arrive at their equipment drop-off points shortly before the delivery of their shipment.[85]

If commercial airlift is not available or if planned launch sites are in hostile territory, military airlift should be used to transport RPAs, support equipment, and launch teams to host-nation locations closest to designated swarm launch sites or to expeditionary airfields with adequate force protection. This option may provide the greatest level of simplicity because swarm teams and their equipment remain together. However, large numbers of US military cargo aircraft and uniformed personnel may degrade operational surprise and increase the need for additional force protection because enemy personnel may become alerted. Nonetheless, the delivery potential of commercial and military airlift is finite. Thus, Instant Basing will likely involve a combination of commercial and military airlift. For a given timeline, one type of airlift may be better suited to deliver personnel and equipment to their destination faster than others. According to USTRANSCOM airlift specialist Michael Spehar, "airflow planning" will be a critical consideration for the effective delivery of airpower assets into theater.[86] If the civil reserve air fleet (CRAF) is used for intertheater transport, he recommends planning "CRAF missions first and scheduling T-tail missions around them."[87] In any case, commercial carriers' delivery procedures may provide another means of pre-positioning RPA swarms for short intervals.

Instant Basing may employ a third method of transporting crated RPAs and associated equipment in which the US military deliberately keeps swarm systems in a state of transit within commercial carriers' logistics systems. The shipping policies of commercial freight carriers like UPS, FedEx, and DHL often provide the ability to reroute, reschedule, or store shipments for short time periods in the event of missed deliveries.[88] In cases where RPA swarms have been shipped but the execution order has been delayed, military shipment coordinators may be able to ensure the security of airpower assets by rerouting their items multiple times. Shipments of military items may be more secure if they are in constant motion aboard commercial aircraft or at interim logistics centers than if they were stored at their destination. Tracking numbers on all items will ensure oversight during transit. This method may be the true manifestation of logistical swarming because it involves the deployment of multiple assets/artifacts according to a master plan, yet is dispersed, hard to detect, and apparently harmless until coordinated and concentrated. If so, the coherence of logistical and operational swarming concepts may provide commanders unforeseen ways and means of force deployment within which supplies and weapons maintain "stealthy ubiquity" without the need for visible logistical lines or concentrated military forces.[89]

This shipping option will also disperse swarm assets throughout the increasingly robust global logistics system instead of concentrating multiple swarms at a single destination's storage facilities. If dispersal within air freight companies' logistical systems is not acceptable to military commanders, shipment coordinators may arrange for RPA assets to be stored at destination storage facilities so that launch and recovery personnel can pick up their equipment at a later date. Purchasing extra insurance and security services may provide an added degree of protection against theft and tampering. Although this option may provide theater commanders additional time, crated swarm components could become damaged because of increased handling. Nonetheless, the use of airfreight companies' delivery and storage procedures may provide launch and recovery personnel a reserve stock of aircraft and support equipment in the event their assigned equipment is damaged during delivery and/or may provide replacements if their aircraft have system failures during launch. Regardless, it will be the operational commanders' decision to use reserve supplies of RPAs. Before such a decision is made, swarm teams must initiate the second stage of Instant Basing.

During the second stage of Instant Basing, deployed teams of swarm technicians will proceed to their designated launch sites, deploy their assigned aircraft, ensure that each aircraft has an acceptable system status, and then relinquish command and control to remote operators.[90] Due to force protection and operational security reasons, launch sites should be located in desolate areas with adequate space for the launch and recovery of swarm RPAs. However, host nations and threat levels in hostile territories may dictate that launch sites are located on foreign government facilities or on coalition bases. After the launch catapult, recovery crane, and line-of-sight swarm control module are assembled, RPAs will be launched as quickly as possible.[91] Once multiple aircraft are airborne, they will sequentially establish their position within the swarm, and one of six team members will check the status of each aircraft and collective swarm. If individual aircraft fail their system check, they may either be recovered for immediate repairs and launched again or repacked for reshipment to the United States. During this process, a second member of the support team will establish contact with the remote C2 element, either an airborne C2 aircraft or a CONUS-based operator using an

MQ-1/9 style satellite architecture, and coordinate for the remote operator to take control of the swarm.

After remote C2 elements assume control of the recently launched swarm, airborne swarms will be sustained by a small number of launch and recovery bases located throughout the area of operations. Instant Basing auxiliary bases will be highly mobile and will have the responsibility of repairing and replacing damaged, lost, or malfunctioning RPAs as required. They will also be responsible for recovering RPA swarms once the regional conflict has been concluded. However, swarms will remain airborne for as long as possible with RPA-to-RPA refueling or air refueling with manned tanker aircraft. After launch and recovery teams relinquish control of their swarms to remote C2 elements, they can begin their redeployment to the United States or to their next assigned intratheater location.

During the third stage of Instant Basing, swarm technicians will disassemble their equipment and deliver it to a commercial or military shipping agent for transport back to the CONUS or another location. If launch and recovery personnel are not required for further duty, they will fly back to their home base via commercial or military airlift. From start to finish, the desired Instant Basing timeline provides theater commanders airpower within four days and only exposes US launch and recovery teams to potential enemy action during three days (see table 3).

Table 3. Proposed Instant Basing timeline

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Travel (CONUS Start)	Travel	Shipment Receipt & Accountability	Launch	Reshipment & Redeployment	Travel	Travel (CONUS End)

Swarms may be launched in less time if they are delivered by military aircraft or launched from US Navy surface ships and submarines. In scenarios involving air-launched swarms, the timeline would be reduced to the time required to transport air-deployable RPA swarms to an area where they could assemble their formations. Furthermore, a reduced timeline involving air deployment of RPA swarms may provide an increased level of surprise as compared to the timeline proposed in table 3. Nonetheless, the use of air-delivered swarms may add complexity and risk to operations relying on RPA swarms since aircraft might have less opportunity to fix problems with individual RPAs or rectify C2 connectivity problems that might develop once the swarms are launched. Thus, if RPA swarms are launched from aircraft, operational planners should consider whether faster deployment justifies the risk of failed swarms.

Regardless of their launch method, RPA swarms require significantly less logistics than existing manned aircraft. For example, launching 1,000 swarm-capable RPAs would only require 400 personnel and 6,500 gallons of fuel.[92] During military operations, a typical US Air Force combat wing of 72 manned combat aircraft consumes 500,000 to 1,000,000 gallons of fuel per day and requires the support of 1,500 to 2,000 people.[93] By percentage, the projected daily fuel requirement of 1,000 small RPAs is 1.3 percent of a typical manned aircraft combat wing, and the RPAs' personnel footprint would be 73 percent smaller than a typical manned air wing.[94] Furthermore, most swarm teams are only needed for their RPAs' initial launch. Once swarms are airborne and launch crews have redeployed, the swarm force's personnel footprint will decrease to a much lower percentage.

On initial observation it may seem as if swarm-capable RPAs might be incapable of delivering sufficient combat effects. Such a conclusion is not necessarily correct, because RPA swarms provide airpower effects differently than manned aircraft. Swarms are intended to provide more organically effective ISR, electronic warfare effects, and, in some circumstances, kinetic effects and may potentially have the ability to collectively change their radar signatures such that swarms might mimic larger manned aircraft.[95] One of the overarching ideas within this swarming concept is that small, dispersed, lightly armed forces that are deployed in large numbers may provide commanders and political leaders more options than manned aircraft and their associated weapons. Although RPA swarms may not carry bomb loads as large as manned combat aircraft, their kinetic payloads may provide sufficient force at much less cost than traditional aircraft. Moreover, the small explosive yields of RPA weapons may provide more proportional force capability because destructive force begins at a much lower level than the smallest bombs carried on the current generation of manned aircraft. One must ask, is a 250-, 500-, 750-, 1,000-, or 2,000- lb. bomb necessary in every situation? Arguably not, and thus the utility of RPA swarms may be best suited for situations involving low-intensity warfare.

In those situations where more force is necessary, other weapon systems capable of carrying large bombs may be required. Nonetheless, the destructive power of lightweight bombs carried by swarming aircraft will likely increase and may be able to deliver destructive power equivalent to the bombs loaded on today's manned combat aircraft. Nanotechnology involving the chemical structures of explosives may greatly increase the destructive yields of bombs delivered from RPA swarms.[96] Ongoing research has already increased the destructive force of some explosives without increasing their weight or volume.[97] Regardless, RPA swarms' most important utility may be their ability to flexibly deliver proportionate airpower effects in conflicts involving significant force limitations. Especially within low-intensity conflicts, weapons with adequate destructive power which risk less collateral damage may provide commanders more utility than the current generation of air-to-ground bombs. Ultimately, the commander's perception of the context of the environment will determine the utility of a given weapon system, and RPA swarms thus provide an important option for the commanders and policy makers of the future.

Instant Basing and its use of swarming RPAs has the potential to provide significant efficiencies and create new power-projection options; however, munitions shipment and distribution may be a problem if future generations of aircraft require the use of high-explosive bombs and chemical propellants for projectile rounds. Because munitions require special handling procedures and security measures and cannot be transported on commercial aircraft, they will probably have to be pre-positioned or airlifted by military aircraft.[98] Once the munitions are in theater, moreover, it may be problematic to deliver them to swarm launch teams in accordance with Instant Basing timelines. Nevertheless, it may be possible to launch armed RPAs from aircraft or naval vessels and have them rendezvous with RPA swarms that lack kinetic capabilities. Once armed RPAs are air-delivered they would then be sustained in the same manner as their unarmed swarm counterparts.

The development and employment of directed-energy weapons and miniaturized railguns may also help alleviate concerns involving the deployment of RPA swarm armaments; however, the RDT&E of such weapon systems are in their early stages. In 2007, a Defense Science Board report revealed that "at medium power levels, solid state laser systems with improved efficiency and reasonable beam quality could provide manned and unmanned aircraft applications at power levels of tens to hundreds of kilowatts for self-defense and, eventually, precision ground attack."[99] Railgun technology is also significant because it uses electromagnetic coils instead of chemical propellants to fire military projectiles farther and faster than traditional gun systems.[100] Furthermore, railgun projectiles destroy their targets with their large kinetic energy instead of explosive charges and might be universally transportable.[101] Regardless of RPA swarms' potential to provide new airpower capabilities with minimal deployment and redeployment timelines and relatively miniscule logistical requirements, Instant Basing will only be effective if it fits the political context of a given scenario.

According to van Creveld, "Strategy, like politics, is said to be the art of the possible; but surely what is possible is determined not merely by numerical strengths, doctrine, intelligence, arms, and tactics, but, in the first place, by the hardest facts of all: those concerning requirements, supplies available and expected, organization and administration, transportation and arteries of communication."[102] The aim of Instant Basing is to make airpower's "hardest facts of all" less limiting by dramatically reducing the need for large airfields, petroleum convoys, and vast numbers of continuously deployed personnel and support equipment.[103] Furthermore, as James Huston observed, "logistics is the application of time and space factors to war" and "provides the substance that physically permits an army to 'live and move and have its being.' "[104] His statements will be even more prophetic if Instant Basing comes to fruition because the logistics concept will allow locust-like swarms of RPAs to emerge at any time from nearly any place planners see fit.

Most importantly, Instant Basing may influence the context of US military thought. Instead of viewing the world from a Westphalian perspective, one in which the globe is divided by territorial boundaries, civilization could be perceived in the context of an overarching complex of interconnected government and commercial logistical firms. Regional crises then become lesions underlying the international logistics network. If the United States maintains a rapidly deployable airpower force comprised of RPA swarms that are constantly in a state of transit throughout the international logistics network, it can maintain a strategic defensive position that simultaneously enables political and military leaders to maintain the initiative in a spectrum of scenarios. According to Clausewitz, the strategically defensive actor seeks to "keep his territory inviolate, and hold it for as long as possible."[105] However, in the context of Instant Basing's potential application, territory will not be the aim; instead, maintenance of international security and stability will be the overarching goal.

In this context the US military might also consider Instant Basing as a construct for global guerilla-type operations to gain and maintain continuing advantage with respect to potential or emerging regional problems.[106] For example, Mao Tse-tung wrote the following ideas during his fight against Imperial Japanese forces:

> When the situation is serious, the guerilla must move with the fluidity of water and the ease of the blowing wind. Their tactics must deceive, tempt, and confuse the enemy. They must lead the enemy to believe that they will attack him from the east and north, and they must then strike him from the west and the south. They must strike, then rapidly disperse. . . . Guerilla initiative is expressed in dispersion, concentration, and the alert shifting of forces. . . . Skill in conducting guerilla operations, however, lies not in merely understanding the things we have discussed but rather in their actual application on the field of battle.[107]

Instant Basing may be used as a type of global guerilla tactic because it intends to provide the United States the capability to employ significant airpower from almost any location in a minimum amount of time and aims to exert influence in a region by making the enemy unable to determine the location or future concentration and application of US forces. Similarly to T. E.

Lawrence's World War I guerilla tactics in the Middle East, future conflicts will be "wars of detachment" where the global logistics network "contains the enemy by the silent threat of a vast unknown desert not disclosing ourselves till the moment of attack."[108] During attacks, instantly based swarms of RPAs will provide the means for rapid punishment (destructive force); however, the implied omnipresence of swarms may also deter enemies from disobeying international norms, laws, and customs. Robert Pape contends, however, that for airpower to coerce enemies to behave as the international order expects, it must be applied in the context of the enemy's strategy.

> For coercion through denial to succeed, the coercer must exploit the particular vulnerabilities of the opponent's specific strategy. All military strategies do not share the same weaknesses. Modern nation-states employ two main types of strategies in conflicts with other states: mechanized (or "conventional") war and guerilla (or "unconventional") war. In this context "mechanized" refers to the dominance of the types of mechanical weapons and transport provided by the industrial revolution, not to battle tactics that rely on armored vehicles and rapid mobility, such as the German blitzkrieg. The objective in mechanized war is destruction of the enemy forces, by means of massive, heavily armed forces that fight intense, large-scale battles along relatively well-defined fronts. . . . Guerilla warfare, in contrast, aims to gain control over population, usually beginning with villages located in remote areas, and to use these anchors to control still larger segments of the population and thus undermine support for the government. Guerillas fight in small units dispersed over large areas with no well-defined front line. . . . From the coercer's point of view, the most important difference between these two strategies is that mechanized war is highly dependent on logistics and communications networks, and guerilla war is not (emphasis in original).[109]

Instant Basing's capability to generate RPA swarms supported by a small logistical footprint may make it particularly suited to providing significant coercive utility in low-intensity conflicts if (1) "coercers can obtain concessions only over the specific territory that has been denied to the opponent," (2) "military pressure" can be "maintained continuously until a satisfactory settlement is reached," and (3) "the coercer demonstrates the capacity to control the disputed territory by force."[110] Furthermore, the organic capabilities included within RPA swarms could provide surveillance, limited airdrop, kinetic effects, and other missions toward military objectives found within low-intensity conflicts. If successfully employed, instantly based swarms may provide a compelling threat that influences the behavior of the enemy through continued punishment in cases of enemy misbehavior, but it may also cause the enemy to believe that it will be punished if it disobeys the international order.[111] According to Nobel laureate Thomas Schelling, "Deterrence involves setting the stage—by announcement, by rigging the trip-wire, by incurring the obligation—and *waiting*" (emphasis in original).[112] If Instant Basing and

RPA swarming capabilities are demonstrated, they may create new ways and means to such ends.

Conclusions about an RPA Vanguard

Regardless of Instant Basing's potential grand-strategic and military-strategic implications, the integration of RPA technology with swarming concepts creates the potential for a new paradigm of US airpower. However, before RPAs are able to swarm and demonstrate meaningful airpower effects, significant RDT&E is required to merge a diverse array of algorithms that control the flight, communications, and weapons employment characteristics of RPA swarms. In the meantime, current medium and large unmanned aircraft are essentially employed as manned aircraft controlled from afar. The MQ-1 Predator, MQ-9 Reaper, and RQ-4 Global Hawk command, control, and communications infrastructures will be important models for future remote operations involving RPA swarms. Furthermore, US airpower remains oriented toward maneuver-type operations as explained in the previous chapter. This trend will continue until technologies involving small RPA swarms mature to such an extent that they can demonstrate airpower effects commensurate with those of the US military's manned aircraft fleet. When that happens, the Instant Basing logistics concept might provide the foundation for rapidly deployable swarm airpower.

The premise of Instant Basing is that swarms of small RPAs might provide significant airpower effects with minimal logistics support; thus, they can be rapidly deployed from CONUS and/or from within the global logistics infrastructure by small teams of launch and recovery personnel. If swarming and RPA technologies mature to such an extent that this concept is possible, Instant Basing may have a significant influence on US airpower. Because RPAs used in Instant Basing do not require airfields, swarms are launched from a variety of locations as determined by the theater strategy. This chapter does not specifically provide a future-swarming CONOPS; however, the next chapter does. After the swarms are launched, their launch and recovery teams return to the United States or other deployed locations to minimize their exposure to enemy elements and reduce overall force protection requirements. According to the proposed Instant Basing timeline, swarms of RPAs can be airborne within four days, and support personnel based in the United States will be back at their original CONUS destination in seven days. If RPA swarms are launched from aircraft or naval vessels, US personnel will be out of harm's way even sooner. Once RPAs are launched they will provide persistent airpower over their target areas and receive air-refueling support from other RPAs until operational commanders order their recovery.

If Instant Basing is successfully demonstrated in the future, it will multiply flexibility in geographic positioning, logistics, security, and politics for operational planners and commanders. Since airfields will not be required, air assets may be placed closer to target areas, providing a range benefit to RPA swarms, and will not be limited by airfield availability like manned aircraft. Swarms of small RPAs will use miniscule amounts of fuel as compared to manned aircraft, and their small size will allow a variety of transportation options. As a result, the logistics requirements of swarm-based airpower could be significantly less than today's manned aircraft.

Force protection will still be a concern; however, the rapid nature of Instant Basing swarm deployments will minimize the exposure of support personnel when operating in permissive environments. In hostile environments, swarm teams will require force protection from joint forces; however, because Instant Basing launch and recovery sites will be dispersed and support presence in the area of operations is brief, force protection requirements are expected to be much less than if swarm assets were statically concentrated on expeditionary air bases.

Diplomacy with host nations will remain a significant consideration. Host nations will always hold leverage over foreign entry into their country. Nonetheless, because RPA swarms are less conspicuous, involve fewer forward-deployed personnel, and do not require airfields, foreign nations will have less leverage to influence the United States. Moreover, because RPA swarms can be formed very quickly and remain airborne, host nations have fewer ways they can affect operations once begun. They may also be more reluctant to restrict US operations since swarms may not be visible to the local population.

Will RPA swarms become a vanguard for a new airpower paradigm? Current and near-future technologies open the door, yet entering such an era requires that the airpower institution reconsider the traditional employment of power and effect the organizational changes necessary to exploit a new concept of operations. Such innovation will likely cohere with and be spurred by the demands of the modern security environment, especially considering the flexibility and opportunity it supplies to senior political and military leaders. They may be well served by the ability of RPA swarms to impose, among other things, a sort of guerilla warfare against nation-states and nonstate actors behaving badly. RPA swarms may provide an added measure of deterrence against sovereign and nongovernmental actors and could increase international stability if enemies suspect their presence throughout the global logistics structure. Regardless, just as regular forces are often surprised by guerilla attacks, it is likely that the military will be surprised by the emergence of new technologies relating to RPA swarms. Longtime military affairs scholar David

Mets is probably correct that "the real success of new weapons usually comes in areas that were unimagined by the scientists and developers."[113] In the future, Instant Basing may keep the military version of locusts alive, but their technological birth and metamorphosis will require significant commitment from the Department of Defense.

Notes

1. Martin C. Libicki, "Small and the Many," in *In Athena's Camp: Preparing for Conflict in the Information Age*, ed. John Arquilla and David Ronfeldt (Santa Monica, CA: RAND, 1997), 195.
2. Ibid., 191.
3. Thomas P. Ehrhard, "Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation" (PhD diss., Johns Hopkins University, 2000). Ehrhard's dissertation offers an excellent survey of RPAs and their development.
4. Thomas P. Ehrhard, *Air Force UAVs: The Secret History* (Arlington, VA: Air Force Association, 2010), 88. Ehrhard's study provides an excellent overview of the development and employment of unmanned aerial vehicles from their initial use in covert missions to their current overt uses within military operations.
5. Tony Mason, "Operation Allied Force, 1999," in *History of Air Warfare*, ed. John Andreas Olsen (Washington, DC: Potomac Books, 2010), 246, 249.
6. David A. Deptula, "Air Force Unmanned Aerial System (UAS) Flight Plan 2009–2047," PowerPoint presentation, 2009, slide 34.
7. Lambeth, "Operation Enduring Freedom, 2001," 275–76; USAF, "Factsheets: MQ-1B Predator"; and USAF, "Factsheets: MQ-9 Reaper."
8. Andrew Callam, "Drone Wars: Armed Unmanned Aerial Vehicles," *International Affairs Review* 18, no. 3 (Winter 2009).
9. Marc V. Schanz, "Reaper Harvest," *Air Force Magazine* 94, no. 4 (April 2011): 36.
10. John A. Tirpak, "RPA Boom," *Air Force Magazine* 93, no. 8 (August 2010), http://www.airforce-magazine.com/MagazineArchive/Pages/2010/August2010/0810RPA.aspx.
11. US Air Force, " Fact Sheet: RQ-4 Global Hawk," http://www.af.mil/information/factsheets/factsheet.asp?id=13225 (accessed 21 March 2012); Deptula, "Air Force Unmanned Aerial System," slide 4; Defense Science Board (DSB), *Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles* (Washington, DC: Office of the Undersecretary of Defense For Acquisition, Technology, and Logistics [OSD/ATL], 2004), iii; and Council on Foreign Relations (CFR), *U.S. Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle Strategic Vision* (Washington, DC: CFR, 2005), 2. The Global Hawk is a large, unarmed RPA capable of providing imagery support. Its significant intelligence collection accomplishments were emphasized in the DSB study and the Air Force 2005 Strategic Vision.
12. Some of the flight profiles and missions listed in fig. 5 are incorrect as published by the DOD. For the most accurate vehicle specifications, refer to service-specific fact sheets and/or the manufacturer's sales literature.
13. Jeremiah Gertler, *U.S. Unmanned Aerial Systems* (Washington, DC: Congressional Research Service, 2012), 44–46; and Thomas Withington, "Micro and Mini UAVs," *Military Technology* 35, no. 8 (August 2011): 73.
14. John G. Drew et al., *Unmanned Aerial Vehicle End-to-End Support Considerations* (Santa Monica, CA: RAND, 2005), 13.

15. Withington, "Micro- and Mini UAVs," 73–79. The term *unmanned aerial vehicle* (UAV) is synonymous with *remotely piloted aircraft* (RPA).

16. Ibid. RPAs in Groups 4 and 5 are often called medium- and high-altitude long-endurance (MALE and HALE) units.

17. Drew et al., *Unmanned Aerial Vehicle End-to-End Support Considerations*, 13.

18. Deptula, "Air Force Unmanned Aerial System," slides 17–18; USAF, "Factsheets: MQ-1B Predator"; USAF, "Factsheets: MQ-9 Reaper"; and USAF, "Factsheets: RQ-4 Global Hawk."

19. Drew et al., *Unmanned Aerial Vehicle End-to-End Support Considerations*, 57–85; AFI 11-2MQ-1, *MQ-1 Operations Procedures*, vol. 3, 29 November 2007, 9; and AFI 11-2RQ-4, *RQ-4 Operations Procedures*, vol. 3, 14 September 2007, 13. According to US Air Force fact sheets, fixed-wing RPAs in Groups 4 and 5 have operational ranges between 770 and 8,700 nautical miles. See http://www.af.mil/information/factsheets/index.asp for weapon system specifics.

20. Deptula, "Air Force Unmanned Aerial System," slide 26.

21. Drew et al., *Unmanned Aerial Vehicle End-to-End Support Considerations*, 61–66, 81–83; Gertler, *U.S. Unmanned Aerial Systems*, 3; and CFR, *U.S. Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle Strategic Vision*.

22. Lt Col Joseph L. Campo, "When Flexibility and Doctrine Collide: Command and Control of Global RPA Operations" (master's thesis, School of Advanced Air and Space Studies, 2011), 31, 33. Per the Institute of Electronics and Electrical Engineers, C-band is the portion of the electromagnetic spectrum between 4.0 and 8.0 gigahertz. Ku-band resides between 10.95 and 14.5 gigahertz.

23. "RQ-4A Global Hawk (Tier II+ HAE UAV)," GlobalSecurity.org, http://www.globalsecurity.org/intell/systems/global_hawk.htm (accessed 22 March 2012).

24. DSB, *Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles*, 19; and AFI 11-2RQ-4, *RQ-4 Operations Procedures*, vol. 3. Takeoff and landing are critical phases of flight.

25. Although electromagnetic signals travel at the speed of light, it takes a few seconds for signals to travel the intercontinental distances commonly involved with remote split operations.

26. Campo, "When Flexibility and Doctrine Collide," 31. LOS connectivity provides LRE personnel near-instantaneous control of MQ-1/9 aircraft since the distance between the LRE and the aircraft is often between 50 and 75 miles.

27. AFI 11-2MQ-1, *MQ-1 Operations Procedures*, 9; AFI 11-2MQ-9, *MQ-9 Operations Procedures*, vol. 3, 28 November 2008 (incorporating change 1, 3 September 2010), 10; AFI 11-2RQ-4, *RQ-4 Operations Procedures*, 13; USAF, "Factsheets: MQ-1B Predator"; USAF, "Factsheets: MQ-9 Reaper"; and USAF, "Factsheets: RQ-4 Global Hawk."The maximum takeoff weights of the MQ-1, MQ-9, and RQ-4 are 2,250 lbs., 10,500 lbs., and 32,250 lbs., respectively.

28. Office of the Secretary of Defense (OSD), *Unmanned Aerial Vehicle Reliability Study* (Washington, DC: OSD, 2003), 6.

29. Ibid., 18.

30. CFR, *U.S. Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle Strategic Vision*, 21.

31. Ehrhard, *Air Force UAVs*, 51; and Nick Turse, "America's Secret Empire of Drone Bases," *Asia Times*, 26 October 2011, http://www.atimes.com/atimes/South_Asia/MJ26Df02.html.

32. AFCENT, "Factsheets: 380th Air Expeditionary Wing."

33. AFDD 2-4, *Combat Support*, 1, 4.

34. Drew et al., *Unmanned Aerial Vehicle End-to-End Support Considerations*, 81–82.

35. W. J. Hennigan, "Pentagon Working with FAA to Open U.S. Airspace to Combat Drones," *Los Angeles Times*, 13 February 2012, http://articles.latimes.com/2012/feb/13/business/la-fi-military-drones-20120214.

36. Drew et al., *Unmanned Aerial Vehicle End-to-End Support Considerations*, 63.

37. See chap. 2 for an extensive discussion on expeditionary logistics and lines of supply.

38. DOD, *Conduct of the Persian Gulf War*, 26, 66, 127.

39. Turse, "America's Secret Empire of Drone Bases."

40. DSB, *Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles*, 9–12.

41. Ibid., x.

42. DOD, *Unmanned Aircraft Systems Roadmap 2005–2030* (Washington, DC: OSD, 2005); DOD, *Unmanned Systems Integrated Roadmap FY2009–2034* (Washington, DC: DOD, 2009); and DOD, *Unmanned Systems Integrated Roadmap FY2011–2036* (Washington, DC: DOD, 2011).

43. DOD, *Unmanned Aircraft Systems Roadmap 2005–2030*, 1.

44. Ibid., B-8.

45. Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, 21.

46. C4ISR is command, control, communications, computers, intelligence, surveillance, and reconnaissance.

47. "AUVSI Review—2007," *Defense Update*, http://defense-update.com/events/2007/summary/auvsi07.htm.

48. Insitu Inc., "ScanEagle," Insitu.com, http://www.insitu.com/scaneagle (accessed 17 March 2012); and Insitu Inc., "Integrator Systems," Insitu.com, http://www.insitu.com/integrator (accessed 17 March 2012).

49. Insitu Inc., "Integrator Systems."

50. Noam Eshel, "FINDER—Autonomous, Expendable UAV/SAIC," *Defense Update*, 1 December 2007, http:// defense-update.com/20071201_finder-uav.html; and Chris Haddox, "Flying High: Boeing's ScanEagle Compressed Carriage Conducts Test Flight," Boeing.com, 7 June 2010, http://www.boeing.com/Features/2010/06/bds_feat_secc_video_06_07_10.html.

51. Eshel, "FINDER."

52. USAF, "Factsheets: ScanEagle," 1 November 2007, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104532/scan-eagle.aspx.

53. Ibid.

54. Eshel, "FINDER."

55. Insitu Inc., "ScanEagle;" Insitu Inc., "Integrator Systems;" USAF "*Factsheets: Scaneagle*"; and Eshel, "FINDER."

56. USAF, *Factsheets: ScanEagle*; and Naval Air Systems Command, "Small Tactical Unmanned Air System Executes Early Operational Capability," *NAVAIR News*, 25 January 2012, http://www.navair.navy.mil/index.cfm?fuseaction=home.NAVAIRNewsStory&id=4887.

57. Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, 21.

58. DOD, *Unmanned Systems Integrated Roadmap FY2011–2036*, 43. It is assumed that "systems" referred to both individual aircraft and groups of collaborating aircraft. No distinction was made otherwise.

59. Rafael Yanushevsky, *Guidance of Unmanned Aerial Vehicles* (Boca Raton, FL: CRC Press, 2011), 178.

60. "Researchers Produce World's First Programmable Nanoprocessor," *PHYSORG.com*, http://www.physorg.com/news/2011-02-world-programmable-nanoprocessor.html (accessed 17 March 2012).

61. DOD, *Unmanned Systems Integrated Roadmap FY2011–2036*, 46.

62. Yanushevsky, *Guidance of Unmanned Aerial Vehicles*, 178.

63. DOD, *Unmanned Systems Integrated Roadmap FY2011–2036*, 48.

64. A sample is a snapshot of the environment. More snapshots (samples) provide more information and smoother flight characteristics.

65. Matthew Turpin, Nathan Michael, and Vijay Kumar, "Trajectory Design and Control for Aggressive Formation Flight with Quadrotors" (paper presented at 15th International Symposium of Robotic Research, Flagstaff, AZ, 28 August 2011), http://www.isrr-2011.org/ISRR-2011/Program_files/Papers/Turpin-ISRR-2011.pdf.

66. Vijay Kumar, "Vijay Kumar: Robots That Fly . . . and Cooperate," *TED.com*, February 2012, http://www.ted.com/talks/vijay_kumar_robots_that_fly_and_cooperate.html. TED is a nonprofit organization with a mission to "spread ideas" by making "the best talks and performances from TED and partners available to the world, for free." The TED website provides a forum where presentations by notable experts in the fields of technology, entertainment, and design are simulcast or archived for public reference.

67. Dong Il You and David Hyunchul Shim, "Autonomous Formation Flight Test of Multi-Micro Aerial Vehicles," *Journal of Intelligent and Robotic Systems* 61, no. 1–4 (January 2011): 321–38.

68. Joint Planning and Development Office, "Are Flocks of Aircraft for the Birds? Think Again," *Jpdo.gov*, http://www.jpdo.gov/newsArticle.asp?id=42 (accessed 19 March 2012).

69. Axel Bürkle, Florian Segor, and Matthias Kollmann, "Towards Autonomous Micro UAV Swarms," *Journal of Intelligent and Robotic Systems* 61, nos. 1–4 (January 2011): 339–53.

70. Ibid., 348–49.

71. Joel George, P. B. Sujit, and J. B. Sousa, "Search Strategies for Multiple UAV Search and Destroy Missions," *Journal of Intelligent and Robotic Systems* 61, no. 1–4 (January 2011): 355–67; F. Paulo Kemper, Koji A. O. Suzuki, and James R. Morrison, "UAV Consumable Replenishment: Design Concepts for Automated Service Stations," *Journal of Intelligent and Robotic Systems* 61, no. 1–4 (January 2011): 369–97; "Game-Changer: USA Developing UAV Aerial Refueling," *Defense Industry Daily*, 7 January 2012, http://www.defenseindustrydaily.com/49m-for-boeing-to-advance-uav-aeral-refueling-05168/.; and Bruce V. Bigelow, "Northrop Grumman Planning First UAV-to-UAV Aerial Refueling," *Xconomy*, 1 July 2010. http://www.xconomy.com/san-diego/2010/07/01/northrop-grumman-planning-first-uav-to-uav-aerial-refueling/.

72. Grace V. Jean, "Remotely Piloted Aircraft Fuel Demand for Satellite Bandwidth," *National Defense* 96, no. 692 (July 2011): 38; and Keith W. Balts, "Satellites and Remotely Piloted Aircraft," *Air and Space Power Journal* 24, no. 3 (Fall 2010): 35.

73. DOD, *Unmanned Systems Integrated Roadmap FY2011–2036*, 89.

74. Clausewitz, *On War*, 119.

75. Joe Pappalardo, "Flocking ScanEagles," *Air and Space Magazine*, August 2007, http://www.airspacemag.com/ist/?next=/military-aviation/flocking-scaneagles-20369494/; and Insitu Inc., "Integrator Systems." As of 2007, one technician successfully controlled three ScanEagles. During the same time period, a typical ScanEagle crew required four personnel to launch, control, and recover the aircraft. It is assumed that increased aircraft/swarm autonomy will allow one team member to control a swarm of 15 aircraft by the time Instant Basing is a realistic option. Fifteen Integrator RPAs require 97.5 gallons of diesel, JP-8, or Jet-A fuel. This amount of fuel can be easily transported in two

50-gallon drums. Thus, swarm size is dictated by fuel requirements at launch, and two extra crew members are provided for extra assistance in aircraft/equipment assembly, launch, and disassembly.

76. Haddox, "Flying High." INSITU ScanEagles currently operate from US warships, and ScanEagle compressed carriage (SECC) variants are in development. SECC aircraft are capable of being launched from submarines, aircraft, and other types of vehicles.

77. US Military Sealift Command, "Pre-positioning," http://www.msc.navy.mil/pm3/ (accessed 14 March 2012).

78. David Axe, "Scan Eagle in Afghanistan," *YouTube*, http://www.youtube.com/watch?v=hWyk1XudaME; and Insitu Inc., "Launch and Retrieval," Insitu.com, http://www.insitu.com/launch_and_retrieval (both accessed 26 March 2012). Current generations of small RPAs are shipped in specially designed containers. Launch and recovery equipment, such as those used with Insitu aircraft, can be folded for compact shipment and storage.

79. See chap 2. Fred Pleitgen, "Attackers in Pakistan Hit Another Convoy Carrying Fuel for NATO Troops," CNN.com, 10 April 2010, http://articles.cnn.com/2010-10-04/world/pakistan.supply.route_1_convoy-nato-supply-pakistani-taliban-spokesman?_s=PM:WORLD; and "Rocket Attack on NATO Fuel Supply Convoy in Pakistan," Guardian (UK) , 8 December 2011, http://www.guardian.co.uk/world/2011/dec/08/rocket-attack-nato-pakistan.

80. US Transportation Command, *USTRANSCOM 2011 Annual Report*, 14

81. FedEx representative, telephone interview by author, 26 March 2012; UPS representative, telephone interview by author, 26 March 2012; and DHL representative, telephone interview by author, 26 March 2012.

82. Ibid. Many air cargo companies offer premium services that might decrease the risk of items being lost. If they are lost, insurance will provide compensation.

83. Local defense travel offices will make travel arrangements for swarm teams.

84. Local DOD financial managers (comptrollers) will likely be responsible for oversight of swarm team deployment expenses. Launch and recovery teams should be provided maximum financial flexibility since their deployments will be dynamic and will likely require on-the-spot payments, rentals, bribes, and so forth to meet their launch timing.

85. If the swarm team misses delivery, international freight companies often hold items for a number of days before they are returned to sender. Swarm teams may also be able to pick up their aircraft and equipment at local distribution centers.

86. Michael Spehar, "Practical Perspective of Airflow Planning" (unpublished article, May 1999); and US Transportation Command, *USTRANSCOM 2011 Annual Report*, 14. "Airflow planning" is a systematic sequencing of airlift assets to and from theaters of operation. The CRAF is a reserve fleet of commercial aircraft that are contractually bound to provide on-demand air service to the US military during contingency operations. "T-tail" refers to US intertheater airlift aircraft.

87. Spehar, *A Practical Perspective of Airflow Planning*, 7.

88. See the missed shipment procedures of UPS, FedEx, and DHL at the following websites: www.ups.com, www.fedex.com, and www.dhl.com. Commercial freight companies often allow up to five business days following a missed delivery.

89. Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, 45.

90. Accountability of RPAs and support equipment should be conducted prior to arrival at designated launch sites. Furthermore, launch crews will have to procure an adequate amount, perhaps 100 gallons, of diesel fuel, JP-8, or Jet-A fuel for each group of 15 aircraft from local sources. Host nations or local retail gas stations may be able to provide fuel. If military airlift is used, fuel may be airlifted with RPA systems.

91. This assumes that RPAs are launched and recovered by INSITU-type launch and recovery equipment. It is possible that future RPAs will not require the same level of support equipment for launch and recovery.

92. Each six-person launch and recovery team is responsible for the launch of 15 small RPAs. Their aircraft require approximately 97.5 gallons of fuel.

93. O'Hanlon, *Science of War*, 147.

94. In an effort to keep statistics as conservative as possible, percentages were calculated using the lowest consumption and personnel figures.

95. Because individual swarming aircraft are small, they may be able to fly in tight formations such that their radar signature appears similar to larger civilian or military aircraft. Their ability to change the shape of the swarm may also provide the ability to change radar signatures as desired by mission constraints.

96. Michael Berger, "Military Nanotechnology: High Precision Explosives through Nanoscale Structuring," *NanoWerk*, 5 June 2008. http://www.nanowerk.com/spotlight/spotid=5956.php.

97. John Gartner, "Military Reloads with Nanotech," *MIT Technology Review*, 21 January 2005, http://www.technologyreview.com/computing/14105/page1/.

98. James D. Hood (432 EAMXS/CC), interview by author, 12 March 2012.

99. DSB, *Defense Science Board Task Force on Directed Energy Weapons* (Washington, DC: OSD/ATL, December 2007), viii.

100. Geoff S. Fein, "ONR's Record-Setting Test to Showcase Railgun's Military Relevance," Office of Naval Research Media Center, 7 December 2010, http://www.onr.navy.mil/Media-Center/Press-Releases/2010/Electromagnetic-Railgun-32-Fire.aspx.

101. Ibid.

102. Creveld, *Supplying War*, 1.

103. Ibid.

104. James A. Huston, *Sinews of War: Army Logistics 1775–1953*, Army Historical Series (Washington, DC: Government Printing Office, 1966), viii.

105. Clausewitz, *On War*, 614.

106. Everett Carl Dolman, *Pure Strategy: Power and Principle in the Space and Information Age* (New York: Frank Cass Publishers, 2005), 6.

107. Mao Tse-tung, *Collected Writings of Chairman Mao*, ed. Shawn Conners, vol. 2, *Guerrilla Warfare*, 1st ed. (El Paso, TX: El Paso Norte Press, 2009), 58.

108. T. E. Lawrence, *Seven Pillars of Wisdom: A Triumph* (Blacksburg, VA: Wilder, 2011), 137.

109. Robert A. Pape, *Bombing to Win: Air Power and Coercion in War* (Ithaca, NY: Cornell University Press, 1996), 30.

110. Ibid., 31–32.

111. Thomas C. Schelling, *Arms and Influence* (New Haven, CT: Yale University Press, 2008), 70.

112. Ibid., 71.

113. David R. Mets, *Airpower and Technology: Smart and Unmanned Weapons* (Westport, CT: Praeger, 2009), 33.

Chapter 4

Locust Swarm's First Test

There is evil hiding in my country's shadows. Please save Nigeria before it is too late.

—Pres. Adisa Martins, 25 December 2019

Locusts came out of the smoke onto the land, and they were given the same power as scorpions of the earth. . . . The appearance of the locusts was like that of horses ready for battle. . . . Their teeth were like lions' teeth, and they had chests like iron breastplates. The sound of their wings was like the sound of many horse-drawn chariots racing into battle.

—Revelation 9:3–9

During his limousine ride back to the White House, Pres. Dominic Johnson was thinking how the Washington skyline looked especially beautiful. Snow, streetlights, traffic, and a starry sky created a kaleidoscope of colors. Christmas Eve services at the National Cathedral had gone well, and he looked forward to some sleep and a peaceful Christmas morning with his wife and children. The president cherished moments like these because they were free of crisis, were shared with his family, and had nothing to do with the upcoming 2020 election.

Johnson's mood quickly changed when he spotted Sarah Nguyen, his national security advisor, waiting inside the White House entrance. She was not one to intrude on the president's family time and often took care of problems herself. This had to be bad.

Crisis in Nigeria

Hours earlier, the Nigerian terrorist organization Boko Haram (translated as "Western education is forbidden") had begun systematically killing Nigerians attending Christmas Eve services. The attacks were part of Boko Haram's plan to eradicate non-Muslims from Nigeria and create an Islamic state.[1] The group initiated its offensive by placing bombs inside Christian churches and waiting for the buildings to fill. After the services began and the doors closed, Boko Haram strike teams secured the exits and detonated their bombs. Car bombs demolished the entrances of 12 foreign-owned oil refineries and triggered panic among Nigeria's foreign nationals. Boko Haram operatives also captured several Christian government officials, beheaded them, and posted their heads in prominent places with notes that read "I was an infidel oppressor." Between 8:00 p.m. and midnight, Boko Haram killed thousands of Christians, especially Americans, and spread chaos among the remaining population.

Prior to this crisis, the Nigerian government had faced an assortment of domestic maladies yet was able to maintain a tenuous peace. Nigeria is the world's eighth-largest oil producer and Africa's most populous state.[2] Approximately 203 million people live in an area roughly twice the size of California (see fig. 9).[3] Poverty, pollution, corruption, religious conflict, and terrorism are constant concerns. Approximately 70 percent of the population lives in poverty, 21 percent are unemployed, oil spills pollute much of the coastal region, and corruption is rampant.[4] Furthermore, Nigeria is polarized by seemingly incompatible religious beliefs. The northern portion of the state is predominantly Muslim and governed in accordance with sharia law, while the southern half is predominantly Christian.[5] Nonetheless, despite occasional skirmishes, the self-imposed segregation of Nigeria's Muslim and Christian populations has produced an entente between the factions. This environment provides Boko Haram an excellent opportunity to recruit additional members and prepare assaults against its Christian enemies.

Although Boko Haram has conducted terrorist attacks in the past, many believe the group has lost its intent and capability to conduct coordinated large-scale attacks. From 2002 to 2012, it was responsible for numerous offensives against Christian government officials, police stations, churches, and government-sponsored schools.[6] It also gained extensive international attention following a 2011 car-bomb attack against the United Nations headquarters in Nigeria's capital, Abuja.[7] Many experts worry that Boko Haram's affiliations with al-Qaeda in the Islamic Maghreb (AQIM) and al-Shabaab might increase its ability to recruit dissatisfied Muslim youth and conduct complex attacks against Nigerian targets.[8] For example, US Army general Carter Ham stated in 2011, "What is most worrying at present is, at least in my view, a clearly stated intent by Boko Haram and by al-Qaeda in the Islamic Maghreb to coordinate and synchronize their efforts. I'm not so sure they're able to do that just yet, but it's clear to me they have the desire and intent to do that."[9] Nonetheless, international military aid and training helped the Nigerian government keep Boko Haram in check with proactive attacks against its leadership and supporters. In 2009 Nigerian security forces killed Boko Haram's leader, Muhammad Yusuf, and hundreds of his followers.[10] In 2012, its armed forces continued their assaults on the organization and forced it into dormancy by the end of 2013.[11] In the following years, the terrorist group seemed to disappear with little trace. Reporters and Nigerian officials heard occasional rumors of Boko Haram activity; however, most people assumed the group had been defeated (see fig. 9).[12]

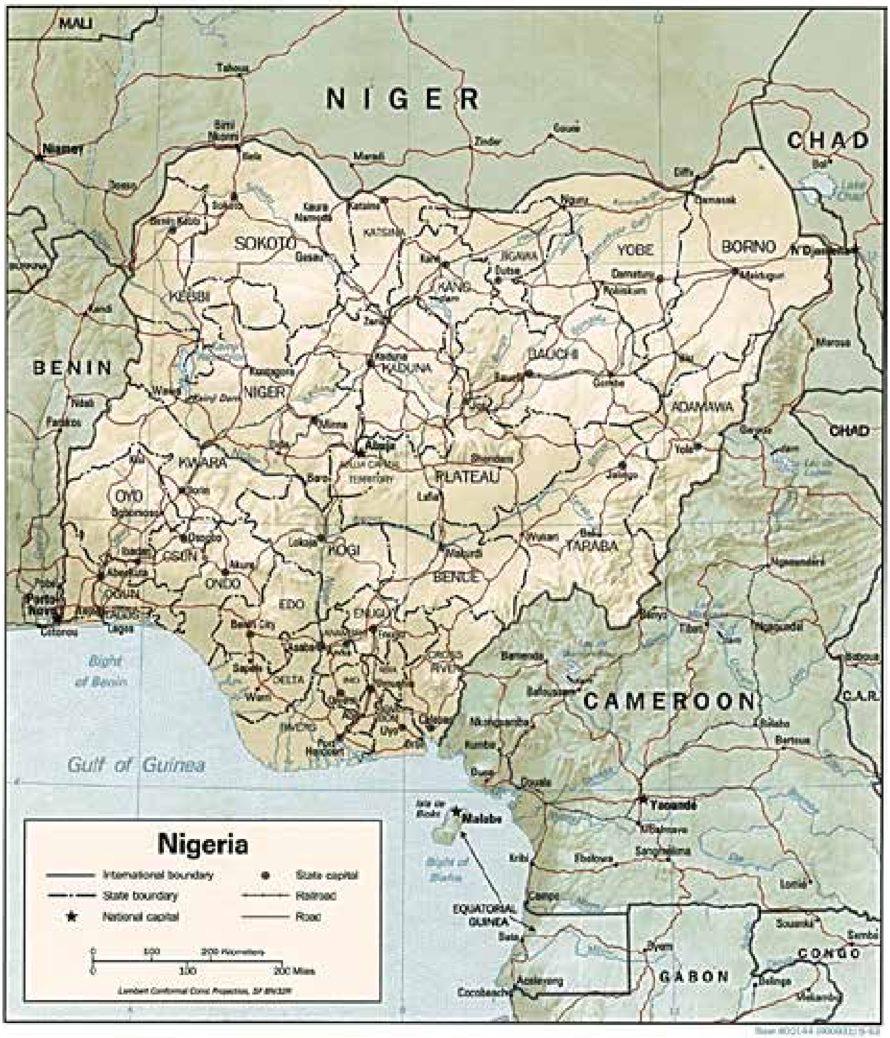

Figure 9. **Nigeria**
(Reproduced from CIA, "Nigeria," *World Factbook*, [Washington, DC: Brassey's, 2015], https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html.)

On the contrary, Boko Haram bided its time until a major attack was possible. Following the assassination of Muhammad Yusuf and the losses incurred from the government's 2012 counterattacks, its leaders changed their strategy. Instead of fighting small battles that brought few benefits, they ordered a halt to violent actions and banned any overt reference to Boko Haram. Meanwhile, its members infiltrated Islamic communities throughout Nigeria and earned significant positions of authority within those societies. Boko Haram's clandestine members used their positions to gather intelligence and stockpile small arms and explosives in secure locations. From 2016 to 2019, Boko Haram, AQIM, and al-Shabaab operated training camps in Niger that covertly trained hundreds of militants for the 2019 Christmas Eve attacks.

Surveying Response Options

After a preliminary briefing by his national security advisor, President Johnson calls for an immediate meeting with the National Security Council (NSC).[13] Following the advice of the secretary of state, secretary of defense, and chairman of the Joint Chiefs of Staff (CJCS), the president includes the US ambassador to Nigeria and the commander of US Africa Command (USAFRICOM) via video teleconference. The president's primary concerns involve the safety of US citizens in Nigeria, impact on the global economy, and the possibility that genocide has occurred. In 2019, Nigeria maintains its position as the sixth-largest oil exporter and fifth-greatest oil supplier to the United States.[14] President Johnson fears that any decrease in crude production could increase oil prices and slow the global economy. He is also worried that the Christmas Eve attacks might be the beginning of a Nigerian genocide.

During the NSC meeting, it becomes obvious that the United States has few intelligence resources in position to analyze the conflict. Intelligence assets have been focused elsewhere, and the unexpectedness of the crisis means that little information is available. Furthermore, the armed forces have few means to respond quickly. Following the 2014 redeployment from Afghanistan, the Pentagon allocated the majority of its combat forces to the Pacific in defense against China's growing military might.[15] Africa was not a high priority; therefore, few bases exist there. The only US air bases on the African continent are in Djibouti, Kenya, and Ghana.[16]

President Johnson inquires about projecting force from the United States and the cost of such a plan. The secretary of defense responds that this option is possible but will require time to reallocate ISR, cargo, and combat assets from other theaters. She adds that sustained operations will require additional air bases in or near Nigeria at significant cost. The president is also worried that military operations might cost his administration political capital because he is already under significant scrutiny for his inability to tame the $20 trillion US national debt.[17] Nonetheless, he feels that because this situation threatens US citizens traveling abroad and potentially involves genocide, it is the duty of the United States to act as quickly as possible, even before a coalition can be created. Moreover, he wants this task accomplished at minimum cost.

At the end of the meeting, President Johnson issues guidance to his staff. He asks his ambassador to offer the Nigerian government military assistance for humanitarian, intelligence, and security operations. The president also orders the Departments of Defense and State to develop a plan that will bolster the Nigerian government's ability to maintain the security of its population, including foreign nationals, and protect its oil refineries. He reiterates that such a plan should be conducted in the most cost-effective manner.

Following the meeting, the secretary of state works to gain the support of Nigeria's neighboring countries. Ghana, Benin, and Cameroon offer their support as long as ground troops are not deployed to or from their countries. However, they approve the use of their airfields as cargo and air-refueling bases and permit the presence of US support personnel on these bases. These were each former European colonies and thus are sensitive to the presence of Western military forces.[18] Niger refuses to support US efforts to stop the Boko Haram offensive because of its strong ties to Nigeria's Muslim population.

Shortly thereafter, Nigerian president Adisa Martins calls President Johnson to ask for US help. He states that Boko Haram terrorists roam the streets at night and are searching for government officials, policemen, military service members, and Christians. They use stolen church registries to refine their hunt. Martins has declared martial law; however, Boko Haram's numerous dispersed attacks prevent Nigerian military and police forces from responding in a timely manner. The Nigerian president emphasizes that his government's forces hold marginal control of the country and might be defeated in the near future. President Johnson assures him that the United States is willing to conduct operations in support of his government. President Martins concludes their conversation by saying, "Thank you for your help. There is evil hiding in my country's shadows. Please save Nigeria before it is too late."

Course-of-Action Development and Selection

In response to the developing crisis, USAFRICOM's joint planning staff begins assessing options. Joint planners determine they will not need to gain air superiority. Based on their understanding of Nigerian air defenses, Boko Haram poses little threat to airborne assets. They additionally assume that this conflict is low intensity, involving only personnel and lightly armed vehicles. The planners determine that Cameroon's airfield in Garoua might serve as an important expeditionary base because of its proximity to Abuja and its 10,000-foot-long runway (fig. 10).[19] They assess that Garoua has a high probability of supporting refueling operations because Cameroon possesses a significant oil refining capability.[20] They also decide that Ghana's airfield in Accra might be suitable for tanker and cargo aircraft because of its long runway and existing US presence.[21]

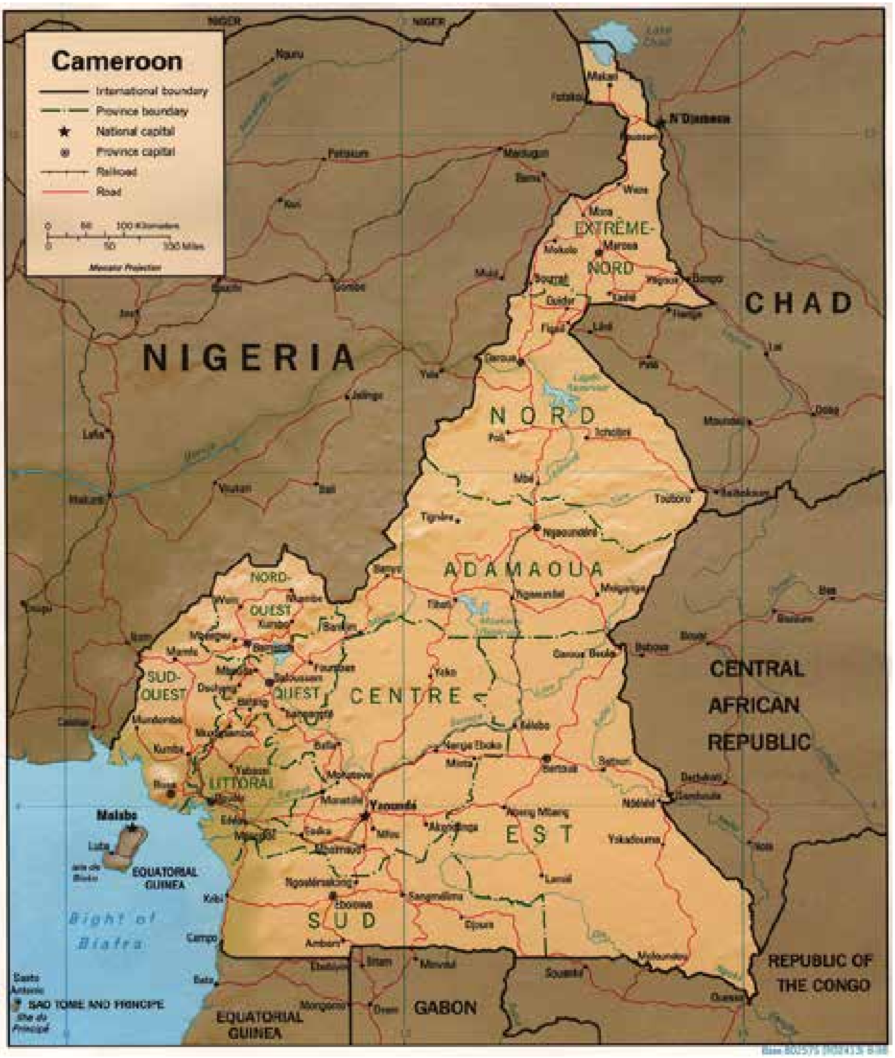

Figure 10. **Cameroon**
(Reproduced from CIA, "Camaroon," *World Factbook*, [Washington, DC: Brassey's, 2015], https://www.cia.gov/library/publications/the-world-factbook/geos/cm.html.)

In accordance with the president's guidance, USAFRICOM planners develop six operational requirements. First, US air assets have to be deployed rapidly. Second, the crisis requires the commitment of multiple ISR capabilities to assess the environment and develop targeting information. Third, US forces need points of contact from the Nigerian government to help coordinate air operations against Boko Haram militants. Fourth, US air assets require adequate force capability to secure key locations so that Nigerian military and police elements can operate with improved freedom of action and mobility. Fifth, there is the need for persistent airpower. And finally, a significant emphasis is placed on cost-effectiveness.

After the USAFRICOM planning staff conducts operational design and mission analysis, they develop multiple courses of action (COA) involving manned and unmanned aircraft. The combatant commander chooses a COA involving swarms of small RPAs, called Locust Swarms, because he thinks they best satisfy the president's intent and the operational requirements of Nigeria's crisis.[22] Armed Locust Swarms are rapidly deployable and can be airdropped over key Nigerian locations including government and police headquarters, oil refineries, airfields, and military bases. Locust Swarms possess persistent ISR and kinetic-attack capabilities, are cheaper to operate than manned aircraft, and have a C2 structure that enhances coordination with host-nation officials during operations. They can also be kept airborne indefinitely with air-refueling support. USAFRICOM also intends to operate manned and unmanned tanker aircraft from naval vessels patrolling the coast of Nigeria and from land bases at Accra, Ghana, and Garoua in Cameroon. The Locust Swarms will be remotely piloted from CONUS and European locations.[23]

Planners estimate that an initial deployment of 100 swarms will require tanker support and 25 RPA combat air patrols (CAP).[24] As the security situation improves, small tanker RPAs launched from Instant Basing locations in southern Nigeria will gradually reduce the need for tankers based outside the state.[25] Ideally, Instant Basing teams will be deployed within 16 hours of Locust Swarm deployment. The establishment of Instant Basing locations will also reduce the demand for RPA CAPs, because local RPA bases can control swarms via line-of-sight (LOS) communications. If conditions deteriorate and Martins's government loses its ability to maintain order, the United States can escalate its use of force via intercontinental bombers or carrier-based jet aircraft. If the situation becomes irredeemable, it can recover its Locust Swarms to US naval vessels or regional land bases such as Garoua.

Command and Control

Locust Swarms can conduct autonomous operations, according to the 2011 DOD *Unmanned Systems Integrated Roadmap*: "They received goals from their human controllers and translated them into tasks to be performed without human interaction."[26] Their algorithms and software allow them to survey their environment autonomously until they detect potential threats. Swarms are programmed to alert their controller and command-and-control element if threats are detected so they can either collect additional information or employ kinetic weapons. The process minimizes the workload of controllers and C2 elements and facilitates the management of large numbers of Locust Swarms. The standard autonomous alerting capability is available regardless of the communication means used to link human controllers with their swarms.

Planners intend to command and control Locust Swarms through satellite, LOS, and Internet connectivity.[27] Satellite connectivity will be the primary means of C2 until Instant Basing teams can provide LOS connectivity. As protected launch and recovery locations become available, swarming operations will use Nigerian government and commercial Internet service providers (ISP) serving urban and industrial areas.[28] Thus, the Internet will provide Instant Basing LOS elements connectivity with theater and CONUS C2 elements without satellite links, airborne C2 aircraft, or in-country C2 facilities.

The Internet also provides an important means of ensuring that the Nigerian government can communicate with US forces, observe operations, and authorize the use of force if necessary. With the help of the US ambassador to Nigeria and other State Department officials, special operations forces (SOF) personnel will deliver coded common access cards (CAC) to designated Nigerian officials.[29] SOF members will also provide a discrete, 128-bit encrypted website address affording designated Nigerian representatives current video feeds and the ability to communicate with US forces via an included chat capability.[30] If individual CACs are lost, stolen, or compromised, their access can be disabled. Thus, Nigerian officials have a secure capability to positively identify targets and authorize US use of force before an attack. This line of communications gives the United States a degree of deniability should collateral damage occur, and it also bolsters the legitimacy of the Nigerian government because it holds the ultimate authority for attacks against local targets.

Executing the Plan

In the period leading up to air operations, the US ambassador to Nigeria maintains contact with President Martins and gives him a document outlining USAFRICOM's plan to guard government facilities, airports, and oil refineries. The outline lists specific locations that would be protected by Locust Swarms and explains that their sensors have a modest ability to detect armed personnel entering cordoned areas.[31] Furthermore, it requests that Nigerian police and military units secure 11 major airports in the southern portion of Nigeria so that cargo aircraft can deliver Instant Basing equipment and begin sustainment operations.[32] The document also states that Locust Swarms carry small bombs capable of destroying lightly armored vehicles and personnel.[33]

On 26 December, US special forces establish Internet connectivity between Nigerian officials and the AFRICOM air operations center (AOC) and provide elementary training on the website features. During subsequent collaboration, representatives from the Nigerian armed forces report that Nigeria's airfields remain in operation. They also confirm that Boko Haram's attacks are directed at Nigeria's Christian population, government officials, and oil refineries. Moreover, local officials notice that the intensity and frequency of Boko Haram's assaults have decreased. News reports confirm these observations. For example, CNN correspondent Jenny James reported that "the Nigerian people remain fearful that more attacks are coming . . . and an uneasy calm prevails throughout Nigeria's capital city." Nonetheless, the AOC validates information provided by the Nigerian government with available intelligence and decides that Nigeria's airfields would allow the deployment of Instant Basing teams following an initial air delivery of Locust Swarms. Based on staff intelligence assessments, the USAFRICOM commander orders that air operations commence immediately.

On 27 December, strategic-airlift planes deploy 100 Locust Swarms into Nigerian airspace.[34] As planned, they are delivered over major cities and industrial areas in the southern half of Nigeria. Although the vast majority of swarms deploy successfully, 5 percent of RPAs are destroyed or lost because they fail to assimilate with their swarm. The remaining RPAs assemble into fuel-saving formations, similar to flocks of migratory birds, until they arrive over their respective areas of interest.[35] Meanwhile, supporting vessels from the Navy's Sixth Fleet are en route, and approximately 400 Instant Basing personnel are positioned at Accra, Ghana, and Garoua for eventual deployment to airfields throughout southern Nigeria.[36] Tanker MQ-9 RPAs with autonomous takeoff and landing capability are also based at Garoua. When the swarming RPAs are employed, they will require refueling within 24 hours.[37]

Consequently, it is important for Instant Basing teams to begin refueling operations within the next 16 hours.[38]

As Locust Swarms arrive over their observation areas, most do not detect any irregularities. However, a Locust Swarm over a refinery near Port Harcourt detects a group of 10 suspicious individuals huddled near its perimeter fence. They appear to be holding rifles and rocket-propelled grenade launchers. The swarm alerts its controller and C2 element and initiates coordination with the Nigerian government. After viewing the group from multiple RPA sensors, USAFRICOM and Nigerian representatives agree that they are not Nigerian military or police personnel on patrol and determine the potential attackers are hostile. Because the suspected terrorists threaten the refinery and Nigerian forces are too far away to respond in adequate time, the Nigerian government approves the use of force via its Internet link. Therefore, USAFRICOM's joint force commander (JFC) orders the observing Locust Swarm to attack. The swarm immediately centers itself over the militants and uses two of its nanotechnology-boosted, precision-guided munitions to destroy the enemy element.

In Abuja, multiple Locust Swarms detect suspicious personnel approaching Nigeria's national police headquarters. Members of the Nigerian police force confirm that large groups of armed individuals are converging on its headquarters and request reinforcements. Shortly thereafter, a firefight breaks out between Boko Haram militants and police forces barricaded inside the compound. Nigerian authorities have been watching video feeds of the situation and authorize use of force. The USAFRICOM JFC subsequently orders nearby Locust Swarms to engage the enemy elements.

The Nigerian police headquarters is a large building centered within one of Abuja's largest city blocks. Due to its considerable size, the significant area surrounding the building, and numerous approach paths of converging Boko Haram assailants, a single Locust Swarm is incapable of providing 360-degree surveillance and multidirectional kinetic attacks. Therefore, five responding Locust Swarm controllers relinquish control of their swarms to a single controller at the USAFRICOM AOC. The USAFRICOM controller then assumes control of the swarms and initiates a multiple-swarm encirclement of the police headquarters (see fig. 11). The five swarms involved in this maneuver maintain a constant clockwise track around the city block so that all the militants can be observed, isolated, and attacked via sustained multidirectional pulsing strikes. Locust Swarms begin directing their bombs against Boko Haram elements farthest from the police headquarters first so they will drive attacking forces toward the building. As enemy elements are forced closer to the facility, they become more vulnerable to police gunfire and increasingly concentrated Locust Swarm attacks.

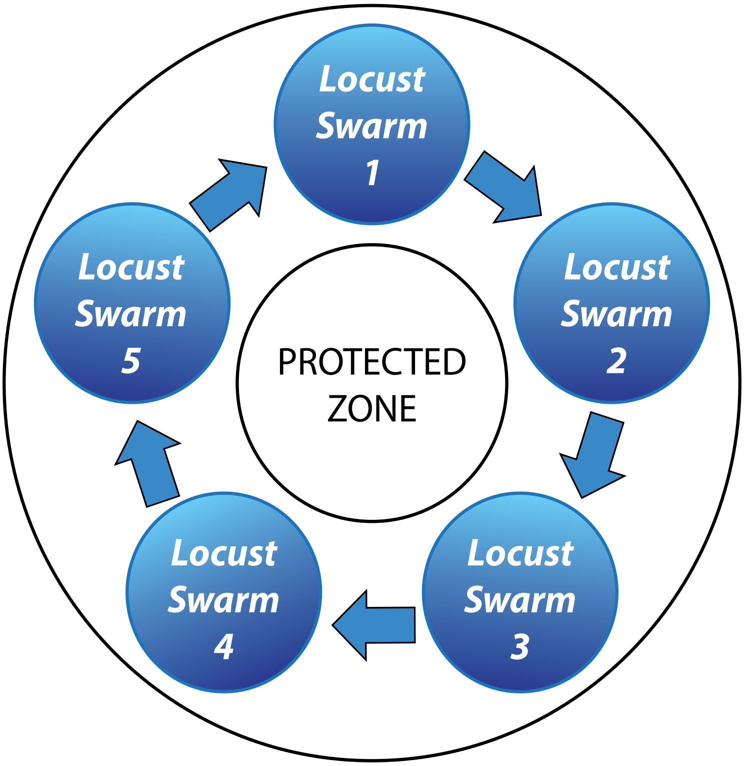

Figure 11. Tactical encirclement by multiple Locust Swarms

Shortly after the Locust Swarm tactical encirclement begins, the majority of Boko Haram's attackers are killed and the rest surrender. As soon as the Nigerian police clear the area, USAFRICOM's unified swarm controller returns control to the individual Locust Swarm controllers so they can resume other missions. Through this victory, US forces save the lives of a significant number of Nigerian policemen. The tactical success also allows Nigerian military and police officials to gather valuable intelligence from captured Boko Haram personnel. Thus, Locust Swarms demonstrate their ability to protect specific constabulary elements and vital infrastructure so Nigerian police and military forces can better focus on regaining a monopoly of force throughout their territories.[39] Locust Swarms, however, require logistics support to provide the Nigerian government time.

Sustaining Locust Swarms

By noon on 28 December, Instant Basing personnel have assembled their launch and recovery equipment in Nigeria, launched approximately 50 swarms of small tanker-configured RPAs, rearmed Locust Swarm aircraft as required, and begun to establish Internet connectivity with the USAFRICOM AOC. Instant Basing personnel cycle fuel to airborne Locust Swarms via their tanker RPAs, which are augmented by 10 tanker-configured MQ-9 RPAs based in Garoua, Cameroon.[40] MQ-9 tanker RPAs refuel swarms that are too far from Instant Basing locations and augment swarms of small RPA tankers when they are unable to provide sufficient air-refueling support.[41]

The AOC also uses multiple methods to ensure that operations have a sustained kinetic-force capability. First, Instant Basing teams replenish individual RPAs needing rearmament.[42] Also, in cases where Locust Swarms operate beyond the range of Instant Basing teams, military aircraft air-drop supplemental RPAs into Locust Swarms needing additional force capability.[43] A third option allows missions to be exchanged so that when one swarm's munitions have been expended, another can take its place. This option is used until Instant Basing teams and airlift can replenish Locust Swarms' force capability.

Instant Basing teams also have the significant task of establishing Internet C2 links. In some cases Internet connectivity is not available as planned. Swarm technicians then use their LOS equipment to connect to Locust Swarms, which provide a link to distant swarm operators and the USAFRICOM AOC. By 29 December, 38 of 50 Instant Basing locations have Internet connectivity with C2 elements, and only four daily MQ-9 tanker sorties are required. Thus, the initial requirement for 25 RPA CAPs is reduced to four CAPs within two days of the initial deployment.

As operations continue, various elements of the Locust Swarm and Instant Basing infrastructure require replacement or maintenance. As swarms self-identify mechanical difficulties within individual aircraft USAFRICOM is alerted. Logistics personnel within the AOC order the delivery of replacement vehicles; some of these are available via commercial airlift, while others have remained in constant motion within commercial logistics company global networks.[44] Replacement launch and recovery equipment is delivered in the same manner. However, because Instant Basing support equipment lacks an automatic reporting capability, technicians are required to order replacement equipment via communications links with their respective C2 elements. Commercial logistics carriers are prohibited from carrying munitions, so Instant Basing crews transfer munitions from recovered RPAs to replacement vehicles prior to their launch. Failed swarm aircraft are then sent back to CONUS repair facilities via commercial logistics firms. The combination of Locust Swarms' self-alerting capability and Instant Basing crews' ability to order and receive replacement components in a timely manner greatly enhances the US propensity to sustain a force presence over Nigeria.

Improved Stability in Nigeria and the US Force Drawdown

Security significantly improves in the days following the initial introduction of Locust Swarms. Although Boko Haram continues to execute sporadic attacks, indigenous military and police forces regain their ability to protect the population and infrastructure. Locust Swarms provide important intelligence, surveillance, and reconnaissance and, in some cases, increase the firepower of Nigerian forces; however, unlike early battles in Port Harcourt and Abuja, Nigerian constabularies are winning victories on their own. As a result, Pres. Adisa Martins rescinds martial law on 30 December. Nevertheless, he requests that US forces remain overhead for an indefinite period to ward against future Boko Haram offensives.

President Johnson does not want to commit US military forces to a prolonged presence in Nigeria. He judges that they have sufficiently bolstered the Nigerian government so that it can maintain order and begin to solve domestic problems without outside involvement. Furthermore, the US ambassador reports that some Nigerian officials desire an offensive into Muslim-dominated regions of the state as punishment for their assumed support of Boko Haram. President Johnson does not want any US involvement in such actions. Consequently, he orders redeployment of forces from Nigeria.

On 31 December, Instant Basing teams begin recovering Locust Swarms and associated tanker RPAs. They disarm, package, and send aircraft and equipment back to US locations via authorized commercial carriers. In some cases, US Navy ships operating off the coast of Nigeria recover Locust Swarms. MQ-9 tanker RPAs based at Garoua are also shipped back to the United States. US military cargo aircraft then transport remaining munitions and personnel back to their primary duty stations.

At the request of the Nigerian government, approximately 20 Locust Swarms and Instant Basing teams remain behind to ensure the security of key locations such as government facilities in Abuja and coastal refineries. President Martins's government provides them full accommodation on military bases near Locust Swarm observation areas. Nonetheless, at the behest of President Johnson, the USAFRICOM commander drafts a letter to President Martins that details US plans to remove all forces within the following two weeks.[45] It also states that the United States is committed to Nigeria's security and will come to its aid if Boko Haram, or any other terrorist organization, threatens it again.

Findings

The purpose of this scenario is to provide a glimpse of future military air operations involving swarming RPAs and to demonstrate the potential utility of an Instant Basing concept of logistics. It is intentionally vague in some areas because it is impossible to predict the exact specifications of future weapons, equipment, or capabilities. Nonetheless, the scenario revealed five key findings.

First, Locust Swarms provided US leaders a relatively low-cost, low-risk option. Using fuel consumption as a measure of operational cost, and excluding the cost of weapon-system procurement, air operations in Nigeria were remarkably cost-effective compared to traditional air operations. In six days of air operations, 2,175 Locust Swarm and supporting tanker RPAs consumed approximately 73,000 gallons of fuel (see table 4). In comparison, daily air and ground operations at Bagram Air Base, Afghanistan, consume an average of 205,175 gallons.[46] Because Locust Swarm operations required only 400 forward-deployed ground support personnel, the risk of significant US combat casualties was negligible. This risk was reduced further because host-nation forces provided security for Instant Basing personnel. Furthermore, the permissive air environment in Nigeria facilitated sustainment of Locust Swarms and allowed US air assets to operate without the threat of losses from air defense systems.

Table 4. Fuel usage of Locust Swarm aircraft and tanker RPAs

	27 Dec	**28 Dec**	**29 Dec**	**30 Dec**	**31 Dec**	**1 Jan**
#of *Locust Swarms*	95	95	95	95	45	20
Total *Locust Swarm* Aircraft	1,425	1,425	1,425	1,425	675	300
# of Tanker Swarms		50	50	50	25	0
Total Small Tanker RPAs	0	750	750	750	375	0
Deployed Instant Bases		50	50	50	50	20
Instant Basing Personnel	0	400	400	400	400	160
Fuel Usage (gallons)	9,262.5	14,137.5	19,012.5	19,012.5	9,262.5	1,950
Total Fuel Used (gallons)	72,637.5					

Second, the success of Locust Swarm operations hinged on the ability to receive air-refueling support from Instant Basing teams and tankers originating from outside of Nigeria. Locust Swarms require refueling every 24 hours.

Consequently, USAFRICOM's ability to immediately deploy Instant Basing teams and provide additional air-refueling support from the airfield in Garoua allowed air operations to continue. If Instant Basing refueling operations were not possible due to insufficient force protection at Nigerian locations, significant numbers of Locust Swarm aircraft might have been lost. Cargo aircraft necessary for the air deployment of expendable RPA tankers may not have been available in sufficient numbers to supply all Locust Swarms. Furthermore, MQ-9 tankers based at Garoua had insufficient range and fuel capacity to service all of the airborne swarms. Consequently, if Locust Swarms come to fruition, an intermediary tanker should be developed that can conduct air refueling with slow Locust Swarm aircraft and KC-130 equivalent aircraft.[47] An intermediary tanker with such capability would eliminate the need for small tanker RPAs and would reduce the need for the immediate deployment of Instant Basing teams.

Third, the operation required the extensive use of large cargo and air-refueling aircraft for the initial force deployment. The security situation in Nigeria was too uncertain for Locust Swarms to be employed by Instant Basing teams. As a result, large strategic-airlift aircraft were required to deliver sufficient numbers of Locust Swarms without risking the safety of ground support personnel.[48] Large air-refueling aircraft were also required to extend the range of the strategic-airlift aircraft.[49] During redeployment of forces, a reduced but significant number of airlift and air-refueling aircraft were required to transport cargo, personnel, and RPAs out of Nigeria.[50] In situations where Instant Basing equipment could not be pre-positioned or placed into constant motion within global commercial logistics networks, military airlift was the only sustainment option.

Fourth, the Internet was a critical enabler of US operations in Nigeria because it provided timely connectivity with the Nigerian government and reduced US satellite bandwidth requirements. In the future, global access to the Internet will likely increase as information and communication services become standard features of cellular telephones and computer systems.[51] Provided sufficient information security measures, the US military should leverage the global information grid to the maximum extent possible to enhance its ability to command and control its forces, communicate with coalition partners, and reduce logistics inventories of stand-alone military communications systems. USTRANSCOM already uses the Internet to control its vast logistics network and to communicate with civilian logistics firms. Although the command has endured a significant number of cyber attacks, it is employing encryption technologies to decrease the risk of future information security breaches.[52] Nonetheless, USTRANSCOM may serve as an important model during the development of future C2 networks capable of exploiting foreign information grids. Exploiting the ubiquity of the Internet, moreover, may increase the agility and flexibility of operations in environments that allow US forces to connect with host-nation public information networks.

Fifth, inadequate force protection of Instant Basing personnel and equipment may limit the feasibility of Locust Swarm sustainment in future air operations. In the above scenario, the Nigerian government was able to protect Instant Basing teams. Operations in denied environments involving the significant presence of enemy ground forces and air defenses might prevent the deployment of sustainment teams. Consequently, US forces must gain access to secure areas by suppressing air defenses and clearing enemy territories of ground threats. Radar-absorbent materials, swarm techniques involving radar cross-section mimicry and rapid dispersion, and electronic warfare capabilities may enhance Locust Swarms' ability to operate in hostile environments.[53] If future Locust Swarms hold such capabilities, their use may increase the likelihood that Instant Basing teams can quickly sustain Locust Swarm operations. If not, other air and ground assets may be required until the logistics requirements of Locust Swarms can be guaranteed.

Conclusions

This scenario is intended to demonstrate a plausible conceptual framework for future air operations involving swarming RPAs, information technologies, and global logistics networks. Like current manned and unmanned weapons systems, future air vehicles will require the ability to communicate with C2 elements and will be dependent on sustainment. The Locust Swarm concept, however, may provide significant force capability with a greatly reduced logistics and C2 footprint. In the Nigeria scenario, swarms provided proportional force against Boko Haram militants by using forward-deployed Instant Basing teams and Internet connections with USAFRICOM's air operations center.

The integration of Locust Swarm and Instant Basing concepts may provide the joint force a simplified means of sustaining airpower capability. Individual Locust Swarms may provide many of the same capabilities that now require a diverse array of specialized manned and unmanned weapon systems, thus simplifying logistics support.[54] The Instant Basing logistics system may also allow Locust Swarms to operate as self-sustained combat elements far from airfields. Consequently, a force structure comprised of Locust Swarms may greatly reduce the need for numerous combat air force wings. Regardless, the availability of airfields will remain an important consideration because Locust Swarms and Instant Basing equipment are dependent on military and commercial airlift.[55] Even if Locust Swarm and Instant Basing do not precipitate force structure changes and provide opportunities for budgetary savings, these concepts are valuable because they can provide additional options to the US national leadership.

Military operations often require significant economic, military, and political capital. Military campaigns are expensive, frequently result in the destruction of US equipment, and may cost the lives of US service members. For example, military operations in Iraq, Afghanistan, and other global war on terrorism operations since 9/11 have cost the United States approximately $1.3 trillion and the lives of more than 6,400 US military service members.[56] Although Robert Kagan wrote that the American public "still sees war as an unfortunate but unavoidable fact of international life," recent polls indicate that a majority of Americans oppose the use of force in crises that do not threaten the security of the United States.[57] In 2011, 63 percent of US citizens polled opposed military operations in Libya, and in March 2012, 64 percent opposed potential actions in Syria.[58] Given these findings, it may be difficult for US policy makers to deploy US forces if the public believes that the effects of military operations fail to justify the cost.

If relatively low-cost Locust Swarms come to fruition, they may provide future administrations additional force employment options that may be more acceptable to the American public. Because Locust Swarm and Instant Basing concepts may allow rapid deployment/redeployment of airpower with minimal threat to US personnel, policy makers may have a more acceptable option to respond to emerging crises before they become politically untenable. Nonetheless, future forces of swarming RPAs will require significant institutional commitment from the Department of Defense.

Graham Allison and Philip Zelikow observed, "A program, once undertaken, is not dropped at the point where objective costs outweigh benefits."[59] However, before the perceived benefits of Locust Swarms and Instant Basing can be realized, such concepts must gain sufficient technological momentum to ensure that institutional resistance does not prevent their success.[60] As with other new technologies, swarming RPAs will require that defense personnel acquire "skill and knowledge, special purpose machines and processes, enormous physical structures, and organizational bureaucracy."[61] Furthermore, the development of Locust Swarm and Instant Basing concepts will require leaders capable of integrating emerging swarming technologies with heterogeneous elements such as existing weapon programs, doctrine, and institutional politics.[62] Thus, the success or failure of low-cost swarms of RPAs will depend on a combination of DOD RDT&E dollars and committed military leaders who can shape institutional acceptance and convince the defense establishment that Locust Swarms and Instant

Basing concepts are worthy endeavors. Such endeavors may be necessary to keep evil in the shadows.

Notes

1. Rep. Patrick Meehan and Rep Jackie Speier, *BOKO HARAM: Emerging Threat to the U.S. Homeland* (Washington, DC: House Committee on Homeland Security, Subcommittee on Counterterrorism and Intelligence, 30 November 2011), 6–7.

2. Elizabeth Leahy et al., *Shape of Things to Come: Why Age Structure Matters to a Safer, More Equitable World*, Population Action International, 2012, http://populationaction.org/reports/the-shape-of-things-to-come-why-age-structure-matters-to-a-safer-more-equitable-world/.

3. James M. Ward, "Human Population Calculator," *Metamorphosisalpha.com*, http://www.metamorphosisalpha.com/ias/population.php (accessed 24 April 2012) and CIA, "Nigeria," *World Factbook*, https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html (accessed 18 April 2011). Nigeria's projected population is based on CIA World Factbook figures from 2012.

4. CIA, "Nigeria," *World Factbook*; and Caroline Duffield, "Nigeria: 'World Oil Pollution Capital,'" *BBC News*, 15 June 2010, http://www.bbc.com/news/10313107.

5. John Pike, "Nigeria Christian/Muslim Conflict," *GlobalSecurity.org*, http://www.globalsecurity.org/military/world/war/nigeria-1.htm (accessed 24 April 2012).

6. David Blair, "Nigeria Army Claims Retaliation as 11 Boko Haram Members Killed," T*elegraph* (UK), 29 January 2012, http://www.telegraph.co.uk/news/worldnews/africaandindianocean/nigeria/9047512/Nigeria-army-claims-retaliation-as-11-Boko-Haram-members-killed.html; Andrew Harding, "Nigeria Attacks: What Boko Haram Assault Means," *BBC News*, 22 January 2012; http://www.bbc.com/news/world-africa-16672760; "Sectarian Attacks Kill 15 in Nigeria," *New York Times*, 7 January 2012, http://www.nytimes.com/2012/01/08/world/africa/boko-haram-attacks-in-nigeria-kill-at-least-13.html; Karen Leigh, "Nigeria's Boko Haram: Al-Qaeda's New Friend in Africa?," *Time*, 31 August 2011; David Cook, "Rise of Boko Haram in Nigeria," *CTC Sentinel* 4, no. 9 (September 2011): 3–5; and "Nigeria Boko Haram Attack 'Kills 63' in Damaturu," *BBC News*, 5 November 2011, http://www.bbc.co.uk/news/world-africa-15605041.

7. Robyn Dixon, "Nigeria Militant Group Boko Haram's Attacks Attract Speculation," *Los Angeles Times*, 13 September 2011.

8. Leigh, "Nigeria's Boko Haram"; and Meehan and Speier, *BOKO HARAM*, 15–16. AQIM and al-Shabaab are regional al-Qaeda–affiliated terrorist organizations that operate in Africa. AQIM's primary base of operations is Algeria and northern Mali; al-Shabaab operates from Somalia.

9. Leigh, "Nigeria's Boko Haram."

10. Cook, "Rise of Boko Haram in Nigeria," 4.

11. Blair, "Nigeria Army Claims Retaliation"; and Ibrahim Garba, "Boko Haram: Nigeria's Army Kills Nine Suspects after Attack," *Christian Science Monitor*, 21 March 2012.

12. Robert Dale, "Where Did Boko Haram Go?," *Economist*, 21 April 2017, 12–15.

13. JP 5-0, *Joint Operation Planning*, 11 August 2011, II-2.

14. CIA, "Nigeria," *World Factbook*; and Department of Energy (DOE), *Crude Oil and Total Petroleum Imports Top 15 Countries* (Washington, DC: DOE, 2011).

15. Kevin Sieff, "Afghanistan, U.S. Reach Pact on Post-2014 American Support," *Washington Post*, 22 April 2012; and Jonathan Masters, "Pentagon Pivots to Asia," Council on Foreign Relations, 6 January 2012.

16. Zachary Fillingham, "U.S. Military Bases: A Global Footprint," *Geopolitical Monitor*, 14 April 2012.

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18. Bureau of African Affairs (BAA), "Background Note: Ghana," US Department of State (DOS), http://www.state.gov/r/pa/ei/bgn/2860.htm; BAA, "Background Note: Benin," DOS, http://www.state.gov/r/pa/ei/bgn/6761; and BAA, "Background Note: Cameroon," DOS, http://www.state.gov/r/pa/ei/bgn/26431.htm (all accessed 24 April 2012).

19. "CAMEROON Airports with Runways at Least 10,000 Feet," *Acukwik.com*, http://www.acukwik.com/airports/CAMEROON/-R-/10000 (accessed 25 April 2012).

20. CIA, "Camaroon", *World Factbook,* https://www.cia.gov/library/publications/the-world-factbook/geos/cm.html (accessed 18 April 2011).

21. "GHANA Airports with Runways at Least 10,000 Feet," AC-U-KWIKAcukwik.com, http://www.acukwik.com/airports/GHANA/-R-/10000 (accessed 24 April 2012).

22. JP 5-0, *Joint Operation Planning*. See JP 5-0 for an in-depth explanation of the joint operations planning process.

23. Tirpak, "RPA Boom."

24. Locust Swarms used bandwidth comparable to MQ-1/9 aircraft. Each CAP supports four MQ-1/9 RPAs. Consequently the initial deployment of 100 Locust Swarms required 25 CAPs. Swarms operate as networks and use parallel processing to collectively prioritize tasks and targets. Locust Swarm algorithms dictate that swarms continually designate one aircraft to link with satellites or line-of-sight (LOS) equipment to ensure that swarm operators maintain control. Any aircraft has the capability to serve as a router between the swarm and control links. Bandwidth requirements were kept to a minimum since only one RPA within each swarm required satellite or LOS connectivity.

25. In case the security situation in Nigeria precluded deployment of Instant Basing teams, planners developed a contingency plan that used air-deployable tanker RPAs to provide an additional 24 hours of fuel to Locust Swarms. This contingency option would add significant cost to operations because air-deployable tanker RPAs are expendable, and their delivery requires military airlift and tanker support.

26. DOD, *Unmanned Systems Integrated Roadmap FY2011-2036*, 46.

27. Command and control of tanker and cargo aircraft was maintained in accordance with Air Mobility Command instructions.

28. CIA, "Nigeria," *World Factbook*; and Jaco Maritz, "Broadband in Nigeria: The Revolution Is Coming," *TradeInvestNigeria*, 16 March 2008, http://www.tradeinvestnigeria.com/news/276815.htm. In 2011, Nigeria had approximately 10,000 Internet service providers (ISP) and almost 1,000,000 subscribers. The majority of Nigeria's ISPs are located in its largest cities and industrial areas. ISPs used in this scenario would be vetted based on their commercial reputation, security practices, and reliability of service. Instant Basing teams would be provided a list of approved ISPs prior to operations.

29. Information Assurance Training Center, "Information Assurance Fundamentals Training," Lesson 15: Encryption and Common Access Cards (CAC)," US Army Signals Center, https://ia.signal.army.mil/IAF/IASOLesson15.asp (accessed 24 April 2012). CACs increase computer security by authenticating specific users.

30. Ibid. Use of 128-bit encryption significantly decreases the likelihood that nonapproved actors can gain access to operational information.

31. Insitu Inc., “Integrator Systems;” J. Scott Goldstein et al., *Detection of Dismounts Using Synthetic Aperture Radar* (Hanscom AFB, MA: Air Force Research Laboratory, May 2010); and “Electronic Weapons: New Foliage Penetration Radar,” *Strategy Page*, 2 March 2012, http://www.strategypage.com/htmw/htecm/articles/20120302.aspx. Synthetic aperture radars have demonstrated a modest capability to penetrate foliage and detect dismounted armed personnel.

32. “Airports in Nigeria,” *MapsofWorld.com*, http://www.mapsofworld.com/international-airports/africa/nigeria.html (accessed 25 April 2012). Eleven airfields were identified in the outline provided to President Martins. They included Abuja, Jos, Yola, Makurdi, Calabar, Enugu, Port Harcourt, Benin City, Akure, Ibadan, and Ilorin.

33. Insitu Inc., “Integrator Systems;” Goldstein et al., *Detection of Dismounts Using Synthetic Aperture Radar*; “Electronic Weapons,” *Strategy Page*; Berger, “Military Nanotechnology”; and Gartner, “Military Reloads with Nanotech.” Locust Swarm RPAs were equipped with an electro-optical visible light and infrared sensor, synthetic aperture radar, and one nanotechnology-boosted precision-guided bomb.

34. Air-refueling tankers extended the range of strategic air-lift aircraft.

35. Dong Il You and David Hyunchul Shim, "Autonomous Formation Flight Test of Multi-Micro Aerial Vehicles," *Journal of Intelligent and Robotic Systems* 61, no. 1–4 (January 2011): 321–38.

36. “Area of Responsibility,” Commander U.S. Naval Forces Europe–U.S. Naval Forces Africa, US Sixth Fleet website, http://www.c6f.navy.mil/AORPAGE.html (accessed 23 April 2012). Each Instant Basing team consisted of six swarm technicians and two security forces personnel. When deployed, each team had a seven-day supply of MREs.

37. Each Locust Swarm aircraft could operate for approximately 24 hours before refueling was required.

38. Instant Basing teams procured fuel from civilian fueling stations at their arrival airfields. Teams and equipment were delivered to each of their respective launch locations, deployed small tanker RPAs to Locust Swarms, and conducted air refueling within 16 hours. An additional eight hours was allotted for operational delays.

39. Stathis N. Kalyvas, *The Logic of Violence in Civil War* (New York: Cambridge University Press, 2006), 18; and John Mackinlay, *The Insurgent Archipelago: From Mao to Bin Laden* (New York: Columbia University Press, 2009), 182. A significant measure of state legitimacy is its ability to monopolize the use of violence within its borders. A government is best able to provide security when it can use overwhelming force against foreign and domestic enemies.

40. Small tanker-configured RPAs are similar to INSITU Integrator-type aircraft except they carry only sensors and equipment necessary for navigation, communication, and air refueling. Their remaining payload capacity is used for fuel storage.

41. USAF, “Factsheets: MQ-9 Reaper”; “Funds to Boeing, NGC to Advance UAV Aerial Refueling,” *Defense Industry Daily*; and Bigelow, “Northrop Grumman Planning First UAV-to-UAV Aerial Refueling.” MQ-9 tanker aircraft are converted MQ-9 Reaper RPAs. They hold 4,000 lbs. of fuel within internal fuel tanks and carry 3,750 lbs. of fuel in external wing-mounted tanks. MQ-9 tanker RPAs cruise at more than twice the speed of Locust Swarm RPAs. MQ-9 Reapers were gradually replaced by swarming RPAs because swarms involved more sensors and could observe more area using the same bandwidth as a single MQ-9 aircraft.

42. Instant Basing teams arriving by military airlift carried replacement munitions. Munitions required positive control by military personnel and transport by military means.

43. As an interim force management method, the AOC also considered the use of swarm exchanges. Locust Swarms operating in close proximity could be exchanged such that swarms with the greatest number of munitions provide cover.

44. See chapter 3 for a more detailed overview of how Instant Basing uses commercial logistics firms.

45. Remaining Locust Swarms and Instant Basing teams would be redeployed in the same manner as the main force.

46. US Government Accountability Office (GAO), *Defense Management: DOD Needs to Increase Attention on Fuel Demand Management at Forward-Deployed Locations* (Washington, DC: GAO, February 2009), 41. The cited figure was from June 2008.

47. US Navy, "Fact File: C-130 Hercules Logistics Aircraft," http://www.navy.mil/navydata/fact_display.asp?cid=1100&tid=500&ct=1 (accessed 29 April 2012); US Marine Corps, "KC-130J Marine Super Hercules," http://www.marines.com/operating-forces/equipment/aircraft/kc-130j-super-hercules (accessed 30 April 2012).

48. USAF, "Factsheets: C-17 Globemaster III," 27 October 2004; http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104523/c-17-globemaster-iii.aspx; and USAF, "Factsheets: C-5 A/B/C Galaxy and C-5M Super Galaxy," 15 May 2006. http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104492/c-5-abc-galaxy-c-5m-super-galaxy.aspx. In the scenario, large strategic airlift aircraft such as C-5 and C-17 cargo planes dropped the initial deployment of Locust Swarms.

49. USAF, "Factsheets: KC-10 Extender," 1 October 2003; http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104520/kc-10-extender.aspx; USAF, "Factsheets: KC-135 Stratotanker," 15 September 2004; http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104524/kc-135-stratotanker.aspx; and USAF, "Factsheets: KC-46A Pegasus," 4 May 2011. http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104537/kc-46a-pegasus.aspx. Large tanker aircraft such as KC-10, KC-135, and KC-46 aircraft were used to air-refuel cargo aircraft used in the operation.

50. More military airlift assets would have been required if global logistics companies were not available.

51. Carolyn Duffy Marsan, "10 Fool-Proof Predictions for the Internet in 2020," *Network World*, 4 January 2010, http://www.networkworld.com/article/2238913/wireless/10-fool-proof-predictions-for-the-internet-in-2020.html.

52. Carlo Munoz, "TRANSCOM Pegged as Prime Target for Cyberattacks," *BreakingDefense.com*, 28 February 2012, http://breakingdefense.com/2012/02/transcom-pegged-as-prime-target-for-cyberattacks/.

53. Cihangir Kemal Yuzcelik, "Radar Absorbing Material Design" (master's thesis, Naval Postgraduate School, 2003); and JP 3-13.1, *Electronic Warfare*, 25 January 2007. Because individual swarming aircraft are small, they may be able to fly in tight formations that mimic the radar signatures of larger civilian or military aircraft. If air defenses engage tightly formed swarms, they can rapidly disperse such that they overwhelm the tracking capability of enemy guidance systems. Furthermore, because airpower capabilities are distributed throughout the swarm, loss of a single aircraft will not significantly degrade the holistic effects that swarms may deliver.

54. See chaps. 2 and 3.

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Abbreviations

ACS	agile combat support
AEW	air expeditionary wing
AFDD	Air Force Doctrine Document
AFI	Air Force Instruction
AOC	air operations center
AQIM	al-Qaeda in the Islamic Maghreb
AWACS	airborne warning and control system
BLOS	beyond line-of-sight
C2	command-and-control
C2ISR	command and control, intelligence, surveillance, and reconnaissance
C4I	command, control, communications, computers, and intelligence
C4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
CAC	common access card
CAP	combat air patrol
CBO	Congressional Budget Office
CJCS	chairman of the Joint Chiefs of Staff
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CMOS	complementary metal-oxide semiconductors
COA	course(s) of action
CONOPS	concept of operations
CONUS	continental United States
CRAF	civil reserve air fleet
DOD	Department of Defense
EOC	early operational capability
FOL	forward operating location
FSL	forward support location
GCC	geographic combatant commander
GCS	ground control station
GS	ground stations
HET	heavy equipment transporter
IADS	integrated air defense system
ISP	Internet service provider
ISR	intelligence, surveillance, and reconnaissance
JFC	joint force commander

JOPP	joint operations planning process
JP	Joint Publication
JSA	joint storage area
LOC	lines of communication
LOS	line-of-sight
LRE	launch and recovery element
MCE	mission control element
MSC	Military Sealift Command
nm	nautical mile
NSC	National Security Council
ODS	Operation Desert Storm
OEF	Operation Enduring Freedom
QDR	Quadrennial Defense Review
RAF	Royal Air Force
RDT&E	research, development, test, and evaluation
RPA	remotely piloted aircraft
RVNAF	Republic of Vietnam Air Force
SAAS	School of Advanced Air and Space Studies
TO	technical Order
SOF	special operations forces
UA	unmanned aircraft
UAS	unmanned aerial system
USAFRICOM	US Africa Command
USTRANSCOM	US Transportation Command

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AFRI AU PRESS
Air Force Research Institute
ISBN: 978-1-58566-252-4
ISSN: 1941-3785