Foreign Policy
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Access Assured

Addressing Air Power Reach, Persistence and Fueling Limitations for Contested and Permissive Air Operations

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CONTENTS

Page

PREFACE

25,000 feet over the Pacific, two KC-46 tanker aircraft fought for their lives. A determined attack was under way as two regiments of MiG-35 interceptors rocketed through the sky toward them. The E-3 airborne warning and control system (AWACS) controllers were calling for help, which both distracted the coalition strikers from their attack and stripped fighters from other missions. As the MiGs came east at over a thousand miles per hour with heavy jamming support, American F-22 Raptor and Japanese F-3 Shinshin jets converged on the threat, filling the sky with missiles. It was not enough. When the MiGs got within 60 miles, the tanker aircraft stowed their booms and dove for the deck. The coalition fighters and strikers deep inside enemy territory were on their own. For the first time the enemy had achieved air superiority over a major battlefield merely by eliminating a pair of logistics planes…

This passage may read like a modern-day thriller, but it is actually paraphrased from *Red Storm Rising*, Tom Clancy's 1986 bestseller. The Cold War-era novel described how World War III might befall but did not envision the stand-off ranges of today's threats to air power assets. After updating the fighters, integrating the future American aerial refueling tanker, and then transporting them halfway around the world, this rewrite illustrates a potential single point of failure for U.S. power projection and the strategy of conventional deterrence.

This past year I was fortunate to have the opportunity to read, reflect, question, listen, and learn from some of the brilliant experts at the Brookings Institution. The Federal Executive Fellowship provided a tremendous experience in my professional development as well as my personal growth. One of the outcomes is this paper which I hope will apply lessons learned from the past with concerns about the challenges of the future.

My selection for the FEF program would not have been possible without the strategic vision of Rear Admiral Michael Smith, whom I never personally met but to whom I am truly grateful for his advocacy of developing a cadre of strategic thinkers within the Navy. Pushing that vision even further with the Navy Strategic Enterprise was the former president of the U.S. Naval War College, Vice Admiral Walter "Ted" Carter (who courageously climbed into the backseat of a Tomcat with this writer at the controls when I was a clueless flight student at Fightertown, USA). Fortunately for the Navy officer corps, he is the ideal leader to continue fostering strategic thought as superintendent of the U.S. Naval Academy. I am grateful for his effort to not only teach me how to fly the big fighter but for his support of my fellowship at Brookings. Providing the persistence to see their vision through, Matt Danehy and Eric Gunn remain the champions of the naval strategist and are worthy strategists themselves.

Alan Syslo and Jack Eaves also deserve recognition for bearing the administrative burden of corralling a group of prima donnas who disappeared from the Navy to ponder deep thoughts in the hallowed halls of think-tanks and universities across the United States and Oxford. I enjoyed the discussions and friendships developed among those prima donnas: Bobby Baker, Clay Beers, Ed Grohe, Paul Movizzo, Tuan Pham, Tim Urban, Dan Malatesta, Mark Hooper, Chris Mussleman, and my fellow Brookings fellow Rob Debuse. Special thanks go out to Jim "Dr.J" Holmes for his encouragement of my academic pursuits in addition to his own insightful musings on Navy strategy. Three other Navy officers played a key role in helping me craft this paper: Peter Swartz was a daily fire-hose of research material and offered critical improvements to the final product; Greg Harris kindly offered his time to critique my ideas and keep me within bounds; and Greg Malandrino brought a current operator's perspective to a desk-jockey.

At Brookings I was frequently in awe of the experts and their CV's. Luckily I was surrounded by a group of FEFs whose honorable service to our nation was only exceeded by their welcoming nature: Ken Ekman, Johnnie Johnson, Tom King, Krista London Couture, and my naval officemate, jarhead / leatherneck extraordinaire, Aaron Marx. Our daily interactions helped shape my thoughts on the broad issues affecting our national security as well as specific points in this paper. Rounding out our office space were some gifted young fellows and research assistants who will be our future foreign policy leaders: Emerson Brooking, Ariana Rowberry, and James Tyson. I was truly impressed with their intellectual maturity and insights.

The Foreign Policy Program and the Center for 21st Century Security and Intelligence were a who's who of policy gurus. Steven Pifer, Robert Einhorn, Richard Bush, Charlie Ebinger, Vanda Felbab-Brown, Daniel Byman, Clifford Gaddy, Fiona Hill, Tanvi Madan, Marvin Kalb, Bruce Riedel, Will McCants, Jonathan Pollack, Tom Wright, Ian Wallace, and Harold Trinkunas all made it easy to step out of a flight suit and into a business suit. Fortunately ties were optional. Ted Piccone was especially gracious as the acting program director who made a significant effort to engage the FEFs as part of the Brookings FP team.

I am especially grateful to three geniuses. Mike O'Hanlon, besides being the most prolific writer on national security issues, was also the most gracious host. Regardless of our expertise, Mike always included the FEFs in every event, every conversation and would always ask for, and respect, our opinions regardless of how outlandish they might have been. Peter Singer was an enthusiastic leader who played the most significant role in developing the FEF program at Brookings. His generous devotion of time and intellectual capital personally helped me focus on a critical but underserviced topic as only someone with his conceptual understanding of defense issues could. If anyone deserves the credit for the quality and impact of this paper, it is him; on the other hand, if the paper is totally lame, he might have to give up on his academic works and venture into some frivolous fiction writing. Last but not least, I cannot say enough

good things about Brendan Orino, who managed our FEF program. His dedicated behind-the-scenes efforts to all things 21CSI were rarely visible but always valuable. Though he couldn't understand the significance of Gilgamesh to A2/AD, his critical eye and personal touch on this paper were crucial and his labor over footnotes and bibliographies was heroic. The State Department will be very fortunate if he decides to become a Foreign Service officer. I am honored to call these three gentlemen friends.

I am sure I am forgetting somebody, but this is starting to read like an Oscar acceptance speech. Oh yeah, my father Ron and his old Marine buddy Chet Mottershead, whose sea stories brainwashed me into joining the military service. I hear the music cue…

EXECUTIVE SUMMARY

In any future strategic environment, air power will be a critical component of the U.S. military strategy. However, U.S. air power faces deep constraints in two divergent areas: range limits in contested airspace and persistence limits in permissive airspace. While the issues of fuel and refueling have not received as much attention as the growth of advanced threats to air assets, their combination threaten to undercut the effectiveness of future air operations and access into potentially denied airspace. At the other end of the combat spectrum, air supremacy in uncontested airspace allows the potential for greater persistence in providing crucial intelligence, surveillance, and reconnaissance, which similarly relies on the sustainment of fuel resources.

Bisecting the future operating environment into distinct domains, contested and permissive airspace, this paper seeks to address the impact of current range and persistence limitations in conjunction with fuel and refueling resources. To meet the range requirements in contested airspace, the Department of Defense (DOD) should mitigate existing vulnerabilities relative to potential threats to ensure not only a credible conventional deterrent, but when necessary, the ability to project power against a progressive adversary. In achieving persistence requirements in permissive airspace, the DOD should evaluate greater efficiencies in providing longer endurance options.

The following recommendations are submitted to address these challenges.

Range limitations in contested airspace:

1. Increase survivability of airborne refueling tanker aircraft;
2. Plan for defense of tanker aircraft in the same manner as other high value airborne assets;
3. Incorporate tactical airborne refueling connectors using current inventory of manned aircraft;
4. Develop tactical airborne refueling connectors leveraging unmanned aerial systems;
5. Ensure that the Requests For Proposals for next air systems address both combat capability and radius to achieve the necessary reach dictated by the assessed threats in the future operating environment.

Persistence inefficiencies and endurance limits in permissive airspace:

6. Acquire a long-endurance, self-sustaining air system that does not require refueling.

CHAPTER ONE
Introduction

Since Lieutenant Frederick E. Humphreys first took to the skies, modern warfare has been critically dependent on fuel.[1] In 2012 (FY12), the Department of Defense (DOD) consumed 4.368 billion gallons of fuel.[2] To put this in perspective, American Airlines' fuel consumption for its entire global operations was just 2.756 billion gallons in 2011.[3] And while the air, land, and sea domains of warfighting all rely on fuel, no community is more dependent than aviation. There is a saying amongst fighter pilots that "speed is life," but to be more accurate, *fuel is life.*

America's military power in the 21st century has relied on a number of key components. Networked communications, precision guided weapons, cyber capabilities, robotic systems, and space assets, among other technological advances, have given the U.S. significant advantages over its adversaries. However, fulfilling our national strategy to support allies, deter aggressors, and, when necessary, project power, requires global operations which have a fundamental but strategic requirement – fuel.[4] As a primary component of power projection, air power necessitates fuel, whether it is a domestically launched long-range bomber or a forward deployed tactical fighter. Even the increasing use of unmanned aerial vehicles, which have a significantly lower specific fuel consumption rate than their manned counterparts, still have substantial demands for fuel to execute missions. While air power relies on networked communications and space assets for tactical advantage, fuel remains its life blood. Adversaries can jam our communications or shoot down our satellites, and our aircraft will still fly; but cut off our fuel supplies and our squadrons will be grounded, or worse, flame-out.

Global application of air power and the operational advantage of air supremacy depend on the sustainment of airborne capability/capacity. Consequently, fuel logistics are a strategic criticality, effectively making the aerial refueling tanker force a strategic asset and potentially a strategic vulnerability. As national military strategy expands its application to the full spectrum of military operations, air power will face challenges in both contested and permissive air space.[5] Range and persistence will be critical factors affected by fuel constraints. Unfortunately, limited attention is given to this vital logistics matter, which threatens to undercut our strategy to maintain a credible conventional deterrent and a decisive power projection capability.

Lessons from the past decade of counterterrorism and counterinsurgency point to the importance of persistence in establishing patterns of life and finding, fixing, tracking, targeting, engaging, and assessing mission execution in permissive air space.

Meanwhile, advanced threat systems continue to expand operating ranges in contested air space. To operate in both of these environments, the U.S. should seek to enhance its current methods of employing air power by considering greater fuel efficiencies and addressing refueling concerns to mitigate vulnerabilities to threat systems and ensure that our next generation of air assets can achieve the required reach and persistence dictated by the future operating environments.

Notes

[1] R.H. von Hasseln, "Frederick E. Humphreys: First Military Pilot," New York State Military Museum and Veterans Research Center, accessed September 2014, http://dmna.ny.gov/historic/articles/humphrey.htm.

[2] Sharon E. Burke, "Energy for the Warfighter: The DoD Operational Energy Strategy," briefing, September 2013.

[3] "Environment: Climate and Energy," American Airlines, https://www.aa.com/i18n/aboutUs/corporateResponsibility/environment/energy-efficiency.jsp, accessed September 2014.

[4] "Quadrennial Defense Review," Department of Defense, 2014, http://www.defense.gov/pubs/2014_Quadrennial_Defense_Review.pdf, V.

[5] Ibid., VII.

CHAPTER TWO

The Playing Fields, Part I: The Ominous A2/AD

Great attention is paid to the concept known by the military acronym A2/AD. Anti-access/area denial is the contemporary threat intent that consumes future warfighting concerns. But confronting an anti-access weapon or traversing a denied area is nothing new. By definition, the Soviet Union's V-75 Dvina, better known as the SA-2 Guideline, was an anti-access weapon designed back in the 1950s and used to deny enemy entrance into areas of value; Gary Powers, whose U-2 spy plane was shot down over the USSR in 1960, could testify that A2/AD has been around for decades.[1] So to access these contested environments, tacticians developed ways to counter the threats. Aircraft would circumnavigate the fixed surface-to-air missile launch sites at safe distances, take advantage of speed and maneuverability to fly below radar acquisition envelopes, overfly systems at altitude, leverage multiple effects by coordinating electronic jamming, expendables, and weapons to neutralize the systems, or stealthily hide behind technologically advanced structural designs and surface coatings. So how is the modern A2/AD environment any different, and why is it such a great concern? The answer is range – or to use a cliché, *the tyranny of distance*.

In comparison to the complexity of today's advanced threat systems, the SA-2 is the equivalent of Hector's brazen spear desperately hurled at Achilles. The new threats incorporate integrated technology, advanced processing, accurate navigation, precision targeting, and coordinated systems to build layers of defense-in-depth designed to push safe operating areas so far away that intended target areas cannot be reached with our own integrated technology, advanced processing, accurate navigation, precision targeting, and coordinated systems. These advanced threats include surface-to-air missiles, land attack cruise missiles, anti-ship cruise missiles, and long range fighters carrying long range air-to-surface cruise missiles and air-to-air missiles. Using mobile naval vessels armed with these weapons systems as force multipliers, adversaries bordering a maritime environment can potentially extend these ranges even further. The threat weapons engagement zones (WEZ) have grown from a few miles to a distance so vast that many current tactical assets may be forced to launch from distances that will physically challenge their ability to reach a target even if they individually can trespass undetected.[2]

To influence an adversary we must be able to survive these threats. The safe option is to provide deterrence while remaining outside of the threat WEZ with the intent of overcoming the distance if combat operations are required. Unfortunately, this

is the ultimate goal of the A2/AD effort. By pushing forces so far away, an adversary limits our ability to respond in a timely manner to any crisis and gives them advanced warnings if and when we do respond. In some cases, this time-distance factor may entirely prevent our ability to respond. This latter situation would be an unfortunate reality for our current inventory of tactical strike and fighter aircraft. Presently, the estimated combat radius of our most advanced fighters is just over 600 nautical miles.[3] The projected range of some advanced threats to our basing options, ashore and afloat, far exceeds that distance.[4] Without external aerial refueling options, staying outside the threat WEZ means our fighter aircraft cannot reach their intended targets.

The alternative is to operate with presumed impunity inside the WEZ. We can base our fighters or steam our aircraft carriers well inside the threat ranges of these new, advanced threats and rely on imperfect defensive measures to protect these assets. In peacetime, this has been a standard practice to meet alliance commitments and monitor the global commons. Even in times of potential conflict, our forces have navigated inside threat zones to show political resolve, relying on deterrence to thwart danger. Rather than add to the hype of A2/AD, the Chief of Naval Operations refers to this operating environment as "assured joint access."[5] However, neither circumstance eliminates the risks; instead, risk is accepted and an unprovoked attack is deemed an unlikely occurrence. Escalating conflict to exchanges of kinetic weapons may make this risk unacceptable. We can rely on integrated air and missile defenses, continue developing defensive countermeasures, or leverage distributed basing strategies and mobile naval vessels to complicate an enemy's targeting plan, but risk remains.

Regardless, even if we do flout these risks, unless targets are in the littoral or border regions and our aircraft are launching from ships directly off the coast or hosted air bases along a border, refueling is necessary to ensure that tactical air assets have sufficient reserves to fight their way through hostile airspace. If targets lie in the *deep strike* realm well inside sovereign boundaries, then inflight refueling will be the critical node to enable mission success regardless of where sortie launch originates.

In a study by the Center for Strategic and Budgetary Assessments (CSBA), retired Air Force Lt. Gen. David Deptula and analyst Mark Gunzinger note that air bases may be vulnerable to precision-guided missiles and aircraft may not be able to enter hostile airspace without risking attrition. Specifically referring to naval options, Gunzinger writes, "…the wisdom of deploying carriers within range of anti-ship ballistic and cruise missiles so their short-range fighters can reach their objective areas is doubtful at best."[6] As a result, the study concludes that enemy anti-ship ballistic and cruise missiles supported by space-based sensors and long-range surveillance aircraft may force aircraft carriers to operate 1,000 miles or more offshore.

Similarly, our forward bases in allied countries that fall within such a threat radius may be directly threatened, limiting or preventing sortie generation. Another CSBA study concluded that adversary "development of advanced aerospace

capabilities has highlighted the vulnerability of large, fixed facilities and the limitations of short-range platforms that depend on access to them."[7] These concerns have compelled the U.S. Pacific Command to consider hardening measures to protect these facilities.[8] Exacerbating this physical limit are diplomatic restrictions that can inhibit our ability to fly from allied basing such as those imposed by Saudi Arabia in the late 1990s which contributed to the Air Force's decision to relocate its command and control Combined Air Operations Center air base to Qatar. A RAND study of American overseas bases identified both the physical and political threats that directly affect our access and potentially constrain our operations, concluding that the risks of possible missile attacks coupled with the high costs of hardening measures could shift forces to more distant locations.[9] Such conditions may push U.S. land-based fighters outside of the 1,000 mile range noted in the aforementioned CSBA study. Therefore, extending the reach of our tactical fighters is critical to the credibility of our power projection, the ability to effectively deter a hostile adversary, and thus to the execution of our strategy.

Notes

[1] National Museum of the US Air Force, "SA-2 Surface-To-Air Missile," U.S. Air Force, February 15, 2011, http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=334.

[2] The DF-21D ballistic missile's estimated range is more than 800 nautical miles.

Evan Braden Montgomery, "Time to Worry about China's Military Rise," policy brief, Belfer Center for Science and International Affairs, Harvard Kennedy School, June 2014.

[3] Estimated distance derived from current inventory of U.S. tactical air platforms, including the F-16, F-15 and FA-18, and projections of F-35.

"Air Force Fact Sheets," U.S. Air Force, accessed September 2014, http://www.af.mil/AboutUs/FactSheets.aspx.

"United States Navy Fact File," U.S. Navy, accessed September 2014, http://www.navy.mil/navydata/fact.asp.

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[4] Iran claims the Meshkat cruise missile will have a range of 2,000 kilometers (1,080 nautical miles).

"Ballistic and Cruise Missile Threat," National Air and Space Intelligence Center, 2013, http://www.afisr.af.mil/shared/media/document/AFD-130710-054.pdf, accessed September 2014, p 28.

[5] Jonathan Greenert, "The Future of Navy Operations Under Sequestration," speech given at The International Institute for Strategic Studies, Washington, DC, November 8, 2013.

[6] Mark Gunzinger and David A. Deptula, "Toward a Balanced Combat Air Force," Center for Strategic and Budgetary Assessments, April 11, 2014, http://www.csbaonline.org/publications/2014/04/toward-a-balanced-combat-air-force/.

[7] Evan Braden Montgomery, "Contested Primacy in the Western Pacific: China's Rise and the Future of U.S. Power Projection," *International Security* 38, no. 4 (Spring 2014).

[8] Jonathan Greenert, speech at The Navy League's Sea-Air-Space Exposition, National Harbor, MD, April 7, 2014.

[9] Michael J. Lostumbo, Michael J. McNerney and Eric Peltz, et al., "Overseas Basing of U.S. Military Forces: An Assessment of Relative Costs and Strategic Benefits," RAND Corporation, 2013, http://www.rand.org/pubs/research_reports/RR201.html.

CHAPTER THREE

The Playing Fields, Part II: Drilling Holes In The Sky

No mission is more tedious than flying a holding pattern, and yet no flight mission is more important to counterterrorism, counterinsurgency, or stability operations. After more than a decade of operations with manned and unmanned aircraft flying intelligence, surveillance, and reconnaissance (ISR) missions and ultimately coordinating strikes in permissive airspace, U.S. forces have learned the vital importance of endurance and persistence. Furthermore, energy supply and demand have taught us significant lessons in efficiency for resilience as well as cost savings. However, military acquisitions have limited performance of these missions to short-term durations. Though these uncontested air spaces allow unlimited access for overflight, our own endurance limits constrain our ability to maintain continuous situational awareness.

Flying maximum endurance profiles, our manned fighters can act as *non-traditional* ISR platforms and strike assets for a nominal period of a few hours; sorties in Afghanistan and Iraq typically lasted between five and 10 hours depending on launch location, area of surveillance, aerial refueling availability, and air support requests from ground units. Even our unmanned aircraft, not limited by the physical stamina of a single aircrew, only have fuel reserves to persist for a few additional hours. For example, the Air Force's MQ-9 Reaper can fly up to 14 hours and up to 770 miles (675 nautical miles).[1] The Navy's proposed long endurance MQ-4C Triton, a variation of the Global Hawk, is projected to remain airborne for up to 24 hours (but will not see service until 2017).[2] However, the current requests for ISR, frequently dubbed *orbits*, typically require 24-hour coverage over consecutive days. To meet these coverage requirements, tactical air assets rely on either steady streams of aerial refueling options or a continuous rotation of launch and recovery of numerous aircraft to relieve on-station assets. Neither option is efficient.

As the term orbit implies, this mission involves monotonously flying a continuous circular pattern over a targeted area, slowly building situational awareness of events on the ground. To ensure future persistent ISR, on-scene command and control, and extended strike missions in permissive air space, the next generation of air assets must focus on greater endurance capabilities and persistence in developing patterns of life and finding, fixing, tracking, targeting, engaging, and assessing mission execution.

Many may argue that after lengthy overseas contingency operations, American foreign policy will balk at embroiling military forces in protracted land operations that require extensive air support. This may be the popular sentiment, but external events have a history of forcing the country to act. Ongoing Special Operations missions throughout troubled regions of the world currently require continuous ISR. Additional examples include the recent deployment of U.S. forces to support ISR operations in Nigeria to assist in the search for hundreds of schoolgirls kidnapped by Boko Haram.[3] Even more recently, U.S. air assets have returned to Iraq to protect religious minorities and U.S. ground personnel and to support Iraqi Kurdish fighters in their struggle against the Islamic State terrorist group.[4] Any number of future scenarios can supplement these two examples of unforeseen deployments under permissive airspace. Michael O'Hanlon, a leading expert on foreign policy, has illustrated a few hypothetical cases that could require stabilization and security operations similar to efforts in Iraq and Afghanistan, ranging from Syria and Israel to Kashmir and various Arabian Gulf allies.[5]

Furthermore, a number of potential locations with permissive airspace over the global commons exist where extended coverage would aid operational commitments and ultimately benefit strategic decision making. The National Maritime Domain Awareness Plan for the National Strategy for Maritime Security, which "strives to enhance…ocean/waterway surveillance and maritime intelligence integration…"calls for improvement in "interagency capabilities to effectively share information on people, cargo, vessels, infrastructure, natural and man-made disasters, and other potential threats within the maritime domain."[6] It elaborates on the "critical link to achieving this vision through timely delivery of required information resulting in decision superiority."[7] Clearly, there is a need for extended ISR coverage: ongoing anti-piracy operations in the Gulf of Aden and Gulf of Guinea would benefit from extended coverage to monitor trade routes and the vast sea space in which these criminal activities are taking place; the monitoring of U.S. installations abroad in coastal cities would facilitate responses if overseas embassies and consulates in unstable nations were unable to thwart imminent threats; and as the polar ice cap recedes, the potential opening of regular trade routes, fishing waters, and energy extraction across the vast Arctic region will create a challenging environment to patrol the seas with increasing regularity.

Classic piracy evokes images of eye-patches, black skull-and-crossbones flags, and harks of *Arrgh*, but modern piracy on the high seas is no trivial matter – it is a real threat in the many ungoverned spaces throughout the littorals. Beyond the direct threat to individual mariners and commercial shipping vessels, piracy, like any organized crime, adversely impacts security and economic development efforts in unstable regions and has the potential to affect international trade by hampering the free flow of energy, raw materials, and finished goods that sustain the global economy. Moreover, the financial gains from piracy, like the illicit drug and arms trades, can contribute to

the resources of criminal networks, non-state militants, and terrorist organizations. Current military operations to combat piracy emanating from both eastern and western African nations have led to a significant drop in the frequency and success of piracy events over the last few years. However, the challenges of covering vast sea space as well as the shore based infrastructure from which piracy operations are launched requires dedicated efforts to build and sustain situational awareness using ISR assets. Vanda Felbab-Brown, a prominent expert on illicit economies, notes the value that a military presence in the maritime environment brings to combating piracy: "The policy options most readily available to suppress piracy…include developing better situational awareness…The economic benefits of unhampered trade may well justify the substantial costs of such an expensive, far-flung naval presence."[8] Creating a more efficient method of airborne ISR collection would not only contribute to piracy suppression but would also help reduce some of the expensive costs noted in such a military presence.

Unfortunately, the piracy problem is symptomatic of a greater dilemma – the challenges of security and stability in ungoverned spaces ashore. The littoral regions of the world represent a growing concern to many leading prognosticators of future conflicts. For instance, David Kilcullen, a respected expert on counterinsurgency, predicts that the expanding populations in major cities along coastal regions will continue to grow and foster vast urban territories where governance will be incredibly difficult and pockets of poverty and criminal activity will blossom into some of our greatest security challenges.[9] While these megacities may become the fertile breeding grounds for future insurgents, many might argue that they do not pose an existential threat to our national security.[10] However, when a team of insurgents is able to overrun U.S. installations with limited security on foreign soil, as witnessed in Benghazi, Libya, suddenly the not-so-existential-threat becomes a major concern for foreign policy makers and national security strategists. Following the Benghazi incident, defense officials were quickly tasked with formulating response options to a plethora of potentially unstable nations where U.S. embassies and consulates may be at risk. To ensure a timely response option in such a vast space, critical ISR must be available; to ensure ISR is available, a long endurance airborne platform must be accessible to compliment human intelligence. This is the hard lesson learned over the past dozen years combating insurgencies in both mountainous and urban environments. If the predictions of such megacities are correct, these threats will emanate along the coast where an offshore ISR asset can maintain continuous monitoring orbits operating in international airspace.

Arctic coverage presents a novel challenge, yet historical analogies illustrate the importance of an American presence in this burgeoning environment. As Secretary of Defense Chuck Hagel noted, "Throughout human history, mankind has raced to discover the next frontier. And time after time, discovery was swiftly followed by conflict. We cannot erase this history. But we can assure that history does not repeat

itself in the Arctic."[11] While the rate at which the climate is changing is debatable, the increase in maritime traffic in the Arctic region is not.[12] From 2005 to 2012, shipping through the Bering Strait and across the Northern Sea Route surged by nearly 50 percent, and many officials estimate a steady 10 to 20 percent annual increase in maritime traffic in the near future.[13] Additionally, speculation of untapped energy resources will certainly contribute to the heightened levels of activity in the Arctic and may lead to significant tensions among Arctic states vying for claims. While Arctic strategy is still in its infancy, our presence in the region as an Arctic nation is certain. To monitor rapidly evolving events, a long-endurance ISR asset will be crucial to cover this vast sea space. Unfortunately, we face vast gaps in satellite and communications coverage that will require significant resources to fill with the added complexity of a polar region; a long-endurance aircraft would be a cost-effective mitigation option.

The myriad scenarios justifying long endurance ISR missions are unfortunately too numerous to completely expound: monitoring territory disputes (Black Sea sorties in the vicinity of the Crimean peninsula); potential development of Weapons of Mass Destruction (Arabian Gulf sorties in the vicinity of Iran); illicit trafficking (drugs, arms, humans, etc. in the western hemisphere); and enforcing economic sanctions or trade embargos. The sad reality is that the U.S. military will be in the ISR business long after it has left Afghanistan.

Notes

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"MQ-1B Predator," U.S. Air Force, July 10, 2010, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104469/mq-1b-predator.aspx.

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[3] "US deploys surveillance aircraft to hunt for Nigerian schoolgirls," *The Guardian*, May 12, 2014, http://www.theguardian.com/world/2014/may/13/us--surveillance-aircraft-hunt-nigerian-schoolgirls.

Cheryl Pellerin, "DOD Sends UAV, 80 Airmen to Help Nigerian Search," United States Department of Defense, American Forces Press Service, May 22, 2014, http://www.defense.gov/news/newsarticle.aspx?id=122310.

[4] Tony Capaccio and David Lerman, "U.S. Sending 100 Air Missions Daily Over Iraq," *Bloomberg Businessweek*, August 11, 2014, http://mobile.businessweek.com/news/2014-08-11/u-dot-s-dot-said-to-send-100-air-missions-daily-over-iraq.

[5] Michael O'Hanlon, "How much Army is enough?" *USA Today*, February 25, 2014, http://www.usatoday.com/story/opinion/2014/02/25/defense-cuts-military-army-column/5819023/.

Writing about unanticipated missions potentially requiring U.S. ground forces: "…some possible (stabilization) missions for the future, even if each is unlikely:

• An international implementation force to uphold any deal that belligerents in Syria might ultimately accept.

• U.S. battalions or brigades of up to a few thousand troops per country to shore up Persian Gulf allies after a possible military strike to eliminate Iran's nuclear facilities, followed by a prolonged period of low-intensity conflict with Iran.

• A peacekeeping mission to secure and stabilize Kashmir if disputes over that province lead India and Pakistan to their fifth war — and the prospect of their first nuclear war.

• An implementation force for an Israeli-Palestinian peace deal."

[6] "National Maritime Domain Awareness Plan for the National Strategy for Maritime Security," Executive Office of the President, December 2013, http://www.whitehouse.gov/sites/default/files/docs/national_maritime_domain_awareness_plan.pdf, p v.

[7] Ibid., p vi.

[8] Vanda Felbab-Brown, "The Not-So-Jolly Roger: Dealing With Piracy Off The Coast Of Somalia And In The Gulf Of Guinea," *Foresight Africa: Top Priorities for the Continent in 2014*, The Brookings Institution, January 2014, http://www.brookings.edu/~/media/Research/Files/Reports/2014/foresight%20africa%202014/02%20foresight%20piracy%20somalia%20felbab%20brown.pdf, pp 6-8.

[9] David Kilcullen, "Out of the Mountains: The Coming Age of the Urban Guerrilla," speech given at Securing America's Future in the New "Interwar Years," The Brookings Institution, March 12, 2014, http://www.brookings.edu/events/2014/03/12-securing-americas-future-in-new-interwar-years.

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[11] Lolita C. Baldor, "U.S. eyes increase in Arctic operations," *Air Force Times*, November 22, 2013, http://www.airforcetimes.com/article/20131122/NEWS/311220002/U-S-eyes-increase-Arctic-operations.

[12] Bob Freeman, "The Arctic: A New Ocean for the Nation," Office of the Oceanographer of the Navy, July 23, 2013, http://www.navy.mil/submit/display.asp?story_id=75539.

Dr. Kathryn Sullivan, acting administrator for NOAA, on changing climate: "Since…2007, NOAA has recorded...an unprecedented rate of change in the Arctic. For example, just last year the carbon dioxide levels in the atmosphere…reached an historic benchmark level of 400 parts per million, and summer sea ice melted to an historic low, the second historic low in just five years. Furthermore, the minimum extent of multi-year sea ice has diminished by 50 percent in area and 75 percent in volume compared to 1970s climatology… Before 2050 we can realistically expect a nearly ice-free summer in the Arctic, a lot sooner than we originally expected."

[13] "U.S. eyes increase in Arctic operations."

CHAPTER FOUR

Defining New Requirements For Future Operating Environments

Bisecting the air domain into distinct categories, permissive airspace and contested airspace, enables identification of specific fuel and refueling concerns with–strategic ramifications that are not being sufficiently addressed to meet future contingencies. Though they can be dismissed as insignificant tactical issues or taken together as merely operational concerns, U.S. national strategy is built on the capability and capacity to execute at the operational and tactical levels. While theorists may attempt to cleanly cut military efforts into sharply defined tactical, operational, and strategic levels, the reality is that these layers overlap, each one impacting the other. Consequently, the elimination of an airborne tanker can have detrimental tactical implications. And the cumulative effect of unavailable fuel and refueling assets at the tactical level can result in operational failure. And the inability to conduct operations in a particular region due to fuel constraints can degrade military strategy. Hence, the strategic significance of fuel and refueling must be addressed for the future operating environment in order to execute U.S. national strategy.

Fourth generation aircraft capitalized on technological advances to build single aircraft with multi-mission capabilities. Leveraging these technologies, Air Force F-16s and Navy FA-18s combined air-to-air fighting capabilities, air-to-ground strike capabilities, and electronic warfare capabilities with little to no degradation in performance comparisons to the single-mission, legacy aircraft they replaced. In fact, the individual capabilities of these jack-of-all-trades aircraft frequently exceeded the performance of older, specialized aircraft. In doing so, these highly capable assets provided cost savings by delivering relatively inexpensive aircraft to replace numerous predecessors tailored to narrow tactical missions, i.e. most of the missions of a Navy carrier air wing comprised of S-3, A-6, EA-6, A-7, and F-14 could be accomplished by FA-18.

Ironically, advancing technologies that initially enabled cost-effective, multi-role platforms have now generated growing costs in the forthcoming generation of aircraft. Following the most expensive fighter, the F-22 Raptor, the F-35 Lightning II Joint Strike Fighter is on track to become the most expensive aircraft ever built. Though its projected capabilities are still maturing, the requirement to outfit this fifth generation fighter with low observable surfaces (stealth), sufficient thrust and aerodynamic performance to counter advanced threats, air-to-air and air-to-ground weapons systems, and multi-spectrum/multi-sensor electronic warfare and ISR capabilities have

driven costs well beyond initial projections. The Operational Requirements Document, written a decade and a half ago with the concept of producing an advanced but inexpensive fighter plane for three unique military services based on commonality of systems and economies of scale, did not take into account extended operations combating non-state actors in unstable nations with limited air defenses.

Unfortunately, the mission requirements of the past decade have not demanded such robust capabilities. In fact, the performance limitations of the F-35 with regard to fuel capacity, and hence range and persistence, almost make such a weapons system unsustainable overkill in the uncontested airspace defined by the counterinsurgency environment of the Global War on Terror operations in Iraq and Afghanistan. Of course the F-35, should it meet its projected combat capabilities, will be an incredible asset for national defense and power projection in contested environments. This is not an attack on the F-35; rather it is an argument that as technology has increased requirements, and thus costs, for combat capability, the need for diversified capabilities and cost savings may lead back to a complementary flight line including various lower cost aircraft in mass with unique tactical missions rather than a limited flight line of single system aircraft designed to conduct all potential missions and survive and thrive in the harshest combat environment.

Meanwhile, the technological advancements packed into fifth generation aircraft, conceived years ago, unfortunately come with a key limitation in terms of range relative to newly emerging threats, requiring significant fuel augmentation for operations in contested airspace.

Recognizing the substantial differences between these disparate air domains, a new approach to air acquisitions may entail: 1) an investigation into less expensive, long endurance unmanned aerial systems with internally generated and self-sustained power sources that permit persistent operations in permissive airspace; and 2) a similar study on advanced, strike-capable longer-range tactical fighter aircraft tailored to confront the greater ranges of emerging threats in contested airspace. Ultimately, these divergent examinations may combine to augment or supplement our current inventory of air systems.

Permissive Airspace: The Need for Greater Efficiency

To illustrate the fuel inefficiencies of recent missions in permissive airspace, Admiral Archie Clemens (Ret.), complimenting the joint nature of modern military operations, noted "In Afghanistan, Air Force tankers provided more than 80% of the 'gas in the air' for our carrier fighter pilots, many of whom refueled more than six times during combat missions routinely lasting seven to ten hours."[1] While this is a terrific example of the cooperation of the armed services in joint operations, it is also telling of the reliance that tactical fighters have on aerial refueling. Unfortunately, the missions conducted by these fighters and tankers, though effective, were grossly inefficient.

In terms of total fuel consumed, aerial refueling – or tanking as it is commonly called – is an incredibly inefficient method of sustaining airborne aircraft. In order to conduct refueling, a tanker aircraft must launch and proceed to station, remain in a holding pattern for an extended period of time, offload a portion of its fuel capacity (while constantly consuming its own fuel supplies), then return to base. Specific offload ratios are dependent on a variety of factors such as engine burn-rate, mission range, time on station, altitude, frequency of receiver aircraft, etc. But to highlight the inefficiencies, take for example conventional big-wing tankers like the KC-10 and KC-135 using generic Air Force planning metrics: a KC-10 flying a 2,500 nautical mile (nm) mission radius can provide approximately 80,000 pounds of fuel for offload based on an initial load of 327,000 pounds, or just under 25 percent. A more realistic example in a permissive ISR scenario would be a KC-135 launching with 180,000 pounds on a 500 nm mission radius offloading approximately 122,000 pounds or two-thirds of its total fuel carriage.[2] The latter example is certainly better, but considering that one-third of the fuel load is not applied to the actual mission that the receiver aircraft are flying, it is hard to label this as anything other than inefficient.

Meanwhile, the receiving aircraft are spending precious time vacating their assigned mission to rendezvous with the tanker, connect with the refueling system (drogue basket for Navy/Marine Corps or boom for Air Force), remain in formation until the fuel is transferred, then proceed back to their assigned mission. This chain of events could take anywhere from 10 minutes to over half an hour depending on proximity to the tanker, number of receiver aircraft in queue, and quantity of fuel on-loaded. On a typical mission during Iraqi Freedom, an aircraft launching from outside Iraq (naval aircraft from a carrier stationed in the Arabian Gulf or Air Force aircraft from bases in neighboring countries) would be assigned two mission segments, each for an hour of overhead ISR coverage supporting ground forces. To accommodate these periods, a fighter aircraft would routinely refuel enroute to station, in between air support requested periods, and again on the return to base. Depending on the distance to the designated mission area, they may refuel additional times enroute.

For every second the ISR aircraft are tied to the tankers, they are unable to provide troops on the ground with vital cover. During one mission in Iraq, a section of two fighters were conducting aerial refueling when a report of "troops in contact" with the enemy was relayed over the radio; by the time the fighters detached from the tanker and arrived at the scene of the fight near Baghdad, the insurgents had already receded. On another mission in northern Iraq, a section of two aircraft providing overhead support to ground forces left their station to refuel; upon returning just 20 minutes later, they were notified that a friendly helicopter had been shot down by insurgents near Mosul. After a dedicated search for the responsible attackers failed to identify the insurgents, the mission ended and the aircraft returned to base. Not only is the requirement to continuously refuel inefficient, but in these examples it unfortunately proved ineffective due to lack of persistence.[3]

Contested Airspace: The Reliance and Risk of Aerial Refueling

Even in a benign environment, aerial refueling is challenging; flying two aircraft so close to each other that there is an intentional mid-air collision, albeit a gentle one, can be unsettling. More unnerving for a pilot, though, is staring at empty fuel indicators as low fuel warning lights and aural *bingo* warnings heighten the anxiety. As difficult as aerial refueling is, U.S. air power during the past decade has maintained air supremacy enabling aerial refueling without threat of adversary air defenses. Future threat systems may change that paradigm.

A recent article comparing the unprecedented high costs of next generation fighter aircraft with the capital ships of the past theorized that policy and strategy decision makers might be reluctant to expose these precious national assets to the risks of combat: "anti-access strategies need not threaten to completely destroy an attacker; effective deterrence can threaten simply to destroy enough aircraft to significantly damage an enemy's air force."[4] While this theory, based on the monetary value or worth of power projection assets, may or may not play out in the future, the point that an anti-access strategy could thwart an attacker by merely taking out a limited number of assets rather than fighting an endless war of attrition is certainly worth consideration.

To avoid such losses, the U.S. has gone to great lengths and expense to develop the most advanced, survivable, stealthy strike fighters. This effort to develop a technologically superior asymmetric advantage is designed to give the U.S. leverage in any contested battlespace. But even if U.S. military forces possess more formidable and survivable tactical aircraft, the anti-access strategist may seek an alternative target to disrupt the American advantage. If an adversary can find an easier way to "significantly damage an enemy's air force," a prudent opponent may seek out that weakness and potentially have the same effect.

A tactical standoff between competing fighters may be a losing battle for the less capable aircraft; so a wise adversary, unwilling to lose a battle of attrition, can alter tactics to identify their enemy's weakest link in the kill chain. In the past, the EA-6 Prowler electronic attack platform was that link. With no air-to-air capabilities, limited maneuverability and situational awareness when conducting jamming missions, and limited speed to outrun a fighter, an adversary could negate an entire strike package by shooting down the Prowler. Eliminating the jamming platform exposed fighter and attack aircraft to surface-to-air threats. Trying to take on an entire strike package would be a monumental challenge to a less capable air force, but if one aggressor could leak through the wall of fighters and eliminate the jamming platform, strike forces would be exposed and forced to retrograde.

To protect the critical jamming missions of the EA-6, dedicated fighter escorts were assigned to high value asset combat air patrols (CAP). Loitering behind the strike package, these fighters were tied to the high value asset, namely the Prowler, to

intercept any adversary aircraft that managed to evade the fighter sweep clearing the path for the strike package. The EA-6 was an operational necessity and consequently a strategic asset as well as a strategic vulnerability.

Today, the EA-6 is replaced by the EA-18 Growler, a modified variant of the FA-18 Super Hornet that can defend itself with air-to-air capabilities while conducting electronic attack missions to protect advancing strike packages. Similarly, electronic attack capable aircraft such as the F-16CJ and individual payload jamming pods mounted on fighters can provide electronic protection on more survivable aircraft than the Prowler. This is good news for the electronic attack role. However, it does not necessarily eliminate a weak link in the kill chain.

Given the vast ranges predicted in future contested airspaces, the new strategic vulnerability, and therefore the new high value asset, may be the airborne refueling tanker. While an adversary may not be able to challenge our fighters for air superiority in the near future, reliance on tankers to sustain that superiority makes them prized targets.

Contingency operational planning for any regional conflict calls for an approximate capacity of 200 aerial refueling tankers.[5] With 200 assets, a single tanker aircraft shot down by an adversary can be accepted as a cost of war. But what if losing that logistics aircraft results in the flameout of a dozen strike/fighters expecting to rendezvous with the tanker on their precarious return from a distant strike? With a limited tactical range requiring airborne refueling, front-line fighters operating in a future contested environment will have to ensure the viability of the tanker, which historically has had the luxury of range and defense-in-depth to remain well behind the forward edge of the battle area. With advanced threats that may be able to reach our logistics tail, the tanker may require the same protection measures that the EA-6 required.

Many experts surmise that newly emerging aircraft in development by potential U.S. adversaries have leveraged stealth technology and advanced designs, making detection by our early warning systems more difficult.[6] Additionally, specifications with larger fuel capacity may allow them to fly a combat radius over 1,000 miles without refueling.[7] Coupled with advanced long-range active missiles, some analysts predict that such adversary aircraft could dominate areas far beyond sovereign borders as well as far out to sea, adopting strategic doctrines and operational concepts such as offshore defense. Given these speculated aircraft systems, weapons, and ranges, an advanced adversary could devastate the air facilities and base infrastructure of neighboring nations (including U.S. allies) and naval vessels operating beyond the littorals on the open-ocean/high-seas as well as target "airborne control aircraft; tanker aircraft for airborne refueling; and electronic warfare aircraft…"[8]

Provided advanced warning, a tanker aircraft can run from an adversary fighter but in doing so abandons the friendly fighters. Acknowledging the projected ranges for contested airspace, these fighters may never make it home if their required tankers get shot down or are forced to abort the mission and bug-out. While command and control aircraft and electronic warfare aircraft can retrograde to maximum coverage ranges (distances permitting bare-minimum coverage at the extent of their systems' employment limits) or simply turn and flee, leaving strike/fighter aircraft uncovered but still flying, the tanker will have to remain on station to provide a bridge for any range shortfalls.

Exacerbating land-launched threats is the ability to transport anti-air weapons systems across the maritime domain with ship-launched surface-to-air missiles, which expands their threat ranges from coastal limitations to a range only limited by the expanse of international waters. Not only may tanker aircraft no longer enjoy the safe haven of operating many miles away from the air threat, but additional threats may be floating directly beneath them. America's historic advantage of air supremacy, which has allowed tankers safe haven to loiter well beyond the enemy's reach, may be waning.

Tanker Defense

The KC-46 is the long-awaited tanker replacement for the aging KC-10, KC-130, and KC-135 platforms. As part of the requirements process in its development, the KC-46 was conceived with "the ability to detect, avoid, defeat and survive threats using multiple layers of protection" that "will allow the KC-46 to operate safely in medium-threat environments."[9] This raises the question of what constitutes a medium-threat environment. And consider what would happen if the tanker finds itself in a high-threat environment because adversary systems can now reach what was previously considered sanctuary airspace. Will its "enhanced survivability – new robust defensive systems and cockpit armor protection" be sufficient to survive advanced surface-to-air weapons and air-to-air weapons that directly threaten more maneuverable fighter aircraft designed for the high-threat environment?[10] Presumably, the answer to this question is no.

According to unclassified Key Performance Parameters approved by the Joint Requirements Oversight Council in the Capability Development Document, the KC-46 will have greater situational awareness of threat systems via networked data link information as well as threat detection from radio frequency warning receivers identifying the signals of threat RADAR systems. These will allow the tanker to get a head-start in its bug-out should it find itself in a threatened situation, thus ceding this vital air space to the enemy. Furthermore, it will have infrared defeating systems should it have to execute countermeasures against IR missiles. These systems may allow the tanker to survive the medium-threat environment and take evasive action before it trundles into a high-threat environment, but relative to the maneuverability of a tactical

fighter, the KC-46 will have a challenging flight if it inadvertently finds itself being targeted by an adversary fighter.[11]

In the future operating environment, contested airspace will expand to cover such a large range that these same tankers may be required to encroach into unknown threat envelopes to provide the necessary fuel for strike and fighter aircraft to achieve mission demands. This bridging measure may expose tankers to significantly greater threats than envisioned when the KC-46 was conceptualized.

Notes

[1] Rebecca Grant and Loren Thompson, "Modernizing the Aerial Refueling Fleet," Lexington Institute, October 6, 2006, http://www.lexingtoninstitute.org/modernizing-the-aerial-refueling-fleet/, p 4.

[2] Ibid., pp 7-8.

[3] U.S. Navy Carrier Strike Group deployment to the Arabian Sea in support of Operation Iraqi Freedom, 2006.

[4] Robert Farley, "Are Fighters the New Capital Ships?" *The Diplomat*, March 27, 2014, http://thediplomat.com/2014/03/are-fighters-the-new-capital-ships/.

[5] U.S. Air Force Federal Executive Fellow, interview with the author, The Brookings Institution, Washington, DC.

[6] "Managing the Air Commons in Maritime Asia," Center for a New American Security, March 7, 2014, http://www.cnas.org/events/managing-air-commons-maritime-asia#.VBC-NvldXHo.

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"People's Liberation Navy- Offshore Defense," GlobalSecurity.org, page last modified July 11, 2011, http://www.globalsecurity.org/military/world/china/plan-doctrine-offshore.htm.

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[9] "Defense, Space & Security: KC-46A Tanker," Boeing, http://www.boeing.com/boeing/defense-space/military/kc46a/index.page, accessed September 2014.

[10] Ibid.

[11] "Warfighter Key Performance Parameters," briefing, KC-46 Operations IPT Tanker Directorate.

CHAPTER FIVE
Recommendations

The U.S. can better plan and equip American air forces to address this tyranny of distance and persistence in the execution of our military strategy.

Bridging the range and ensuring the reach in contested airspace:

1. INCREASE SURVIVABILITY OF AIRBORNE REFUELING TANKER AIRCRAFT. As a stop-gap measure, aerial refueling tankers will have to become even more survivable. No add-on features will turn a KC-46 into a fighter, but externally mounted electronic protection systems such as advanced self-protection radar jammers (for example the Navy is currently pursuing an advanced jammer known as the Next Generation Jammer) and advanced expendables can provide additional countermeasures to defeat RADAR missiles in addition to the IR systems already considered in the program of record. Unfortunately, should the KC-46 find itself in visual range of a gunfight, even enhanced defensive systems will be unable to thwart an adversary fighter.

2. PLAN FOR DEFENSE OF TANKER AIRCRAFT IN THE SAME MANNER AS OTHER HIGH VALUE AIRBORNE ASSETS. Tactically and operationally, planning for the defense of tankers needs the same level of effort as the defenses previously afforded to high value assets like the electronic attack platforms. While air forces are adjusting operational concepts to address greater threats, the specific defense of tankers has not received the attention it warrants. Planners accept that the air supremacy (total ownership of the airspace) of the recent past is just that, a thing of the past. Pragmatists are refining tactics, techniques, and procedures and mission essential task lists to operate in a realm of localized air superiority (providing the capability and capacity to inhibit adversary aircraft from temporarily disrupting particular tactical operations), utilizing fighters to temporarily dominate a limited space providing a general defense for all operating aircraft in that space.[1] This is a progressive step in operational planning as well as training, exercises, and war-gaming. Unfortunately, a defensive counter air (DCA) mission to defend an entire strike package may be insufficient to ensure a vital tanker does not vacate its mission.

   Because a tanker cannot flee without risking the fuel starvation of forward fighters, the tankers will need to remain on-station, requiring fighter escorts flying dedicated protection patrols to intercept adversary aircraft that may penetrate a DCA. This is the new High Value Asset CAP. Both the Air Force's

and Navy's most advanced air warfare tactics development institutions are beginning to wrestle with this dilemma.[2] Just as a HVACAP ensured an EA-6 could continue its electronic attack mission when forward fighters were in threat envelopes, so too will a High Value Airborne Asset Protection fighter escort ensure that the tanker can loiter within a potentially high-threat environment to provide limited range strike/fighters the vital fuel required in a future contested environment.

Additionally, from the maritime domain, Navy Integrated Fire Control Counter-Air (NIFCCA) can augment defense of airborne aerial refueling tankers with additional platforms beyond just fighter escorts.[3] While big-wing tankers are not an organic part of the carrier strike group, integration of NIFCCA capabilities should help to defend this key operational enabler and strategic asset.

3. INCORPORATE TACTICAL AIRBORNE REFUELING CONNECTORS. Due to the space constraints of aircraft carriers, the Navy relies on smaller aircraft to conduct inflight refueling during organic missions (independent missions conducted exclusively with aircraft from an aircraft carrier). In the past, these tankers had limited self-defense capabilities, relying on the same sanctuaries as big-wing tankers flying in permissive airspace well behind enemy engagement zones. However, with the retirement of the S-3, the Navy incorporated aerial refueling into the FA-18 Super Hornet's multi-mission capabilities. Now the Navy's only organic tanker has the added benefit of being a fighter. Using the Super Hornet, air forces could still keep big-wing tankers outside of greater threat ranges and use FA-18s to provide tactical tankers that could safely maneuver into high-threat envelopes, providing critical interim tanking for other stealthier strike/fighter aircraft conducting combat missions deeper into contested airspace beyond the limits of their combat radii. These fighter/tankers could provide the necessary top-off during initial ingress into a potentially dangerous airspace and the vital connection between low-fuel strike/fighters and the large tankers flying outside of contested airspace on their return to base or ship. Flying this connector role, the Super Hornets could also provide an additional layer of defense-in-depth in the same manner as the previously mentioned High Value Airborne Asset Protection mission.

4. DEVELOP TACTICAL AIRBORNE REFUELING CONNECTORS LEVERAGING UNMANNED AERIAL SYSTEMS. Unmanned aerial systems could also serve as possible connectors. Using remotely piloted drones as mini-tankers, these tankers could provide the same linkage as the Super Hornet with the advantage of reduced risk to aircrew. Taking this mission a step further, these drones could deliver their fuel payload and then continue into the threat environment, complicating adversary air defenses. Our air forces could flood enemy systems, providing another layer of protection to manned aircraft entering the high-threat

environment. This concept truly embraces the term drone. The massing or swarm effect could overwhelm enemy defenses with false targets, complicating identification of the more lethal strikers.

5. ENSURE THAT THE REQUESTS FOR PROPOSALS FOR NEXT AIR SYSTEMS ADDRESS BOTH COMBAT CAPABILITY AND RADIUS TO ACHIEVE THE NECESSARY REACH. To eliminate the range limitation, DOD can leverage the current Request For Proposals (RFP) for the Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS) aerial system to begin building the next generation fighter by acquiring stealthy, unmanned strike/fighter aircraft with the combat radius to achieve the necessary reach that the current inventory of fourth and fifth generation fighters fails to achieve.[4] This may fly in the face of all military pilots who pride themselves on actually leaving terra firma strapped to an ejection seat. The heresy of relinquishing the role of the fighter pilot to a drone is a painful realization for any self-respecting, gun-slinging, flightsuit-wearing combat aviator. But if the current inventory lacks the reach necessary in the future, pilots must swallow their pride and ensure that the next acquisition meets the range requirements as dictated by the future threat. This is not an endorsement of unmanned over manned aircraft. It is a simple math problem. Current manned tactical fighters may have the combat systems to fight the future threat but may not have the combat radii to transit some of the assessed ranges associated with the anticipated threats in future contested airspace. The next aircraft acquisition coincidentally happens to be an unmanned variant with the potential for greater range limits.

   As a comparative baseline for fuel capacity, there is a tradeoff between a manned cockpit and additional fuel tanks. The single-seat FA-18E carries additional fuel in lieu of an additional aircrew member; the fuel capacity associated with one less cockpit, one less ejection seat, etc., is approximately 1,000 pounds of fuel (or 150 gallons) in comparison to the two-seat FA-18F. With the removal of all associated human interfaces (oxygen system, cockpit pressurization and environmental system, pilot-to-aircraft flight control hardware, etc.) additional fuel capacity would be even greater than 1,000 pounds for the same size airframe. And with a lower specific fuel consumption rate in unmanned aerial vehicles, this additional fuel translates to significantly longer flights. Without drastically affecting the shape and size of current systems deployed aboard an aircraft carrier (notwithstanding the significant internal space within the ship where the control console will have to be installed), designing the UCLASS to meet the combat capabilities of fifth generation strike fighters while additionally achieving the required reach is an attainable goal.

   This does not submit manned aviation to the history books. Rather, it recognizes a projected need in the next evolution of aircraft which was not foreseen during

the development of our current inventory of strike/fighter aircraft. Though many may argue that the future of combat aviation is unmanned, this recommendation recognizes the pros and cons of both manned and unmanned aerial systems; it just so happens that the next program on the block is unmanned. We should design it to fill the gaps in the projected assessments to achieve what the current inventory cannot.

The good news is that the U.S. Navy recognizes this opportunity to advance its air forces. According to a UCLASS requirements officer, the Navy has defined its minimum strike range for the UCLASS at more than three times the combat radii of its current strike/fighters.[5] Should the official RFP adhere to this range requirement while ensuring the same (or greater) low observable RADAR signature and stealth characteristics as current fifth generation manned aircraft, the UCLASS will be a formidable deterrent and power projection vehicle able to overcome the challenges of future contested airspace.

Greater efficiency, greater persistence in permissive airspace:

6. ACQUIRE A LONG-ENDURANCE, SELF-SUSTAINING AIR SYSTEM THAT DOES NOT REQUIRE REFUELING. The fuel concern in uncontested airspace is quite different from the contested challenges. Just as the threat is much less complicated, so too is the solution to the persistence problem. Simply stated, greater efficiency equals greater persistence. The ultimate efficiency is an aircraft that does not require refueling. Presently, such an aircraft does not exist in a military context, but the technology does exist elsewhere. Solar powered aircraft have been experimental novelties for many years, attempting around-the-world endurance flights and unlimited Wi-Fi internet transmissions to the developing world.[6] Such a solar powered aircraft could provide the critical persistence that ISR requirements demand.

   Unfortunately, the capability requirements of military acquisitions tend to expand during conceptual development, which in real terms equates to greater weight and power requirements – the bane of solar powered air systems. In this context, commercial off-the-shelf products may provide the link to timeliness, affordability, and ingenuity. Every program manager is constantly pressured to meet capability requirements on-time and on-budget. In the modern era, rarely have government acquisition processes met this standard when initiated as unique military specifications. Frequently, security restrictions inhibit commercially generated products from entering the military marketplace. However, the minimal requirements for operations in permissive airspace may allow commercially available systems to augment existing capability with military specific modules, both secure and unsecure, to simplify the acquisition process. As the Chief of Naval Operations frequently notes, the military should focus on payloads over platforms.[7] Leveraging existing technology to defray

research, development, test and evaluation, the U.S. armed forces may be able to apply military payloads such as sensors, transmitters, etc., to relatively inexpensive commercial platforms, in this case long endurance solar airframes.

As battery storage and nanotechnologies continue to advance, they may also enhance the combat capabilities of an ultra-light, ultra-high endurance aircraft. Currently, the Office of Naval Research is heavily involved in ultra-long endurance systems and developing and studying advanced batteries, including hybrid fuel cell options. Coupled with commercial developments in battery performance – as exhibited by the battery-powered Tesla Model S, recently named "best overall pick" by Consumer Reports – high-performance, battery-operated systems are feasible options in the near future to support a solar powered aerial vehicle.[8]

A solar-powered unmanned aerial system conducting flight operations at sub-atmospheric altitudes could orbit on-station for days, weeks, months, even years, overflying international airspace to provide ISR as well as back-up or expendable communications links in the Arctic, over known piracy enclaves, and along the borders of ungoverned nation-states. Or, in the event of military interdiction, it could provide both ISR and a Command and Control relay to protect forces operating on the ground while building the "pattern of life" to meet Rules Of Engagement. A long-endurance aircraft may not be able to carry 2,000 pound bunker-buster precision guided munitions and long range cruise missiles, but perhaps it could sustain future lighter-weight systems designed to exploit the electromagnetic spectrum, LASER targeting pods, or even carry limited releasable payloads such as Small Diameter Bombs.

Many may argue that limited functionality and survivability in full-spectrum combat operations would make such an acquisition a waste of tax payer dollars. Though such a system may be exposed due to certain combat weaknesses with respect to aircraft and performance limitations, by leveraging commercial off-the-shelf products, these assets could be acquired for a fraction of the costs associated with developing them through the customary military acquisition process. Furthermore, the singular use in uncontested environments would limit exposure to viable threats and, more importantly, would preserve the fatigue life of more survivable, but more expensive, fighters designed for high-end warfighting. The fatigue life of the current inventory of fighters is rapidly being consumed following extended flight operations in the uncontested environment of the past decade, wearing out the most advanced fighters before we can even capitalize on their asymmetric advantages. Besides, the savings on fuel costs alone could pay for these ultra-endurance systems over the long-term, making this investment a win-win acquisition.

Notes

[1] U.S. Department Of Defense Air-Sea Battle office personnel, interview with the author, August 2014, Washington, DC.

[2] Commander at the Naval Strike and Air Warfare Center, interview with the author.

The defense of large aerial refueling tankers is a burgeoning discussion that everyone (Navy Fighter Weapons School – TOPGUN; Navy Plans, Programs and Tactics – STRIKE; USAF Weapons School; etc.) is evaluating in the context of more capable threats in greatly contested airspace.

[3] Jonathan Greenert, speech at The Navy League's Sea-Air-Space Exposition.

[4] The draft Request for Proposal for the UCLASS X-47B was released April 17, 2014 to four vendors involved in the preliminary design review with the Navy for a conceptual UCLASS developmental effort.

[5] U.S. Navy Staff officer, e-mail message to the author, July 31, 2014.

[6] Sam Churchill, "Google Buying Drone Company Titan," dailywireless.org, April 14, 2014, http://www.dailywireless.org/2014/04/14/google-buying-drone-company-titan/.

[7] Jonathan W. Greenert, "Payloads over Platforms: Charting a New Course," *Proceedings* 138, no. 7 (July 2012), http://www.usni.org/magazines/proceedings/2012-07/payloads-over-platforms-charting-new-course.

[8] Jeff Plungis, "Tesla Model S Is Ranked Best Overall Car by Consumer Reports," *Bloomberg Businessweek,* February 25, 2014, http://www.businessweek.com/news/2014-02-25/tesla-model-s-is-ranked-best-overall-car-by-consumer-reports.

CHAPTER SIX
Conclusion

American air forces must work to increase aircraft on-station time and operational range through cost-effective investments in aircraft energy efficiency to ultimately reduce logistics force vulnerabilities. Certainly the present critical shortcomings in persistence and range must be evaluated and addressed as future operating environments proffer continued missions in permissive airspace as well as new challenges in contested airspace. As the joint military services confront the ever increasing need for extended intelligence, surveillance, and reconnaissance and the air forces develop air power tactics to assure access into denied battlespaces, the limits of the current inventory of ISR and strike/fighter assets coupled with the vulnerabilities of aerial refueling tankers inevitably lead to two conclusions: endurance limits of ISR aircraft need to persist beyond a 24-hour period; and range limits for power projection aircraft need a fueling bridge to accomplish mission demands should threat capabilities force them to operate beyond current combat radii.

Much has been written on ends, ways, and means – matching current limited resources and expected future resources (means) to meet (ways) our strategic goals (ends).[1] Much has been written on the need for 24-hour ISR orbits recognizing the tenuous balance between size/weight, mission payloads, engine/fuel capacity limitations, and cost.[2] Much has been written on the advanced threats emerging in the 21st century and the subsequent impact to stand-off ranges.[3] And much has been written on the acquisition of the next generation of unmanned air systems, the UCLASS, as the panacea for all air power needs, advocating for capabilities to accomplish both benign ISR requirements as well as establishing air supremacy and attacking targets through long-range strikes. [4] No doubt the UCLASS has the potential to bring tremendous capability to the air power inventory; but rather than expending tremendous resources to build a single aircraft to do everything, perhaps it may be more cost-effective to assess the domains in which air assets may be operating and return to an inventory of multiple, cheaper assets designed to operate in specific environments augmenting fewer more capable, but more costly, high-end assets.

The past decade of non-traditional ISR has imposed great wear and tear on America's most valuable fighter assets, eating away precious Fatigue Life Expectancy of extremely expensive aircraft. These inefficiencies led to recognition of the value of unmanned aerial vehicles and the subsequent tremendous growth in these assets. However, a 14-hour maximum endurance of our most persistent UAV is insufficient and funding multiple assets and fuel resources to meet continuous 24-hour coverage is too costly.

Meanwhile, the present day evolution of advanced strike/fighter aircraft, commonly referred to as fifth generation, was conceptually envisioned decades ago before the current inventory of threats materialized. While access challenges to denied spaces exist just as they did thousands of years ago when city-states were surrounded by imposing walls, the circumference of states' modern day barriers now extend well beyond what was conceived when our current fighters were designed. The expanded area within the possible threat sphere must be factored into operational risk planning. The U.S. acknowledges the potential threats to overseas bases and ships. Mitigation plans to harden air base infrastructure and cloak aircraft carriers within contested ranges may work; or they may not. Is it worth gambling on these measures with billions of dollars' worth of fighter aircraft which, in a fiscally austere era, essentially become strategic national assets? The possibility that these threats may push key power projection assets, specifically the fifth generation fighters deployed to deter potential adversaries, beyond their capable ranges will require aerial refueling that may place airborne tankers in harm's way.

Absorbing these lessons, DOD needs to build a robust, survivable, persistent, long-range air power inventory that includes multiple assets designed across the full spectrum of combat operations to exploit either permissive or contested airspace and, in some cases, both.[5] Rather than employ costly high-end assets in permissive environments, the military services should evaluate the potential feasibility of self-powered, long-endurance, and relatively inexpensive unmanned air systems, capitalizing on technologies and innovation rapidly emanating from the commercial sector. Rather than limit the capability of the UCLASS, the military services should evaluate the current shortcomings and risks to our fifth generation strike/fighters and ISR assets in contested environments and set the requirements for the UCLASS to ensure those gaps are addressed.

The exciting debates in the fields of space, cyber, robotics, stealth, information technologies, and exploitation of the electro-magnetic spectrum frequently overlook the vital and enduring necessity of logistics. Until the military services acquire an inventory of more persistent ISR aircraft and longer range strike/fighters, fuel and the assured ability to inflight refuel in both permissive and contested airspace will be the critical node to executing U.S. strategy by deterring adversaries with a credible power projection force and maintaining situational awareness. We have the fifth generation technologies and capabilities to conduct the next fight, but we have to be able to get there. And stay there.

Notes

[1] Bill Sweetman, "Challenges For Pentagon's New Second-In-Command," *Aviation Week & Space Technology*, April 7, 2014, http://aviationweek.com/defense/challenges-pentagon-s-new-second-command.

For example, "thinking about strategy, in the sense of matching goals to resources."

[2] Dave Majumdar, "Cost Will Drive UCLASS Designs," USNI News, April 2, 2014, http://news.usni.org/2014/04/02/cost-will-drive-uclass-designs.

For example, "The service is operating within severe cost constraints and both industry and Navy officials say that the requirement for the UCLASS to deliver an intelligence, surveillance and reconnaissance (ISR) orbit at "tactically significant ranges" for $150 million will not change. Theoretically, two aircraft can cover one orbit if that aircraft is capable of flying for 14 hours, which means the maximum price point for a UCLASS air vehicle is about $75 million, according to industry sources. But in addition to designing an aircraft for certain payload and range characteristics, the designers must take into account the available engines. For example, if the only engine available for the size and weight class of a particular design has a higher specific fuel consumption rate than was originally expected, engineers will have to add more fuel capacity—which in turn increases the size and weight of the aircraft. That in turn increases cost. Another factor is that there currently is no carrier-based jet engine that has low enough specific fuel consumption numbers to propel an aircraft that might have to remain in the air for as long as 14 hours. All of that has to be balanced with cost."

[3] Thomas Davis, David Barno and Nora Bensahel, "The Enduring Need for Electronic Attack in Air Operations," Center for a New American Security, January 2014, pp 1-2.

For example, "…potential U.S. adversaries are fielding highly capable Integrated Air Defense Systems (IADS) built around modern, indigenously produced fighter aircraft; advanced, multi-frequency radar for target acquisition and fire control; and highly accurate surface-to-air missiles (SAMs) with increasingly long reach."

"Similar leaps have also occurred in both the sea and air domains. Detection ranges have become much greater, weapons systems have achieved much further reach and precision technologies allow first round kills. When these factors are combined, they enable defenders to prevent access to selected locations and deny attackers the ability to operate freely in large areas."

[4] "Challenges for Pentagon's New Second-In-Command."

For example, "At CSBA, Bob Work co-authored a 2007 paper that advocated the use of long-range, very stealthy unmanned aircraft as a way to boost the reach-and-strike power of the carrier… [to] provide the Navy's future carrier air wings with the organic, extended-range, survivable, and persistent surveillance-strike capability needed to meet a number of emerging 21st century security challenges."

Shawn Brimley, "Congress's Chance to Fix Aircraft Carrier Drones," *DefenseOne*, May 4, 2014, http://www.defenseone.com/ideas/2014/05/congresss-chance-fix-aircraft-carrier-drones/83731/.

"A drone designed for power projection ought to have sufficient stealth capability to operate in denied environments, a weapons payload large enough to maximize striking power and in-flight refueling capabilities to take full advantage of an unmanned system's endurance capability... Mabus was right to argue that power projection, not surveillance, must be the raison d'etre of the Navy's investment in unmanned carrier aviation. It is the major operational challenge facing the aircraft carrier and ought to be the driving investment vector for naval aviation—period… review of UCLASS requirements, paying special attention to the issues of aerial refueling, weapons payload and stealth capability… But last month the Navy instead reportedly issued classified requirements for UCLASS to deliver intelligence, surveillance and reconnaissance. Instead of creating a drone that can carry missiles or other strike power into enemy airspace, defense contractors have been told to submit proposals for an aircraft designed to

fly around the aircraft carrier for 12 to 14 hours delivering persistent surveillance over uncontested airspace, with a light strike capability to eliminate targets of opportunity."

[5] "The Enduring Need for Electronic Attack in Air Operations," pp 6-7.

"Given recent technology trends, and the fielding of ever more capable and agile radar designed to amass large amounts of sensor data and then process it into a clear picture, strike packages are certain to require a mix of aircraft: some stealthy, some non-stealthy, some highly specialized and some unmanned. Enhanced weapons, with greater range and some stealth, will also be needed to increase the probability of reaching targets."

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