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14. ABSTRACT The United States has developed an impressively successful air superiority paradigm over the last century to counter nearly any adversary's manned aircraft and long-range ballistic missiles. It is even developing and using thousands of unmanned air vehicles (UAV) to reduce the risk to, and limitations of, combat aircrew. However, a Kuhnian anomaly has appeared that challenges the US air superiority paradigm: adversary UAVs. The ever-increasing pace of technological advancement is giving adversaries access to smaller, cheaper, and more capable UAVs. These UAVs, particularly the man-portable ones (mUAVs), are highly mobile, difficult to detect, and even harder to kill. Furthermore, an adversary can use off-the-shelf technology in creative ways to attack US troops or even US aircraft. This disparity between US air superiority methods and new adversary air weapons creates a capability gap the US must address. Closing this capability gap requires more than just new missiles or aircraft; it requires a paradigm shift in the way the US views air superiority. The previous symmetry which air superiority purveyors enjoyed no longer defines the entire air warfare environment. An asymmetry in air combat is emerging due to the introduction of the adversary UAV anomaly.					
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**NAVAL WAR COLLEGE
Newport, R.I.**

**Asymmetric Air Warfare:
A Paradigm Shift for US Air Superiority**

by

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Major, USAF

A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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20 May 2013

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Preface

Thousands of scholarly articles and books exist on the increasing use of “drones” in warfare. Everyone from US War Colleges to media to bloggers are discussing how the US uses (and should use) its unmanned air vehicles (UAV). To be sure, this emerging technology has many uses in warfare and presents many ethical concerns. However, very few studies exist on the impact of the worldwide proliferation of UAVs with regard to how to defend against them. The reasons for this are unknown, though a similar one-sided focus happened with the introduction of both manned air warfare and cyber warfare. This paper seeks to expand the discussion on the operational impact of the proliferation of UAVs to potential US adversaries.

Paper Abstract

The United States has developed an impressively successful air superiority paradigm over the last century to counter nearly any adversary's manned aircraft and long-range ballistic missiles. It is even developing and using thousands of unmanned air vehicles (UAV) to reduce the risk to, and limitations of, combat aircrew. However, a Kuhnian anomaly has appeared that challenges the US air superiority paradigm: adversary UAVs. The ever-increasing pace of technological advancement is giving adversaries access to smaller, cheaper, and more capable UAVs. These UAVs, particularly the man-portable ones (mUAVs), are highly mobile, difficult to detect, and even harder to kill. Furthermore, an adversary can use off-the-shelf technology in creative ways to attack US troops or even US aircraft. This disparity between US air superiority methods and new adversary air weapons creates a capability gap the US must address. Closing this capability gap requires more than just new missiles or aircraft; it requires a paradigm shift in the way the US views air superiority. The previous symmetry which air superiority purveyors enjoyed no longer defines the entire air warfare environment. An asymmetry in air combat is emerging due to the introduction of the adversary UAV anomaly.

Introduction

*Air superiority is not a birthright, nor is it easy to provide. Today's adversaries have been deterred from meeting us in the air largely due to our technological, operational, tactical, and training dominance. This is an advantage we must not sacrifice. If we can't provide the air superiority that guarantees American ground forces both freedom to attack and freedom from attack, then the way the US military currently fights on the ground will have to change. Air superiority is fundamental to the American way of war.*¹

During a future operation to capture a High Value Target, two U.S. soldiers are killed by an explosion that witnesses will say was caused by an enemy UAV. *"It flew over the hill...you could hear it buzzing around. We started shooting at it, but the thing was the size of a bird and just flew right at them. It hit the ground and exploded by the LT and Sergeant Stone. Where the hell was the Air Force? Don't we have F-22s or something?"* begs a soldier who sees the event. It will have been just over 60 years since the last US ground troops were attacked by enemy aircraft.² A week later, an E-3 Airborne Warning and Control System (AWACS) aircraft crashes on a forward-deployed air base, killing all 36 Airmen aboard. Investigators find tiny helicopter blades and electronics parts in the wreckage of the E-3 engines. An anonymous Air Force source will find a swarm of UAVs positioned in the AWACS' takeoff path caused the crash. The UAVs will have been ingested into the AWACS engines and have caused the engines to fail at a critical phase of flight.

These scenarios are hypothetical, but they show the clear and present danger the proliferation of man-portable unmanned air vehicles (mUAVs) present to the decades-long-

¹ Gen Mark A. Welsh III, interview by Strategic Studies Quarterly, transcript, Air University, Maxwell AFB, AL, http://www.au.af.mil/au/ssq/digital/pdf/winter_12/welsh.pdf.

² Peter Grier, "April 15, 1953, *Air Force Magazine*. 94, no. 6 (2011), <http://www.airforcemag.com/MagazineArchive/Pages/2011/June%202011/0611april.aspx>.

era of US air dominance.³ Chief of Staff of the Air Force, General Mark Welsh echoed the words of a century of warriors in describing the importance of air superiority to the success of future operations. For decades, US forces have fought and won command of the air, primarily via superior training, tactics, personnel, and technology. However, recent advances in computing and manufacturing have created robotic air vehicle technologies that challenge the US air superiority paradigm and are now easily available from commercial sources. The proliferation of these technologies among adversaries that cannot directly confront US airpower will create an asymmetric problem for US forces. In order to ensure the success of future operations, the US must immediately and significantly shift its air superiority paradigm to counter the threats posed by the proliferation of UAVs among unfriendly actors.

Background

To clarify the problem, it is important to describe the two major terms used in this paper *paradigm* and *air superiority*. According to Thomas Kuhn, the philosopher credited with the concept of paradigm shift, a *paradigm* is a way of thinking, or “law, theory, application, and instrumentation together.”⁴ He also notes that a prevailing way of thinking will continue, even in the face of “anomalies” that defy the existing paradigm, until a paradigm shift occurs. In this paper, the air superiority paradigm includes the definitions, uses, methods, weapons systems, concepts, theory, and doctrine surrounding US air superiority. *Air superiority* is the “degree of dominance in the air battle by one force that permits the conduct of its operations at a given time and place without prohibitive

³ A mUAV is the author’s term for man-portable UAV. A UAV, in this paper, is any air vehicle without pilot or crew onboard regardless of size. The terms *mUAV* and *UAV* both include remotely piloted aircraft (RPA).

⁴ Thomas S. Kuhn, *The Structure of Scientific Revolutions*. 3rd ed (Chicago, IL: University of Chicago Press, 1996), 10.

interference from air and missile threats.”⁵ Put another way, it “prevents enemy air and missile threats from interfering with operations of friendly air, land, maritime, space, and special operations forces, assuring freedom of action and movement.”⁶ Thus, if enemy air or missile threats interfere with operations by denying freedom of action or movement to friendly air, land, maritime, space, or special operations forces, the US cannot attain air superiority. This paper will attempt to show that this is now the case because the current US air superiority paradigm is based on countering large, high-speed, high-altitude, long-range threats, and is unprepared to address the Kuhnian “anomaly” posed by mUAVs.

A Clear and Present Danger

The frightening and deadly scenarios in the introduction are just two examples of how increasingly capable UAVs are changing the modern air battlefield. The last decade has shown a marked increase in the proliferation of UAVs throughout the world. Though the use of UAVs has been mostly by friendly forces, unopposed adversary UAVs also create an asymmetric threat capable of effective interference with friendly operations and disruption of friendly joint operational functions. The accelerating pace of technological change will also give future US adversaries easier access to smaller, more capable UAVs and further widen the asymmetry in air combat.

⁵ Chairman, U.S. Joint Chiefs of Staff, *DOD Dictionary of Military and Associated Terms*, Joint Publication (JP) 1-02 (Washington, DC: CJCS, 08 November 2010, as amended through 15 April 2013), 12; In contrast to *air superiority*, *air supremacy* is *air superiority* over the entire operational area and such that the enemy cannot create “effective interference using air and missile threats.”; Confusingly, JP 3-01 never explicitly defines *air and missile threats*. It only cursorily discusses a few examples including manned and unmanned aircraft, cruise missiles, ballistic missiles, and surface-to-air missiles. *Air and missile threats* also include anti-aircraft artillery and air-to-surface weapons, though the JP does not specifically mention them. To be sure, this paper defines *air threats* as “powered, heavier than air weapons which rely on lift to carry their weight and that may kill, destroy, or impede friendly air or surface forces.” For the purposes of this paper, *missile threats* include “ballistic missiles, air-to-surface missiles, surface-to-air missiles and cruise missiles.” These definitions do not include unpowered ballistic weapons like artillery and bullets, or powered tactical weapons like Rocket-Propelled Grenades.

⁶ Chairman, U.S. Joint Chiefs of Staff, *Countering Air and Missile Threats*, Joint Publication (JP) 3-01 (Washington, DC: CJCS, 23 March 2012), I-2.

UAV Background

UAVs have become a staple of the modern battlefield, and the UAV environment is evolving rapidly. In the last decade alone, the number of US UAVs has grown from “near zero” to over 7,000.⁷ But according to a 2012 Government Accounting Office Study, the US is not alone; from 2005 to 2012, the number of countries possessing “drones” increased from 50 to over 75.⁸ UAVs also come in all shapes and sizes, from the airliner-sized Global Hawk to palm-sized Nano air vehicles. The number of UAV mission-sets is also as diverse as their size, from ISR to strategic attack. mUAVs are not unique, however; all types of UAVs present a threat to US operations.

The Threat to Operations

Adversary mUAVs, if unopposed, pose a significant threat to US operations. Three simple scenarios show ways unopposed adversary mUAVs could interfere with US operations: 1) the slow cruise missile, 2) an enemy ISR platform, and 3) the counterair swarm.

The simplest adversary mUAV weapon is the slow cruise missile used to cause tactical damage with operational effects. Some mUAVs can carry at least 10 pounds of explosive, enough to qualify as an anti-personnel weapon. This meets the joint doctrine definition of a cruise missile, but because it is cheap, slow, and small, current counter-cruise missile planners typically dismiss it from this category.⁹ An adversary may use this weapon

⁷ Peter W. Singer, “A Revolution Once More: Unmanned Systems and the Middle East,” Brookings Institute, accessed 26 April 2013, <http://www.brookings.edu/research/articles/2009/10/11-robotic-revolution-singer>.

⁸ U.S. Government Accountability Office, *Nonproliferation: Agencies Could Improve Information Sharing and End-Use Monitoring on Unmanned Aerial Vehicle Exports* (Washington, DC: GAO, 2012), summary.

⁹ JP3-01, *Countering Air and Missile Threats*, D-6; “A [cruise missile] is a guided missile, the major portion of whose flight path to its target is conducted at approximately constant velocity and depends on the dynamic reaction of air for lift and upon propulsion forces to balance drag. CMs are unmanned, self-propelled vehicles that sustain flight through the use of aerodynamic lift over most of their flight. CMs usually navigate

to kill friendly troops on the battlefield or in-garrison, attack logistics lines, ships, C2ISR assets, and airbases, ultimately denying tactical and operational *protection, logistics, command and control, intelligence*. An adversary can also employ this capability anywhere: in friendly areas or in the US homeland. It is particularly likely during counterinsurgency, stability, and reconstruction operations when the conventional air threat is low. Tactical attacks like these will create significant operational interference by diverting friendly soldiers' attention to the air instead of their primary ground mission.

This type of threat, however, is not new. In 2006, Hezbollah sent three Ababil UAVs to attack Israel, though the Israeli Air Force shot them down.¹⁰ The same thing happened in 2012 and again in April 2013.¹¹ RAND's Ted Harshberger says "such intrusions are likely to become more common."¹² In September 2011, the FBI arrested a man in Massachusetts with an mUAV and a plan to attack the Pentagon.¹³ He was only prevented from carrying out his attack because he tried to buy explosives from undercover FBI agents.¹⁴ The mUAV cruise missile is the simplest of the ways an adversary may disrupt US operations.

Potential adversaries also use mUAVs to enable other kinetic operations. According to one Army air defense artilleryman, these are currently the biggest threat on the battlefield

autonomously to targets and, depending on their sophistication, can position themselves through a number of update methods along extended flight routes.

¹⁰ David E. Johnson, *Hard Fighting: Israel in Lebanon and Gaza*. RAND Monograph (Santa Monica, CA: RAND Corporation, 2011), 54.; The Ababil is 10 feet long and truck-launched, so it is larger, more expensive, and more difficult to acquire and operate than the hand-launched ones this paper describes.

¹¹ Michele Chabin, "Hezbollah denies sending drone shot by Israel," *USATODAY.com*, 25 April 2013, accessed 2 May 2013, <http://www.usatoday.com/story/news/world/2013/04/25/israel-hezbollah-drone/2112127/>.

¹² Ted Harshberger, "Expect More Drone Use Like Recent Israeli Episode," *The RAND blog*, 11 October 2012, accessed 22 April 2013, <http://www.rand.org/blog/2012/10/expect-more-drone-use-like-recent-israeli-episode.html>.

¹³ Kevin Johnson, "Man accused of plotting drone attacks on Pentagon, Capitol," *USATODAY.com*, 29 September 2011, accessed 22 April 2013, <http://usatoday30.usatoday.com/news/washington/story/2011-09-28/DC-terrorist-plot-drone/50593792/1>.

¹⁴ *Ibid.*

because they give away friendly position and aid enemy targeting.¹⁵ Tactically, adversaries can use ISR mUAVs to direct enemy sniper or indirect fires against US positions. They also harass navy ships and perform surveillance on US bases; in fact, the US downed an Iranian UAV in Iraq in 2009.¹⁶ But the US is not alone; Israel has shot down Hezbollah surveillance UAVs repeatedly and Russia also shot down a Georgian UAV.¹⁷ Adversary mUAVs may also challenge friendly *information operations* critical to US operations by uncovering friendly military deception (MILDEC) plans or disrupting friendly operations security (OPSEC). Though ISR UAVs may not carry weapons, their enabling role makes them a threat to US operations.

The third scenario, the swarm of mUAVs, could be used against air operations. A swarm is a group of mUAVs acting in concert toward a particular goal. An adversary can program a number of small mUAVs to takeoff, rise to a certain altitude, and stay there until they run out of power. The swarms do not have to be smart, fast, excessively persistent, or carry a weapons payload. The speed at which an aircraft travels combined with the fragility of its jet engine intakes makes it an easy target for even low-tech, stationary swarms like these. This poses the same threat to air operations as bird strikes, except the swarm is *intending* to hit the aircraft.¹⁸ Aircraft approach paths, especially in friendly (or safe) areas,

¹⁵ Maj Shawn Geib (US Army), interview by the author, 9 April 2013.

¹⁶ Rod Nordland and Alissa J. Rubin, "U.S. Says It Shot Down an Iranian Drone Over Iraq," *The New York Times*, 16 March 2009, accessed 22 April 2013, http://www.nytimes.com/2009/03/17/world/middleeast/17iraq.html?_r=0.

¹⁷ BBC News Corp, "Russia 'shot down' Georgian drone," *BBC News Online*, 21 April 2008, accessed 22 April 2013, <http://news.bbc.co.uk/2/hi/7358761.stm>; Johnson, *Hard Fighting*, 54.

¹⁸ In 1995, a flock of birds in the takeoff path of an AWACS caused catastrophic engine failure leading to the crash and loss of the aircraft and 24 crewmembers – Staff Sgt. J.D. Erhard, "Elmendorf tower, Yukla 27 Heavy has an emergency," *JBER News*, 28 September 2007, accessed 15 May 2013, <http://www.jber.af.mil/news/story.asp?id=123070056>.

are relatively fixed and vulnerable. Unfortunately, current air base defense doctrine does not mention UAVs as a threat to air operations.¹⁹

The same counterair swarm could target naval air operations or, at a higher altitude, be used as an area denial weapon in a way analogous to sea mine warfare. If an adversary can use mUAVs to threaten friendly air bases or naval flight operations, this anti-access capability denies operational reach, or *movement and maneuver*. Denying the basic power projection platforms of US airpower would create significant operational limitations. In addition to the kinetic effects of a swarm, the Airspace Control Authority will have more aircraft to track, identify, and deconflict – the difficulty of which increases exponentially with the number of airborne assets, creating *command and control* challenges.²⁰ Regarding the effectiveness of swarms, LtCol Boehm, Joint Staff/J8 Chief of Air and Missile Defense, says “quantity has a quality all its own.”²¹ This threat already exists; Iran trains to small boat swarm tactics at sea and could presumably apply the concept to air warfare. China’s PLAAF is also exploring UAV swarms to disrupt US air operations.²² mUAVs also threaten joint *intelligence* because their operational mobility and diminishing size make it nearly impossible to assess enemy mUAV numbers, capabilities, and locations using traditional capabilities like overhead imagery. These scenarios are based on currently available systems,

¹⁹ Chairman, U.S. Joint Chiefs of Staff, *Joint Security Operations in Theater*, Joint Publication (JP) 3-10 (Washington, DC: CJCS, 3 February 2011), Chapter IV.

²⁰ This is especially true of UAVs which do not follow the manned aircraft tracking construct – they do not takeoff and land from airbases or carriers, they are too small to see on RADAR, they do not have IFF, and they do not have a pilot to make coordination decisions while airborne. These characteristics create technical challenges that the US can overcome, but not in a rapid manner.

²¹ LtCol John Boehm (Chief, Air and Missile Defense, Joint Staff/J8 JIAMD), e-mail message to author, 17 April 2013.

²² Roger Cliff et al., *Shaking the Heavens and Splitting the Earth: Chinese Air Force Employment Concepts in the 21st Century*. (Santa Monica, CA: RAND Corporation, 2011), 103, accessed 22 April 2013, <http://www.rand.org/pubs/monographs/MG915>.; Peter W. Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-First Century* (New York: Penguin Press, 2009), 245.

and technological improvements will only increase the diversity and capabilities of the future UAV threats.

Better, Smaller, Cheaper

The capabilities of modern mUAVs are improving exponentially. Technology is driving down cost and increasing access to more potential adversaries, further widening the asymmetry in air warfare. Moore's Law states microchip power will double approximately every eighteen months to two years.²³ Kurzweil's Law of Accelerating Returns posits this exponential increase applies to technology in general, not just microchips.²⁴



Figure 1. \$50 MeCam²⁵

²³ Paul E. Ceruzzi, "Moore's Law and Technological Determinism: Reflections on the History of Technology", *Technology and Culture*. 46, no. 3 (2005), 584-593, accessed 19 May 2013, http://muse.jhu.edu/journals/technology_and_culture/v046/46.3ceruzzi.pdf.

²⁴ Singer, *Wired for War*, 99-100.; Dr. Peter Singer, director of the Center for 21st Century Security and Intelligence at the Brookings Institute, says this accelerating change is what makes modern bombers approximately 500 times more lethal than those in World War II and half a million times more lethal than foot soldiers of the Roman era.

²⁵ AlwaysInnovating, MeCam product website, accessed 19 May 2013, <http://www.alwaysinnovating.com/products/mecam-photos.htm>.

Many potential adversaries use off-the-shelf technology in creative ways, so their effective development timeline keeps pace with technological advancement, while the US procurement cycle often lasts decades.²⁶ Also, now that aircraft are unmanned, the greatest factor driving up their size and cost – the human body – is no longer a factor.²⁷ Consider the capabilities of a \$500 iPhone™ – GPS, compass, pressure sensor, accelerometers, more computing power than many modern warplanes, wireless communications, and a camera – all in the size of a deck of cards. With wings and an engine (or rotors), this has all the capabilities of a modern tactical reconnaissance aircraft. If one adds a few pounds of explosive or worse, sarin gas or a radiological payload, this becomes a cruise missile. Hundreds of companies sell “drones” to amateur enthusiasts for \$500-\$1000. Furthermore, websites like DIYdrones.com show how to buy, build, equip, and modify these UAVs for various purposes.²⁸ Some UAV makers are going even smaller and cheaper; Figure 1 shows a hand-sized copter with a price tag of approximately \$50. The mission planning software is also free, open source, and available on the internet.²⁹ An amateur even built a UAV that flew across the Atlantic Ocean ten years ago.³⁰

Today’s technological environment gives any potential adversary the ability to acquire the capability to interfere with US operations without the expense or difficulty of acquiring and operating symmetric weapons technology. Friendly operations are in jeopardy from these threats unless the US can counter them.

²⁶ Steven Metz, quoted in Singer, *Wired for War*, 240.

²⁷ *Rise of the drones*. (United States: PBS Distribution, 2013), DVD-ROM.

²⁸ Do-it-yourself Drones, website, accessed 22 April 2013, <http://www.diydrones.com>.

²⁹ Ardu-pilot mega, open source software repository, accessed 22 April 2013, <https://code.google.com/p/ardupilot-mega/wiki/Mission>.

³⁰ Singer, *Wired for War*, 270.

Air Superiority In Danger

*Negating a UAS/UAV through traditional counterair methods is like swatting a fly with a hammer...*³¹

The existing US air superiority paradigm is inadequate to counter mUAVs, despite the threat they pose to US operations. This paradigm, optimized to counter high-speed, high-altitude manned aircraft and ballistic missiles, has been immensely successful to date. However, mUAVs create an asymmetric threat to US air superiority because these small aircraft exploit weaknesses in the system. The four main methods of countering air and missile threats: Counter-proliferation, Offensive Counterair (OCA), and Active and Passive Defensive Counterair (DCA), are currently inadequate to counter the emerging threat.

The Current Paradigm

The US air superiority paradigm is an expensive and lumbering Mahanian 20th century warfare architecture which seeks to maintain a “big-battle” technological advantage over other states, clear the battlespace via kinetic destruction of enemy forces, and defend rear areas from long-range enemy threats.³² The technological advantage comes in two ways: 1) the powerful US military-industrial complex leads the arms race of expensive, highly-capable weapons systems which potential adversaries struggle to challenge and 2) counter-proliferation methods like treaties, agreements, and sanctions attempt to prevent potential adversaries from gaining advanced weapons technologies. The US typically begins the conflict through Offensive Counterair (OCA) and other air attacks to destroy and weaken enemy capabilities to conduct air and surface operations, thus enabling freedom of action for friendly air and surface forces. The opening weeks of “shock and awe” during DESERT STORM, ALLIED FORCE, and IRAQI FREEDOM are examples. During the conflict,

³¹ Boehm, e-mail message.

³² Singer, *Wired for War*, 229.

friendly fighter aircraft, SAMs, and C2ISR systems defend rear areas and naval assets against long-range enemy attacks through DCA operations. All of these methods are optimized for state-vs-state warfare characterized by AirLand Battle concepts of friendly and enemy territory. Even though the new AirSea Battle concept seems to stress the importance of basing access, much of its effort seems focused on countering long-range anti-access capabilities like ballistic missiles. Despite the many kinetic methods to counter enemy air and missile capability, the first step is counter-proliferation.

Counter-proliferation Challenges

Decreasing costs make mUAVs an attractive asymmetric airpower option for potential US adversaries and ineffective counter-proliferation efforts give our enemies greater access to these technologies. Two intergovernmental organizations exist which specifically aim to reduce proliferation of mUAV-type technologies: the Missile Technology Control Regime (MTCR) and the Wassenaar Arrangement. The MTCR is the “primary mechanism” for cruise missile and UAV counter-proliferation, but as of April 2012, only 34 countries are partners and the MTCR has no enforcement mechanism, only trade agreements.³³ Like the MTCR, the Wassenaar Arrangement only has 41 members and has problems gathering consensus on technology limits and sensitive information sharing.³⁴ The ineffectiveness of these counter-proliferation mechanisms leaves only OCA and DCA available to counter adversary mUAVs.

³³ Missile Technology Control Regime, Introduction, accessed 22 April 2013, <http://www.mtcr.info/english/index.html>.; The MTCR “is an informal and voluntary association of countries which share the goals of non-proliferation of unmanned delivery systems capable of delivering weapons of mass destruction, and which seek to coordinate national export licensing efforts aimed at preventing their proliferation.”; Igor J.P. Gardner, “Theater Land Attack Cruise Missile Defense: Guarding the Back Door” (research paper, Air University, School of Advanced Air and Space Studies, Maxwell AFB, AL, 1999), 39, accessed 23 April 2013, <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA391828>, Available as Defense Technical Information Center Report (DTIC) ADA391828.

³⁴ The Wassenaar Arrangement, Participating States, accessed 22 April 2013, <http://www.mtcr.info/participants/index.html>.; GAO, *Nonproliferation*, 20.

Offensive Counterair

OCA against MUAVs is a difficult task due to their tactical and operational mobility. The goal of OCA is to “destroy or disrupt [air and missile threats] prior to launch” through the Find, Fix, Track, Target, Engage, Assess (F2T2EA) targeting process.³⁵ “Finding and fixing” these MUAVs prior to launch is a nearly impossible task because they may not be stored or launched from a fixed location.³⁶ The hunt for large SCUD missiles during Operation DESERT STORM shows how difficult mobile launch-sites are to find and destroy – the coalition flew 1,460 sorties, but destroyed 0 (zero) SCUD missiles before launch.³⁷ The small size and difficulty of detection give an adversary the operational reach to deploy MUAVs anywhere their supporters exist, in enemy or friendly “territory.” Tracking and targeting may also be futile because the time between mUAV launch and its attack maybe shorter than the targeting cycle timeline.

The other OCA missions, Fighter Escort and Fighter Sweep, are currently ineffective against mUAVs due to weapons system limitations and the mUAV’s operational mobility. The small size, small RADAR cross-section, low infrared signature, and low-slow flight profile make air-to-air combat against small mUAVs difficult for traditional counterair fighters.³⁸ Traditional air-to-air fighters must also be close enough (and low enough) to find, identify, and engage the mUAV before it attacks the defended asset – an unlikely scenario as

³⁵ JP3-01, *Countering Air and Missile Threats*, xviii.; U.S. Air Force, *Targeting*, Air Force Doctrine Document (AFDD) 3-60 (Washington, DC: Department of the Air Force, 8 June 2006, incorporating Change 1, 28 July 2011), 49, accessed 23 April 2013, <http://www.au.af.mil/au/lemay/main.htm>.

³⁶ Jeff Kueter and Howard Kleinberg, *The Cruise Missile Challenge: Designing a defense against asymmetric threats*. (George C. Marshall Institute, 2007), 30, accessed 22 April 2013, <http://www.marshall.org/pdf/materials/522.pdf>; Singer, *Wired for War*, 221.

³⁷ Gardner, “Cruise Missile Defense,” 53.

³⁸ Col Michael S. Perkins, USMCR, “Joint Counterair and Theater Missile Defense Doctrine to Defend Against Unmanned Aerial Systems and Cruise Missiles in Asymmetric Warfare” (research paper, Air University, Air War College, Maxwell AFB, AL, 2009), 8.; “Both UASs and Cruise missiles present a difficult targeting solution due to their small radar cross section, and low infrared signatures.”; Author; Airborne pulse-doppler RADAR is nearly useless against small, slow, low-altitude targets because it is designed to filter things like cars and birds out to declutter the pilots’ RADAR systems.

the number of friendly fighter assets dwindle.³⁹ Even if the fighter is able to find, identify, and target the mUAV, its weapons are only marginally effective against such small, slow targets. Missiles and explosive cannon rounds also pose collateral damage issues over urban environments where a significant portion of recent US fighting has taken place. Also, the 12-foot long, Mach 3+ AMRAAM, the US's primary air-to-air missile, costs over \$350K USD and gives an asymmetric cost advantage for the adversary even if the missile successfully engages the target.⁴⁰ Though the US, Israel, and Georgia have recently shot down adversary UAVs, these larger UAVs had wingspans of approximately 20 feet and speeds of about 150 knots, very different from small mUAVs that fly between 0 and 50 knots. These OCA limitations, however, are only part of the reason the current US paradigm is ineffective.

Defensive Counterair

DCA contains "active" and "passive" air and missile defense.⁴¹ Passive DCA seeks to minimize the effects of a successful enemy air or missile strike through hardening, redundancy, and survivability efforts. Active DCA seeks to destroy the enemy threat before it reaches its friendly target. Current DCA capabilities, however, are inadequate to counter the new mUAV threat.

Active DCA includes "active air defense and ballistic missile defense" and uses the same OCA air-to-air weapons systems and adds surface-to-air capabilities.⁴² Surface-to-air missiles like Stinger, and Ballistic Missile Defense (BMD) systems like PATRIOT, Aegis, and THAAD also have limited, though some, capability against small, slow MUAVs.⁴³

³⁹ As an example, if the enemy launches the UAV from a short distance from the target like inside an urban area, the fighter aircraft will not likely have the appropriate position or time to complete the engagement.

⁴⁰ US Air Force, AIM-120 AMRAAM fact sheet, accessed 19 May 2013, <http://www.af.mil/information/factsheets/factsheet.asp?id=79>.; Advanced Medium Range Air-to-Air Missile.

⁴¹ JP3-01, *Countering Air and Missile Threats*, I-3.

⁴² Ibid.

⁴³ Theater High Altitude Air Defense

Recently, systems like Counter-Rocket And Mortar and Close-In Weapon System have demonstrated the ability to destroy small targets, but these systems are fixed to ground stations or Navy vessels.⁴⁴ This fixed-site limitation also applies to emerging defenses like the Navy's Laser CIWS that recently shot down a UAV in a controlled test.⁴⁵ The Marine Corps Development Command is also seeking to purchase truck-mounted laser weapons to counter UAVs, but the program announcement only requires one "shot" per 20 minute recharge time and would be limited to approximately 4 miles due to line-of-sight limitations.⁴⁶

In addition to limited engagement capabilities, these methods do not solve critical challenges in air warfare: identification and fires de-confliction. Manned aircraft (and some large UAVs) carry Identification, Friend or Foe (IFF) devices, follow procedural identification methods, and have characteristics that allow identification both beyond- and within-visual range. mUAVs generally do not meet any of these conditions. Though a fratricide (friendly fire) incident against a friendly mUAV may not directly kill anyone, it will certainly hinder the mUAV's associated operations and may pose an indirect threat to friendly personnel. Collateral damage will also be a problem if a fighter fires a missile at a mUAV flying over a city. Destroying targets while airborne, however, is not the only way to limit their negative effects.

⁴⁴ Singer, *Wired for War*, 39.; CRAM costs \$75M.

⁴⁵ Naval Sea Systems Command Public Affairs, "Navy Laser Destroys Unmanned Aerial Vehicle in a Maritime Environment," accessed 23 April 2013, http://www.navy.mil/submit/display.asp?story_id=53705.

⁴⁶ Office of Naval Research, "Ground-Based Air Defense Directed Energy On-The-Move" Special Program Announcement 13-SN-0014 (2013), accessed 19 May 2013, <https://www.fbo.gov/utills/view?id=11c689ee633c9b8f3d4b6679aa8f6395>.; The range in the example assumes a UAV at 100 feet with no terrain masking except earth curvature.

Passive DCA operations limit the effect of an air or missile attack if OCA and active DCA fail.⁴⁷ For highly mobile assets like aircraft, however, these passive methods are less feasible. The speeds of modern aircraft generate enough kinetic energy that hitting a stationary mUAV, even a tiny one without any explosive, may damage or destroy the aircraft. Large, sluggish aircraft may be unable to avoid mUAVs in flight, even if they can detect them. Also, despite its effectiveness for protecting fixed targets, Passive DCA receives far less effort from air defense planners than OCA and Active DCA.⁴⁸

Unfortunately, the US air superiority paradigm is woefully inadequate to defend against enemy mUAVs because the weapons systems and tactics the US uses to gain air superiority are unable to counter mUAVs. This ineffectiveness is caused by the emergence of an anomaly in the air superiority paradigm.

The Paradigm Shift

*Anomalies are initially ignored by the dominant community of practitioners [because] they are slow to realize that the normal and cherished paradigm has been invalidated or challenged by a new development or a new realization.*⁴⁹

Thomas Kuhn describes the basis for a paradigm shift as an “anomaly” that challenges the existing paradigm.⁵⁰ Previous military paradigm shifts have occurred with the introduction of the Japanese *kamikaze*, nuclear weapons, and cyber warfare. To shift the air superiority paradigm, the basic theory and mindset of US air superiority must expand from a

⁴⁷ JP3-01, *Countering Air and Missile Threats*, I-3.; Passive air and missile defense includes “Detection and warning, Chemical, biological, radiological, and nuclear defenses (CBRN), Camouflage, concealment, and deception (CCD), Hardening, Reconstitution, Dispersion, Redundancy, Mobility.”

⁴⁸ Boehm, e-mail, 10 May 2013.

⁴⁹ Col Timothy P. Schultz, Ph.D, (Strategy and Policy Department, U.S. Naval War College), e-mail message to author, 15 May 2013.

⁵⁰ Kuhn, *Structure of Scientific Revolutions*, 62.; “. . .the characteristics common to the three examples above are characteristic of all discoveries from which new sorts of phenomena emerge. Those characteristics include: the previous awareness of anomaly, the gradual and simultaneous emergence of both observational and conceptual recognition, and the consequent change of paradigm categories and procedures often accompanied by resistance.”

geographically-based focus on traditional air and missile combat to a threat- and platform-based one that includes “asymmetric” mUAV threats.

In *Counterair and Counterland*, Col Ellwood Hinman writes, “in a large air force with plentiful fighter wings and a plethora of fighter aircraft, unrivaled control of the air [in the JOA] may be possible.”⁵¹ This statement has two points relevant here: one, current air superiority thinkers still view air superiority through a traditional fighter combat lens and two, gaining air superiority over a large area is contrary to the principle of economy of force. In its section on air superiority, the 2013 USAF Posture Statement echoes this mindset on traditional fighter combat; it includes three weapons systems, the F-22, F-35, and F-15, none of which have significant capability against mUAVs.⁵²

Colonel Hinman proposes a positive, but slight, vector change to shift from seeking generalized air supremacy over the JOA to one in which the JFC has varying degrees of air control over the JOA – see Figure 2. However, the JFC must further discard the joint doctrine idea that air superiority is a one-dimensional “degree” on a scale of air control to a multi-dimensional condition, the dimensions of which include not only time and space, but also the type of force and the force needing protection. Air superiority is not something to be applied or identified on a map, it is a condition to be attained through the proper management of the differing dimensions of friendly and enemy force and determined by whether friendly assets have effective protection from a certain threats at certain times in certain places.

⁵¹ Col Elwood P. Hinman IV, "Counterair and Counterland: Concepts for the 21st Century." (Joint Force Quarterly, Winter 2006), 86.

⁵² Hon. Michael B. Donley and Gen. Mark A. Welsh III, House, *Presentation to the Committee on Armed Services: Fiscal Year 2014 Air Force Posture Statement. 113th Cong., 1st sess, 2013, 6.*

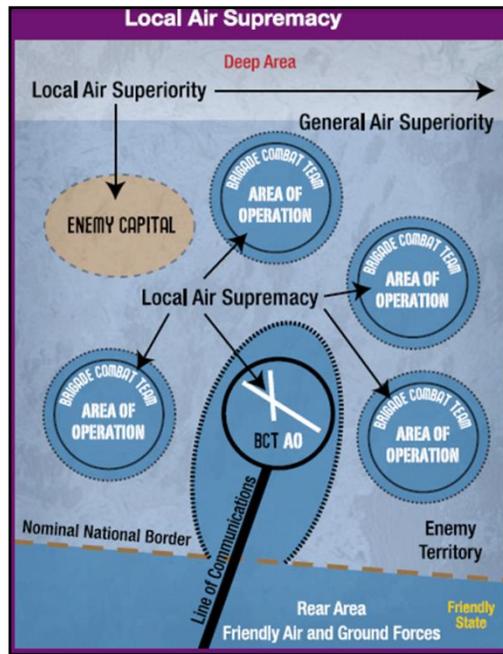


Figure 2. Hinman’s “Varying degrees of air control”⁵³

Historical air and missile threats include ballistic missile threats and enemy aircraft that the JFC could address as a “boundable” problem. The mobility of the mUAV threat means this is no longer the case. Because adversary missiles typically target stationary locations, mostly due to limited capabilities, the JFC could place the protective counter-ballistic missile bubble like PATRIOT around these “defended assets” and have freedom from missile attack and some air attack. To defend static locations from air attack, he would conduct OCA operations against enemy airfields and SAMs and assign fighter aircraft to protect friendly locations. Friendly fighter aircraft are also highly mobile, so they can also protect mobile surface forces as they move. However, the high mobility of mUAVs “unbounds” the air threat problem and creates a capable fleet-in-being which the US must now address.

⁵³ Hinman, “Counterair and Counterland,” 89.

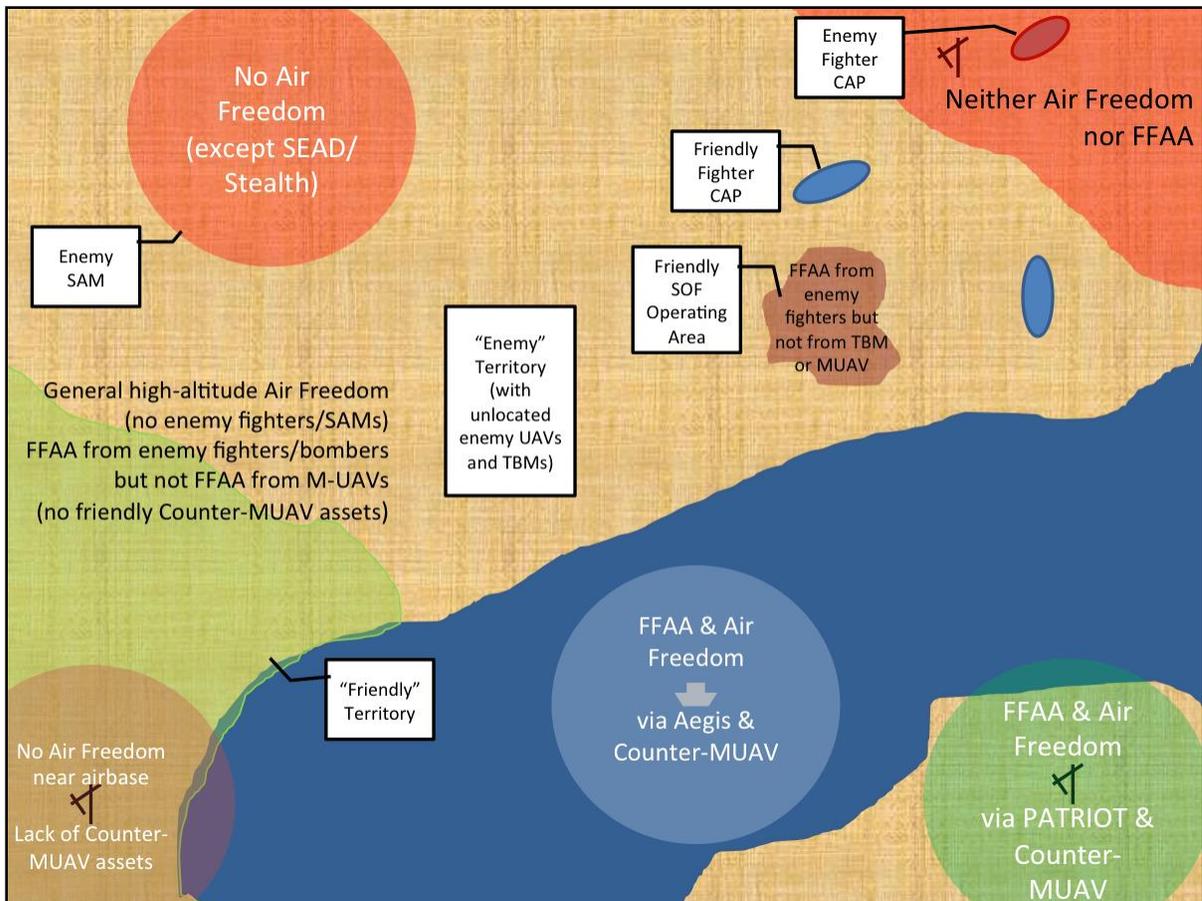


Figure 3. JOA Air Superiority Diagram

Operational air superiority is attained when friendly forces meet two conditions: *freedom from air attack (FFAA)* and *air freedom*. These two conditions should be measured per friendly asset against separate enemy threats as the simplified illustration in Figure 3 shows. An accurate depiction of a JOA will be much more complicated, even complex. This amplifies the point that air superiority should not be measured purely by time and space.

Freedom From Air Attack

To ensure *freedom from air attack* – the ability of friendly surface forces to conduct operations without prohibitive interference from threats in the air – the JFC must switch from a mindset that “gains” freedom from air attack over a large geographic area to one that “ensures” freedom from air attack through decentralized defenses. However, traditional air

and ballistic missile threats still exist, so current counterair efforts should continue, but the architecture should expand to include the asymmetric mUAV threat. The JFC must close the counter-mUAV capability gaps via the short-term Joint Urgent Operational Need (JUON) and long-term Integrated Priority List (IPL) process.⁵⁴ The capability gap will also drive a reassessment and planning mitigation of operational risk while awaiting JUON and IPL solutions. Even when these solutions arrive, incorporation into tactical and operational training exercises will increase operator familiarity, validate capabilities, and generate lessons learned.⁵⁵ It is likewise important to explore further theory and doctrinal implications of the asymmetric mUAV threat via staff, think tank, and war college studies and war games. Similar changes are also necessary to enable *air freedom*.

Air Freedom

To gain and maintain *air freedom* – the ability of friendly air forces to conduct operations without prohibitive/effective interference – the JFC should assess the tactical safety of aircraft, air bases, and air lines of communication (ALOCs) based on all threats, including mUAVs. Air superiority planning and risk assessment must now include the

⁵⁴ Some solutions for *freedom from air attack* capabilities must include wide-area surveillance systems with distributed, decentralized nodes for detection, identification, and engagement. The solutions must be mobile enough to travel with the tactical units they protect. This is easier on fixed locations like bases and ships, but more difficult on ground maneuver units. The high mobility required for these engagement systems means large, heavy systems like PATRIOT or even C-RAM must make way for man-portable counter-mUAV weapons. Laser weapons and such high-tech, high-cost devices may work against mUAVs, but so would a long-range version of a shotgun, provided the unit is targeted by a detection and identification system. The surveillance and identification nodes should directly feed the decentralized targeting and engagement systems. Targeting and engagement for reactive defense must happen at the unit level, not at an Air Operations Center, to complete the defensive engagement in time. Decentralization also increases ambiguity in identification, so to mitigate the possibility of fratricide, planners must create procedural deconfliction between friendly tactical counter-mUAV units and manned and unmanned aircraft. Due to the high risk of fratricide, the AADC often retains engagement authority for friendly surface-to-air units. As threat mUAV mobility and numbers grow, however, decentralized decision-making will be required to react fast enough to neutralize certain threats.

⁵⁵ Operational and tactical exercises must include real or simulated adversary mUAVs as threats to both air operations and surface forces. These exercises, along with daily training, will help prepare tactical operators to counter the threat. It will also enable operational planners and operators to identify capability gaps and risks to operations for incorporation into risk assessment and JUON/IPL requirements.

possibility that highly mobile, unlocated mUAVs can affect air operations, even in friendly rear areas.⁵⁶ The JFC's JUON and IPL capability requests should incorporate both ground-based and airborne systems for real-time swarm threat avoidance and/or neutralization, similar to existing bird and weather hazard avoidance systems. Also, operational *air freedom* theory and doctrine, like *freedom from air attack*, should be studied by academic and staff organizations. Finally, it is important to train operational planners and tactical operators against the mUAV threat to *air freedom*.

Tactical air superiority experts are intimately familiar with mission-specific, threat-based *air freedom* and *freedom from air attack*. However, operational air superiority planners sometimes mistakenly scale these concepts to large geographical areas. Though this has been successful given the historically limited scope of air and missile threats, the mUAV threat environment makes it no longer feasible or economical.⁵⁷ Many adversaries, however, still possess significant "legacy" air and missile threats. Thus, the new US air superiority paradigm should not shift away from traditional counterair efforts, but should instead expand to address both traditional and emerging threats.

Conclusion and Recommendations

Rapidly evolving mUAV technology and its resulting proliferation creates a clear and present danger to US air superiority. The impressively successful US air superiority

⁵⁶ Procedural *air freedom* improvements include modifying flight schedules, altitudes, and takeoff and landing profiles to reduce the adversary counterair mUAV swarm threat around air bases. Air planners already use combat departures and arrivals to lessen the adversary MANPAD (and bird) threat and should consider the mUAV swarm threat similarly.

⁵⁷ In an analogy to sea control, Corbett countered Mahan's close-escort theory by noting most privateering losses during the revolutionary war occurred near choke points because the privateers could not effectively operate in the open ocean. For now, the limited range of man-portable UAVs is analogous to the limited range of privateers. As a short-term mitigation, this concept will apply to *air freedom* in terms of air base and carrier defense, but as the range and capability of UAVs increase, embedded counter-UAV protection for aircraft will become necessary, as evidenced by the success of convoys during the Battle of the Atlantic against German U-boats.

paradigm evolved to face a Cold War-style threat, but it is not prepared for the threat mUAVs pose to US operations. Though current fighter aircraft and BMD systems are highly capable against their intended threats, they are incapable of effectively countering small, highly mobile mUAVs. If adversary mUAVs can slip past US counterair assets, they can create effective interference with operations and challenge US air superiority. Though this may seem hypothetical, the threat is real.

State and non-state actors like China, Iran, and Hezbollah are exploring or have used UAV technology to exploit vulnerabilities in US air superiority capabilities. The decreasing cost and increasing availability of mUAVs provide asymmetric options to other historically weaker adversaries. Previously, asymmetry was limited to surface warfare due to the high costs of airpower and the limits on weapons proliferation. However, mUAVs are now available for as little as \$50 USD and are not necessarily considered weapons so counter-proliferation efforts like the MTCR and Wassenaar Agreement are ineffective. The proliferation of and desire to use mUAVs create a current and capable threat to US operations.

To maintain its current trend of air superiority, the US must shift its legacy paradigm to address new UAV threats while maintaining the capability to counter traditional air and missile threats. Future air theory and doctrinal studies on the asymmetry posed by mUAVs are required to facilitate the paradigm shift. Also, US air superiority purveyors and customers must recognize, understand, and respect the mUAV threat to operations. The JFC must attain capabilities to detect, identify, and neutralize enemy mUAVs and incorporate these capabilities into tactical and operational training. If the US acknowledges the threat and shifts its air superiority paradigm, it may be able to keep its recent record of air dominance. If not,

the 60-year era in which US ground forces have enjoyed freedom from air attack and the decades-long era of US air dominance will both come to an end.

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