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AIR REFUELING: THE CORNERSTONE OF GLOBAL REACH—GLOBAL POWER

by

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CONTENTS

DISCLAIMER ii

LIST OF TABLES v

ABSTRACT vi

ACKNOWLEDGMENTS viii

INTRODUCTION 1

ROOTS OF AIR POWER DOCTRINE 4
The Importance of Range 5
The Value of Mobility 7
Extending Aircraft Range 8

THE GENESIS OF AIR REFUELING 12

GLOBAL REACH—GLOBAL POWER IS BORN 21
Lucky Lady II Flies Around The World Non-Stop 21
The Flying Boom 21
Composite Air Strike Force (CASF) 23
Lebanon Crisis Averted 24
US Strike Command Stands-Up 25
Air Refueling Operations in Vietnam 26

AIR REFUELING ENHANCES AIRLIFT 29
Operation Nickel Grass: The 1973 Israeli Airlift 29
Operation Restore Hope and Support Hope 31

DESERT STORM 33

US NATIONAL MILITARY STRATEGY 39

TEN PROPOSITIONS REGARDING AIR REFUELING 43
1. Air refueling enhances air power's inherent strengths. 44
2. Air refueling mitigates air power's inherent weaknesses. 44
3. Air refueling serves as a force multiplier 45
4. Air refueling aircraft are high value strategic assets. 45

5. Air refueling operations require local air superiority. 46
6. The number of tankers required depends on theater basing, tempo, and threat. 46
7. Tanker assets should not be based near the forward edge of the battle area (FEBA). 46
8. During air bridge operations, "fuel in the air" is the limiting factor. 47
9. During tactical employment "booms in the air" becomes the limiting factor. 47
10. Air refuelable tankers enhance air refueling efficiency. 48

CONCLUSION 50

BIBLIOGRAPHY 52

Tables

Page

Table 1. Potential Airlift Enhancement Using Air Refueling in the 1973 Israeli Airlift 30

Table 2. Aircraft Target Areas 35

Abstract

This paper focuses on the strategic mobility aspect of Global Reach—Global Power, and more specifically the role of air refueling in accomplishing the US power projection strategy. No aircraft in the Air Force inventory is capable of responsive global power projection without air refueling. The Air Force's tanker fleet is the cornerstone of Global Reach—Global Power. Air refueling serves as a force multiplier, increasing the speed, range, lethality, flexibility, and versatility of combat aircraft.

The paper looks at the roots of air power doctrine, the need for range extension, and the growing importance of mobility to warfare. The paper goes into some detail outlining the development of air refueling, from wing walkers packing gasoline cans, to the development of the KC-135, and the birth of Global Reach—Global Power doctrine. The study examines the expansion of the tanker mission from primarily strategic bomber support, to its multi-mission role in Operation Desert Storm, supporting virtually every fixed-wing asset in the Air Force inventory. Finally, the paper presents ten propositions regarding air refueling:

1. Air refueling enhances air power's inherent strengths.
2. Air refueling mitigates air power's inherent weaknesses.
3. Air refueling serves as a force multiplier.
4. Air refueling aircraft are high value strategic assets.
5. Air refueling operations require local air superiority.
6. The number of tankers required depends on theater basing, tempo, and threat.
7. Tanker assets should not be based near the forward edge of the battle area (FEBA).
8. During air bridge operations, "fuel in the air" is the limiting factor.

9. During tactical aircraft employment “booms in the air” becomes the limiting factor.
10. Air refuelable tankers enhance air refueling efficiency.

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Chapter 1

Introduction

"Deterrence is only credible if we possess a robust means of power projection and the mobility to deploy and sustain our forces." [1]

—General Colin Powell, CJCS

Since Operation Desert Storm, the United States Air Force has operated at a high operations tempo. Many Air Force members are spending over 130 days a year deployed to hot spots like Iraq, Haiti, Bosnia, Somalia, Rwanda, and most recently China.[2] KC-135 and KC-10 tanker units have played a major role in each of these operations. This busy deployment schedule stems from a fundamental change in the US national military strategy following the Cold War.

Today, the US faces an uncertain multi-polar world, fraught with regional instability, weapons proliferation, and a host of developing transnational threats. Simultaneously, reduced defense spending has compelled a reduction in force size and the closure of many expensive overseas bases. In this post Cold War environment, the US has adopted a military strategy based on two strategic concepts—overseas presence and power projection.[3] Overseas presence is accomplished by maintaining a cadre of permanently stationed forces overseas and augmenting them as necessary with temporarily deployed forces. Power projection depends on strategic mobility to rapidly reinforce military forces abroad to deter or defeat any potential adversary. As a result of this strategy change, US military forces are now smaller, highly mobile, and largely US-based. Deploying and sustaining these forces will increase the demand for strategic mobility forces.

The concept of power projection relies on air power's inherent capabilities of speed, range and flexibility to deliver decisive combat power to any point on the globe rapidly, placing any would be adversary at risk. Power projection takes advantage of the strategic mobility strengths resident in today's Air Force. The terms Global Reach—Global Power[4] describe the Air Force's ability to rapidly deploy conventional forces in response to any contingency, with forces that punch hard or influence by their presence. The ability to quickly deploy these US-based forces remains directly dependent on air refueling.

This paper focuses on the strategic mobility aspect of Global Reach—Global Power, and more specifically the role of air refueling in accomplishing power projection. No aircraft in the USAF inventory is capable of responsive global power projection without air refueling. The Air Force's tanker fleet is the cornerstone of Global Reach—Global Power. Air refueling serves as a force multiplier, increasing the speed, range, lethality, and flexibility of combat aircraft. Air refueling increases deployment speed by eliminating en route stops. Aircraft, equipment, and personnel can now be delivered anywhere in the world within hours rather than days or weeks. Air refueling extends aircraft range to the limit of the aircrew, making strategic targets accessible to tactical aircraft. Air refueling increases combat lethality. Combat aircraft can takeoff with a full weapons payload and a reduced fuel load, then refuel after takeoff, permitting the delivery of maximum combat power on a distant enemy target. Air refueling can solve almost any tactical dilemma by increasing the shooter's flexibility. For example, aircraft can: (1) loiter longer over the target; (2) change their ingress or egress routes/altitudes significantly to avoid air defense threats; (3) reduce their required fuel reserves; (4) mass large formations in the air; (5) operate from secure bases outside the range of enemy air attack; (6) and overfly politically untenable or denied forward bases.

Air refueling is a significant force multiplier, however US dependence on air refueling for power projection is not well recognized and deserves further examination. This paper begins with a look at the roots of air power doctrine and the need for long range aircraft, examining the fundamental precepts of Giulio Douhet and Carl von Clausewitz to understand the fundamental strengths and weaknesses of airpower. Next, the study reviews the importance of mobility to warfare, and specifically the quest to extend aircraft range. The paper goes into some detail outlining the development of air refueling, from wing walkers packing gasoline cans, to the development of the KC-135, and the birth of Global Reach—Global Power doctrine. The study then examines the expansion of the tanker mission from primarily strategic bomber support, to its multi-mission role in Operation Desert Storm, supporting virtually every fixed-wing asset in the Air Force inventory. Finally, the paper presents ten propositions regarding air refueling, describing how air refueling assets can best be used to accomplish the Global Reach and Global Power mission.

Notes

[1] "Desert Shield/Storm: USTRANSCOM's First Great Challenge," *Defense Transportation Journal*, June 1991, 19.

[2] Vago Muradian, "Tankers, Why They're so Important--and so Unappreciated," *Air Force Times*, 6 February 1995, 12.

[3] *National Military Strategy, 1995* (Washington: US Government Printing Office), ii.

[4] Hon Donald B. Rice, Air Force White Paper, *The Air Force and US National Security: Global Reach--Global Power*, June 1990, 1-15.

Chapter 2

Roots of Air Power Doctrine

> *"At the heart of warfare lies doctrine. It represents the central beliefs for waging war in order to achieve victory. Doctrine is of the mind, a network of faith and knowledge reinforced by experience which lays the pattern for the utilization of men, equipment, and tactics. It is the building material for strategy. It is fundamental to sound judgment."*
>
> —Gen Curtis Emerson LeMay, 1968.

Determining how best to exploit air power's inherent strengths and minimize its weaknesses is the essence of air power doctrine. Early theorists saw the airplane's great mobility as the necessary means to break the stalemate of World War I trench warfare. Air power advocates believed air forces would someday threaten enemy population centers with sufficient destructive power, the enemy would sue for peace before its land and naval forces had been defeated. After gaining "command of the air,"[1] Giulio Douhet, an Italian airpower theorist, believed that strategic attacks against defenseless enemy population centers using a mixture of high explosives, incendiary, and poison gas bombs would have a devastating physical and moral effect on the population, sufficient to break down the public's confidence in its government's ability to provide basic security.[2] With no means of aerial defense, the enemy leadership would sue for peace.

Douhet's war winning offensive bombing theory was based on three propositions: "the destructive power of the heavy bomber; the impotence of air defense; and the fragility of a modern industrial society in the face of heavy bombing...."[3]Douhet has been widely criticized for exaggerating these propositions. For example, until the advent of nuclear weapons and the subsequent development of conventional precision guided munitions, the bomber did not possess the destructive power Douhet claimed. Second, the development of radar tended to invalidate Douhet's assumption, i.e. that strategic bombers could not be detected in sufficient time to permit interception en route to their targets. Radar permitted early warning of air attacks, giving the defense time to react. Finally, civilian morale and industry proved more resilient than Douhet expected.[4]

Airpower enthusiasts have not given up on Douhet's vision of a decisive, war winning air campaign. Today, with some modification, Douhet's theory provides the basic framework for a successful offensive air campaign. First, intelligence must identify which enemy centers of gravity are vulnerable to air attack and, if destroyed, will result in military victory.[5] Second, enemy air defenses must be rendered impotent by stealth, avoidance, disruption, or destruction. Finally, offensive air power must be delivered accurately and with sufficient mass at the vulnerable points to destroy the enemy centers of gravity. This framework although not easily accomplished, nevertheless provides a logical methodology for air campaign planning. The war winning potential of air forces depend greatly upon superior mobility (speed/range) and continued improvements in aircraft protection and lethality.

The Importance of Range

The performance requirements Douhet laid out for bombers, emphasized the need for speed, range, altitude, defensive armament, and payload.[6] Douhet placed special emphasis on range. A bombardment aircraft should have the greatest range possible, for the longer its range, the deeper its penetration into enemy territory and the more enemy targets could be held at risk.[7] Because of the airplane's significantly greater range, Douhet believed range was the defining characteristic that distinguishes air power from land or sea power. For this reason, Douhet postulated air forces would dominate over both land and sea forces.[8]

The characteristic of extended range gives military forces a strategic dimension. The ability to project power over long distances has always been used with strategic effect. During the nineteenth century, Britain's Royal Navy dominated the globe though sea control, enabling Britain to expand its empire, protect its colonies and conduct profitable commercial trade. The American naval strategist, Alfred Thayer Mahan, also recognized the strategic nature of naval forces because of their capacity to project tremendous power at great distances. The strategic mobility resident in seapower has enabled the leading naval power to defeat (or at least draw) against the leading land power in every major conflict in modern times.[9]

Air forces, like naval forces, have the capacity for strategic impact. However, because air forces are not limited to waterways or constrained by geographic choke points, air forces have inherent strategic value. Although air power has limited persistence as compared to sea and land forces, its freedom of action over the earth's surface gives long range air forces the unique capacity to project power to any point on the globe quickly. Air forces have the potential to bypass armies, fleets, and geographic obstacles and strike directly at the enemy centers of gravity.[10] This idea of deep attack places all enemy targets at risk and demonstrates how air power can concentrate quickly in time and space, focusing maximum combat power at the vulnerable point of attack; whereas the defender, unaware of the planned direction of the attack, is compelled to spread his forces thinly to cover all avenues of attack, hoping to shift them in time to the sector actually attacked as soon as the objectives of the offensive are known. In addition, superior long-range air forces may have the added benefit of operating from secure bases outside of the enemy's combat radius. Thus long range air forces have the potential to put all enemy centers of gravity at risk, while operating from secure bases, immune from air attack.

The Value of Mobility

Mobility in land warfare allows offensive forces to avoid or bypass some or possibly all enemy defenses. Additionally, mobility speeds the concentration of mass from one point on the battlefield or theater of war to another. Mobility speeds the tempo of battle, enabling the nimble attacker to maintain the initiative. Likewise, mobility enables air forces to concentrate quickly for attack and then disperse. Additionally, air forces can use their great mobility to avoid or bypass land and sea forces. Mobility, the combination of speed and range, enhances air power's ability to achieve surprise. Surprise is important to offensive air power because, as Carl Von Clausewitz points out, "...surprise lies at the foundation of all undertakings, for without it the preponderance at the decisive point is not properly conceivable."[11] The primary difference between air and surface warfare is the effect of terrain. In surface warfare, terrain provides protection and restricts mobility. In air warfare, the absence of terrain enhances mobility while giving up its protection. This increased mobility reduces warning time and makes achieving surprise more likely. By using superior mobility, the airborne attacker can threaten an entire theater with air attack, spreading out the defense, and then concentrating superior forces at the decisive point to overwhelm the defense. The defender is at greatest disadvantage when compelled to protect a wide area against multiple axes of advance. In conventional war, surprise is a powerful force multiplier.[12] First, it takes the initiative away from the enemy by confusing the defense and distracting the enemy commander. Second, it ensures the defense cannot reinforce the position with superior force prior to attack. And finally, surprise enhances the ability to maneuver.

Extending Aircraft Range

In the century since the Wright brothers' first flight at Kitty Hawk, airmen have used technology to increase the speed, range, endurance, and payload of air forces. Advances in aerospace technology have extended the range of aviation from a 12 second, 120 foot flight at Kitty Hawk, North Carolina, to a transcontinental flight, to a transoceanic flight, to a flight around the world, a spaceship to the Moon, and now a space probe beyond the solar system.

In this push to increase speed and range, advances in engine power, engine efficiency, aerodynamic efficiency, metallurgy, and now composite materials have enabled airmen to fly faster and farther. But throughout the 20th century, airmen have grappled with the competing demands of speed and range. Traditionally airmen have looked to aircraft design and technological advances to increase speed and range. Increasing an aircraft's speed requires maximizing the thrust-to-weight ratio, which inevitably demands a reduction in an aircraft's size and fuel supply; the engine throttle is also adjusted to achieve maximum thrust. To increase an aircraft's range, the lift to drag ratio is maximized by increasing the size of the aircraft's wing surface and reduce its fuel capacity, then adjusting the engine throttle to achieve maximum fuel economy. It is evident that, efforts to increase speed or range, normally require a tradeoff between the two.

Range extension is not a new coefficient of combat power. The fundamental idea of being able to hit your enemy when your enemy cannot hit you has been the primary driving force in warfare development since ancient days. The spear, the bow and arrow, the catapult, the gun, the airplane with its bomb, all share the common characteristic of greater and greater range.

Air refueling reduces the required range of bombing aircraft to that necessary to fly from the refueling point to the target and back again. It follows that high performance, less vulnerable fighter bombers of comparatively limited range may be employed for deep attack against the enemy. Because the location of air refueling routes can be varied almost infinitely, tactical flexibility is also enhanced. When opposed by such versatility, the enemy tends to disperse air defenses to cover every potential avenue of approach. Additionally, strategic mobility reduces the dependence on maintaining a US presence and logistics support at overseas bases. In the absence of suitable forward bases, air refueling still permits bombers to reach their targets. If forward bases are obtained, they may be vulnerable to air attack. Finally, superior range buoys the offensive spirit, giving a feeling of relative security, while the defender, exposed to air attack and unable to counterattack the aggressor's bases, must deal with the bitterness of helpless impotence. Distance and terrestrial barriers have been mitigated by technology.

Notes

[1] Giulio Douhet, *The Command of the Air* (Washington: Office of Air Force History, 1983). "To have command of the air means to be in a position to prevent the enemy from flying while retaining the ability to fly oneself." A nation which has command of the air is in a position to protect its own territory from enemy aerial attack and even to put a halt to the enemy's auxiliary actions in support of his land and sea operations, leaving him powerless to do much of anything." "To be defeated in the air. . . [means] to be at the mercy of the enemy, with no chance at all of defending oneself, compelled to accept whatever terms he sees fit to dictate." 23-25 "In order to conquer the air, it is necessary to deprive the enemy of all means of flying, by striking at him in the air, at his bases of operation, or at his production centers--in short, wherever those means are to be found." 28 ". . .the best means of destroying [airports, supply bases, and centers of production] is by aerial bombardment [offensive counter air]. . . ." 34

[2] Giulio Douhet, *The Command of the Air* (Washington: Office of Air Force History, 1983), 25 and 35.

[3] Alfred F. Hurley and Robert C. Ehrhart, ed., *Air Power and Warfare* (Washington: US Government Printing Office, 1978), 42.

[4] *The United States Strategic Bombing Surveys, Summary Report* (Maxwell Air Force Base, Alabama: Air University Press, October 1987), 39.

[5] Carl Von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1976), 595-596. Clausewitz defined center of gravity as ". . .the hub of all power and movement, on which everything depends. This is the point which all energies should be directed." Clausewitz gave three likely strategic centers of gravity: the enemy army, his capital, or a principal ally. Col John A. Warden, III, *The Air Campaign, Planning For Combat* (Washington: National Defense University Press, 1988), 9, describes center of gravity as ". . .that point where the enemy is most vulnerable and the point where an attack will have the best chance of being decisive. There is a major difference between a vulnerable point and a center of gravity. A vulnerable point or vulnerability is a weakness through which the center of gravity can be reached and attacked. If no vulnerable point can be found, the attacker must create a vulnerability, by use of deception or diversion to dislocate enemy forces or by reinforcement of sufficient mass to create a vulnerable point.

[6] Giulio Douhet, *The Command of the Air* (Washington: Office of Air Force History, 1983), 38.

[7] Giulio Douhet, *The Command of the Air* (Washington: Office of Air Force History, 1983), 38.

[8] Giulio Douhet, *The Command of the Air* (Washington: Office of Air Force History, 1983), 29.

[9] Colin S. Gray, *Seapower and Strategy* (Annapolis, MD: Naval Institute Press, 1989), 23.

[10] See note 9.

[11] Liddell Hart, *Strategy* (London: Faber & Faber Ltd, 1967), 343. Clausewitz was pessimistic on whether surprise could be achieved and cautioned not to depend on surprise; however, he stated, "We suggest that surprise lies at the root of all operations

Notes

without exception, though in widely varying degrees depending on the nature and circumstances of the operation." (*On War*, 198)

[12] Michael Handel ed., "Clausewitz in the Age of Technology," *Clausewitz and Modern Strategy*, (London: Frank Cass, 1986), 65.

Chapter 3

The Genesis of Air Refueling

"No single innovation of recent times has contributed more to airpower flexibility than the aerial tanker . . . ."[1]

The first attempts at air refueling were not feats of engineering prowess, but of aerobatic and acrobatic skill.[2] On 2 October 1921, an airborne Navy lieutenant used a hook to snatch a can of gas from a barge in the middle of the Potomac River. Several weeks later, on 21 November, Wesley May performed the first recorded aerial refueling when he climbed from the wing of a Lincoln Standard biplane with a 5-gallon can of gas strapped to his back, to the wing of a JN4 Jenny piloted by Earl Daugherty and poured the fuel into the tank of the JN4. Later, in April 1923, under the command of Major Henry H. "Hap" Arnold, the Army Air Service began a series of flights to demonstrate the feasibility of transferring fuel between aircraft.[3] The experiment was conducted by Captain Lowell Smith and Lieutenant John Richter in a DeHaviland DH-4B, receiving fuel by manually grasping a rubber hose hanging down from the "tanker," also a DH-4B, flown by Lieutenants Virgil Hines and Frank Seifert.[4] Once the hose was connected to a fuel tank aboard the receiver aircraft, the refueling valve was opened and the fuel drained into the receiver. On 27 June 1923, the team made two contacts, transferring 25 gallons on the first contact and 50 gallons on the second. The flight lasted for six hours and 39 minutes. The following day, they flew for 23 hours and 48 minutes, transferring 308 gallons of fuel and 15 gallons of oil. Their efforts culminated on 25 October 1923 in a non-stop flight of a little over 12 hours from Sumas, Washington, on the Canadian border, to Tijuana, Mexico, a distance of some 1,280 miles, during which their DH-4B was refueled twice by tankers pre-positioned at Eugene, Oregon, and at Sacramento, California.[5]

Air refueling experiments came to an abrupt halt on 18 November 1923 when the refueling hose became entangled in the propeller of the receiving aircraft, causing it to crash.[6] Army Air Service experimentation did not resume until the famous flight of *The Question Mark,* from 1-7 January 1929. This C-2 Fokker tri-motor high-wing monoplane, piloted by Carl Spaatz, Ira Eaker, Harry Halverson, and Pete Quesada, stayed airborne over Los Angeles, California for 150 hours and 40 minutes—over six days. During the flight 5,660 gallons of gasoline and 245 gallons of oil, as well as meals, water, and other supplies were transferred, while conducting more than 50 air refuelings.[7] *The Question Mark* landed with one engine dead, one faltering, and one spewing oil.

The Question Mark demonstrated the feasibility of increasing an aircraft's fuel load to a gross weight significantly greater than its maximum takeoff gross weight after becoming airborne. Aircraft are able to carry more fuel in flight, because the in-flight speed compared to the slower takeoff speed generates the necessary lift to carry the additional fuel.[8] Major Spaatz, who later became the first Air Force Chief of Staff, recognized air refueling's applicability to all air forces. In his report to the War Department he recommended air refueling be used in bombardment, pursuit, and observation aircraft. He also proposed that all future aircraft acquisitions be equipped for air refueling during manufacture.[9] The War Department, however, failed to see the wisdom in his vision and chose not to act on his recommendations, even though a series of commercial fliers successfully bettered *The Question Mark's* record the very next year.[10]

The initiative for air refueling development then transitioned to Great Britain. Royal Air Force (RAF) Squadron Leader Richard Atcherley developed a safer and simpler method of contact by establishing a tether between the tanker and receiver aircraft using weighted cables with grappling hooks trailed by each aircraft. The tanker then flew a crossover maneuver to cross the cables and lock the grapples together. The two secured lines were now used to haul the tanker's hose to the receiver aircraft for attachment to a refueling receptacle. Atcherley also developed refinements to this hose method including a powered winch to haul the hose in faster, an automatic coupling which opened and closed the fuel valve on the receiver as the hose nozzle entered, and a safety guillotine that would sever the refueling hose in the event of an emergency.[11]

In 1939, Flight Refueling Limited, a British company developed by Sir Alan Cobham, in conjunction with Short Brothers (a British aircraft manufacturer), British Imperial Airways (an airline company), and the British Air Ministry demonstrated the potential of air refueling to make air service between England and the United States commercially viable. Cobham introduced the "Ejector Method" of contact, in which a line-throwing gun, similar to those used in life saving, was used to fire a line from the tanker across a weighted line suspended from the receiver. The lines between aircraft were secured by grappling hooks and then used to haul the refueling hose to the receiver. As a safety measure, Cobham purged the hose lines with nitrogen to eliminate the danger of explosive vapors.

On 5 August 1939, *The Cabot*, a Short C Class flying boat, took off from Shannon, Ireland and received 1200 gallons of fuel shortly after takeoff from an Armstrong Whitworth AW-23 tanker on its Western flight to Botwood, Newfoundland. After a short ground refueling stop at Botwood, the flight continued on to Montreal, Canada, and to its destination of New York City. On the Eastbound leg from Botwood, *The Cabot* received 1,200 gallons of fuel from a tanker based at Gander, Newfoundland. A total of sixteen crossings were made and the success of these trials led to a decision to add two or three flying boats to the service and continue operations in 1940.[12]

As the potential for war loomed in Europe and the Pacific, Army Air Corps leaders began working on methods to increase the range of American bombardment aircraft. In August 1939, Hap Arnold, now Chief of the Air Corps, requested and received a description of Cobham's system from Jimmy Doolittle.[13] Doolittle's letter prompted the Air Materiel Division to begin a study on several methods of increasing the range of US bombers. The methods studied included catapulting, air refueling, and the construction of large airports with longer and possibly even sloping runways to increase takeoff speed, permitting takeoff with heavier gross weights.[14]

When the United States entered the Second World War, the combat radius of existing bombers and fighters made direct attack of Germany and Japan impossible (as Air Corps Strategic bombing doctrine suggested).[15] Additionally, the US feared Hitler might conquer Britain, leaving no airfields from which Germany could be attacked. This prompted the Air Corps to open a design competition for an intercontinental bomber in April 1941. The design specifications called for a 12,000 mile range and led to the development of the B-36.[16] Following the attack on Pearl Harbor, the War Department began serious study of air refueling as a means to extend the range of American heavy bombers.

In January 1942, several ideas were studied. One proposed using Navy PBY flying boats to air refuel B-24 bombers based in Hawaii to bomb Tokyo. The PBYs would be refueled at sea by Navy ships. Another envisioned B-24 tankers based at Midway Island refueling B-17Es en route to Tokyo. The Air Material Center opted to test the latter and began installing Cobham's system on B-17Es and B-24Ds. During the spring of 1943, the Air Materiel Center conducted a series of air refueling tests using the British hose system on a B-24D to refuel a B-17E.[17] The B-24D could transfer 1,500 gallons of fuel in about 18 minutes. In its 30 June 1943 report, the Center recommended that careful consideration be given to using this method of refueling in-flight to extend the present range of B-17's.[18] The impetus for air refueling disappeared as the problem of inadequate range was solved by a combination of gaining air bases closer to Japan and the deployment of longer-range aircraft, such as the B-29 and P-51B.[19] The very long range B-36 was also in development.

World War II bombing campaigns demonstrated how air power could transcend the traditional barriers of space and time. Intercontinental bombers in development would be able to threaten any nation on earth, and the United States would soon be vulnerable as well.[20] The B-36 demonstrated a very long range bomber could be built; however, Air Corps leaders feared the large bomber's slow speed made it extremely vulnerable to enemy air defenses. The Air Corps did not want to re-learn the painful and costly lesson of unescorted bombers over Germany. The requirement to extend the range of fighters presented an even greater technical challenge than extending bomber range, primarily due to the trade off dilemma between speed and range.

In August 1945, Lt Gen Hoyt Vandenberg, Assistant Chief of Staff for Operations, commissioned Air Material Command to study the matter of developing a very long range fighter without sacrificing speed or any other necessary characteristics. He directed three studies be completed. The first was a study of what performance capabilities would have to be sacrificed to realize an unaided 2,500 mile combat radius for a fighter aircraft; the second, focused on examining air refueling fighter escorts; and the third, directed continued study of towing jet fighter aircraft by bombardment aircraft. The sacrificed maneuverability and cost of a very long range fighter made it impractical, however air refueling proved to be the more practical and cost effective solution with no loss in fighter maneuverability.[21] The wing coupling and parasite fighter methods of towing were extremely complicated and no practical solution was found.

In November 1947, the Heavy Bombardment Committee (HBC) reemphasized the importance of high speed as a way of penetrating Soviet air defenses successfully. Studies showed that high speed limited the possibility of attacks to a 55 degree arc of the bomber's tail cone by a forward firing interceptor.[22] Air refueling was to provide the needed range capability. The Committee instructed Air Material Command to develop air-to-air, high capacity, single-point refueling systems and a rendezvous method for all-weather conditions; and as interim solutions, the HBC recommended B-29s and B-36s be modified as tankers for refueling bombers.[23]

In May 1948, Boeing began modifying B-29s with the American version of the British hose system. By the fall of 1949, B-50s refueled by KB-29M tankers were flying training missions at distances over 5,000 nautical miles. These modified KB-29Ms became the core of Strategic Air Command's air refueling capability during the crucial early years of the cold war.

Notes

[1] Major General Perry B. Griffith, "Seven League Boots for TAC," *The Airman*, IV, No. 8 (August 1960), 44.

[2] "Air refueling," "flight refueling," "in-flight refueling," and "aerial refueling" are used interchangeably in the literature of refueling.

[3] Henry H. "Hap" Arnold later became the Commanding General of the Army Air Forces during World War II.

[4] Captain Carroll S. Shershun, "Service Stations in the Sky," *The Airman*, VII (February 1963), 40.

[5] Henry H. Arnold, *The History of Rockwell Field, 1923*, File: 168.65041, M.S. White Papers, USAF Historical Research Agency (HRA), Maxwell Air Force Base, Alabama, 2. Arnold, who observed part of the flight from another aircraft, notes that the actual record flight was delayed by a delay en route over San Francisco to demonstrate the new technique to General "Billy" Mitchell, Assistant Chief of the Air Service, and delegates to the American Legion Convention then being held there.

[6] Vernon B. Byrd, *Passing Gas: The History of In-flight Refueling* (Chico, CA: Byrd Publishing Company, 1994) , 23.

[7] Carl Spatz, *Final Report, The Flight of the Question Mark, January 1-7, 1929*, Carl A. Spaatz Papers, Library of Congress, Manuscript Division (L/MC), Box 110. Dennis Casey and Bud Baker, *Fuel Aloft: A Brief History of Aerial Refueling* (Carlisle Barracks, PA: US Army Military History Institute), 3.

[8] With the limits established by power of the aircraft engine (or engines) to move the aircraft through the air and the resistance or "drag" induced by the passage of the wing through the air, an increase in airspeed generates an increase in the lift produced by the wing. The increase in a wing's lift is proportional to the density of the air and the square of the air speed. To maintain level flight, the lift produced by the wing must equal the gravity force of the aircraft's weight. The important corollary, with important implications for minimum airspeeds at which air refueling must be conducted, is that at a higher wing loading, the wing will stop flying ("stall") at a higher airspeed than at a lower wing loading.

[9] Spaatz, "Flight of the Question Mark." For a summary analysis of the flight and specific problems on which the project participants made recommendations, see Materiel Division Memorandum Report on Refueling of Airplanes in Flight, 23 Feb 1942, in Historical Office, *Case History of Air-to-Air Refueling: Vol. II: Supporting Documents* (Dayton, OH: Air Materiel Command, 1949), File: 202.2-59, Historical Research Agency (HRA), Maxwell AFB, Alabama. (Hereinafter cited as *Case History Supporting Documents*). Volume one of the Case History is a brief narrative based upon analysis of these documents and will be cited as *Case History*.

Notes

[10] Vernon B. Byrd, *Passing Gas. The History of In-flight Refueling* (Chico, California: Byrd Publishing Company, 1994), 47. The team of Dale Jackson and Forest O'Brine set a record over St. Louis of 647.5 hours in July 1930. C. H. Latimer-Needham, Refueling in Flight (London: Sir Isaac Pitman & Sons, Ltd., 1950), 3.

[11] Latiner-Needham, Cecil Hugh, *Refueling In-flight.* London: Pitman, 1950 (AUL No. 629.134), p 3; Byrd, *Passing Gas*, 48.

[12]Byrd, *Passing Gas*, 51-53. Latiner-Needham, Cecil Hugh, *Refueling In-flight.* London: Pitman, 1950 (AUL No. 629.134).

[13] Ltr., J. H. Doolittle to Maj. Gen. H. H. Arnold, 23 Aug 1939. *Case History Supporting Documents.*

[14] Interoffice Memo, Maj H. Z. Bogert, Chief, Experimental Engineering Section, AMC, to Chief, Aircraft Laboratory, AMC, 6 Nov 1939. *Case History Supporting Documents*

[15] Combat radius is the distance from takeoff, complete its mission and return to the takeoff location.

[16] Marcell Size Knaack, *Encyclopedia of U.S. Air Force Aircraft and Missile Systems. Vol II: Post-World War II Bombers, 1945-1973* (Washington: Office of Air Force History, 1988), 5. The initial set of specifications also called for a top speed of 450 mph at 25,000 feet, a 275 mph cruising speed, and a service ceiling of 45,000 feet. These were reduced in August 1941 to the more realistic but still demanding specifications of a minimum overall range of 10,000 miles and an effective combat radius of 4,000 miles with a 10,000 bomb load. The cruising speed required was also reduced to between 240 and 300 mph and the service ceiling was reduced to 40,000 feet.

[17] See Memo Report, Subject: Refueling in Flight, Capt D. L. Yeager, Army Air Forces Engineering Division, 25 June 1943, *Case History Supporting Documents.*

[18] Yeager Report, 25 June 1943, *Case History Supporting Documents.*

[19] MATTERHORN, the B-29 bombing offensive against Japan from Chinese bases approved at the Cairo Conference in late 1943, began with an attack on the Yawata steel works on 15 June. Wesley Frank Craven and James Lea Cate, *The Army Air Forces in World War II, Vol V: The Pacific: MATTERHORN to Nagasaki, June 1944 to August 1945* (Chicago: The University of Chicago Press, 1953), 13-27. By June, 1944, the P-51B was ranging deep into Germany including round-trip escort missions as far as the German capital, Berlin. The P-51 became a true long-range fighter with the "marriage" of the basic North American airframe with the British Merlin 61 engine and the addition of centerline drop tanks. Craven and Cate, *AAF in World War II. Vol VI: Men and Planes* (Chicago: University of Chicago Press, 1955), 218-20.

[20] Air Chief Marshal Sir Philip Joubert, "Long Range Air Attack," in Asher Lee, ed., *The Soviet Air and Rocket Forces* (New York: Frederick A. Praeger, Publishers, 1959) 107. Tu-4s, almost exact copies of the B-29, were coming off five Soviet assembly lines by early 1946

[21] Memo for AC/AS-4 from AC/AS-3, Subject: VLR Fighters, 31 August 1945. *Case History Supporting Documents.*

Notes

[22] Minutes of the First Meeting of the United States Air Force Aircraft and Weapons Board [USAFAWB], 19-22 August 1947. RG 18, 337, Meetings, Box 780, NA II.

[23] HBC Report. "Report on Heavy Bombardment by Heavy Bombardment Committee [HBC] convened to Report to the USAF Aircraft and Weapons Board," 7 Nov 1947. RG 341, DCS/Development, Box 60, NA.

Chapter 4

Global Reach—Global Power is Born

Lucky Lady II Flies Around The World Non-Stop

Between 26 February and 2 March 1949, a B-50A bomber named *Lucky Lady II* became the first plane to fly around the world non-stop. Four in-flight refuelings were conducted by pre-positioned KB-29M tankers, which transferred a total of 49,675 gallons of fuel. The flight started and terminated at Carswell AFB, Texas; and in-flight refuelings were made over Bermuda, Dhahran, Manila, and Hawaii. The flight lasted 94 hours, 1 minute and covered 23,452 miles.[1] Shortly after this flight, Air Force Chief of Staff General Hoyt S. Vandenberg, directed that all future tactical aircraft bought by the USAF would be capable of in-flight refueling.[2]

The Flying Boom

The KB-29M, using the "British System," worked well at speeds less than 190 miles per hour; however, this was the minimum speed at which heavily-loaded B-29s and B-50s could operate. This speed limit was the impetus to develop an alternative refueling method. Boeing proposed the flying boom concept. The proposed system consisted of a telescoping tube, connected to the tanker by a universal joint. The boom could be "flown" into position by the boom operator through the manipulation of a stick in the tanker, which operated two control surfaces or "ruddervators" mounted near the end of the boom. During refueling, the boom operator aboard the tanker maneuvered the tip of this tube into a receptacle aboard the receiver aircraft. A quick- coupling nozzle on the end of the boom made a secure connection, and fuel was dispensed under pressure. The advantages of this system were many: (1) higher rates of fuel transfer; (2) fuel transfer at relatively higher airspeeds; (3) simple contact methods; (4) light weight and ease of equipment installation; and (5) suitability for use with fighter aircraft.[3] This new method was viewed enthusiastically by the Air Force because its simplicity allowed installation in nearly any type of aircraft and promised to be much more operationally suitable for jet aircraft.[4] The first flying boom equipped KB-29P was received on 1 September 1950.[5] A total of 116 B-29s were converted to boom tankers. As a follow on to the KB-29P, Strategic Air Command (SAC) procured a fleet of 814 KC-97 propeller-driven Stratofreighters, with an improved boom system. The KC-97 was an improvement over the KB-29, both in speed and fuel transfer capacity. During the 1950s and early 1960s, KC-97s stood ground alert with the relatively short-ranged B-47s on continental SAC bases and overseas "reflex" bases on Guam, the North African littoral, and in Canada, and Greenland. Air refueling transformed America's intermediate range B-47 into an intercontinental bomber.

Boom-equipped tankers marked the gradual introduction of air refueling capability into fighter aircraft. The first non-stop crossing of the Atlantic by two jet fighters (F-84Es) took place on 22 September 1950 using a wing receptacle developed by Boeing.[6] In July 1952, the 31st Fighter Escort Wing completed a record trans-oceanic mass jet flight of 58 F-84Gs from Turner AFB, Georgia, to Yokota AB, Japan. The flight made seven en route stops and the entire deployment took a total of thirteen days.[7] August

1953 saw the 508th Fighter Escort Wing deploy 17 F-84Gs, non-stop from Turner AFB to RAF Lakenheath, United Kingdom, refueling three times en route, a distance of 4,485 miles.[8]

Although the KC-97 demonstrated that it could refuel jet aircraft, there was a vast difference between tanker and receiver performance capabilities. For jet fighters to fly slow enough, they had to refuel between 13,000 and 16,000 feet, and for the KC-97 to fly fast enough, it used maximum power and a descent. The receiver, despite this "maximum effort" on the part of the tanker, was still just above stall speed, the need for an all-jet tanker was clear. Boeing conducted design studies based on the KC-97, eventually leading to the Model 367-80, a four engine, swept-wing, jet aircraft. The DASH 80 flew for the first time on 15 July 1954. By October, the Air Force had ordered 29 aircraft, based solely on the DASH 80, even before the in-flight refueling capabilities of the aircraft had been demonstrated. The first KC-135A rolled out of the factory in less than two years and made its maiden flight on 31 August 1956. First delivery to the Air Force was on 30 April 1957.[9]

Composite Air Strike Force (CASF)

Seeing the utility of air refueling to enhance strategic mobility, the Tactical Air Command (TAC) developed the Composite Air Strike Force, a small, mobile, nuclear-armed force, capable of responding to any prospective trouble spot in the world. Once there, it was designed to conduct unsupported operations for as long as thirty days.[10] Air refueling was necessary to provide the rapid mobility and flexibility required to deploy overseas directly from continental US bases to areas of tension.

TAC pursued the probe and drogue concept of refueling, rather than SAC's "flying boom" concept. The drogue concept consisted of the tanker extending a hose with a funnel shaped basket attached. The receiver equipped with a refueling probe would fly the probe into the basket to make contact. Once contact was made, fuel would be pumped into the receiver. TAC received their first KB-29P tankers with drogue refueling capability in 1954.[11] These were later replaced, beginning in 1956 by more efficient KB-50s. Jet engines were eventually added to the KB-50 in 1959, to increase its speed and altitude for refueling operations. The KB-50 had a drogue on each wing and along the fuselage, permitting the refueling of three fighters simultaneously. The brand new KC-135As were not available for use by TAC, because they were dedicated to strategic bomber support.

Lebanon Crisis Averted

On 15 July 1958, TAC's CASF concept was exercised for the first time in response to a national emergency—the Lebanon Crisis. The threat of a possible coup against the Lebanese government prompted a request for United States military assistance. TAC alerted the CASF; and within eighteen hours the first flight of four F-100s was in place at Incirlik Air Base, Turkey.[12] "Within sixty hours of the initial alert, a 1,000 man TAC fighting team was deployed and operational in the area. . .forces on the Lebanon beaches were under the watchful eyes of this. . .force, only fifteen minutes away. The shift of military power in the Middle East was complete. A shooting war in the area was averted."[13]

US Strike Command Stands-Up

In 1961, President Kennedy, called for a build-up of flexible, mobile "general purpose" forces to meet the increased threat to US national security that was posed by small conflicts arising in various areas of the world. The result was United States Strike Command (USSTRICOM), a unified command composed of elements of the Strategic Army Corps and the Tactical Air Command.[14] Secretary of Defense McNamara elaborated on the mission of STRICOM, when he said: "The recently created United States Strike Command . . . is intended to provide an integrated, mobile, highly combat-ready force which has trained as a unit and is instantly available for use as an augmentation to existing theater forces under the unified commanders, or as the primary force for use in remote areas. . . ."[15] Strike Command's quick reaction concept was dependent on global mobility, as explained by Major General Clyde Box, former Director of Plans, USSTRICOM: "[USSTRICOM] is vitally interested in all aspects of global mobility. . . . [It] lives with the knowledge that the success of military force when dealing with an international crisis is related directly to the rapidity with which the force is applied. . . ."[16]

The CASF was the first practical application of a concept which has evolved to become today's Air Force concept of Global Reach—Global Power. The idea of rapidly reacting forces deploying anywhere on the globe matured in early 1964, when KC-135s were used on two trans-Atlantic fighter deployments, establishing non-stop distance and time marks. In January, eighteen F-104s flew non-stop from California to Spain, a distance of 6,150 miles, in ten hours and twenty-four minutes. A month later, eighteen F-100s flew from Florida to Turkey on a 6,600 mile, non-stop journey in just under twelve hours.[17] These two historic feats highlighted the vastly improved reaction time possible with KC-135 tankers, versus the KB-50J tanker.[18]

Air Refueling Operations in Vietnam

Air refueling played a new and essential role in operations by tactical aircraft against North Vietnam. Until Vietnam, jet tankers were used only to ferry tactical aircraft overseas. However, during the Vietnam War, pre- and post-strike refuelings became routine. In fact, air refueling was a key factor in the success of air operations in Southeast Asia.[19] Due to the unique nature of the war prior to 1972, only fighter-bombers were used to bomb North Vietnam; and their range was greatly reduced by their heavy bomb loads. The primary aircraft used for bombing North Vietnam was the F-105, with escort provided by F-4 aircraft. Because neither of these planes had the range to reach all of North Vietnam with a full ordnance load and return to their Thailand bases, air refueling was essential to mission accomplishment. Air refueling enabled these aircraft to takeoff with full weapon loads, strike any target in North Vietnam, and still return to home station. In addition, it added flexibility to all missions by allowing for target changes after takeoff, and it permitted second passes on priority targets and loiter capability to attack targets of opportunity. During target ingress/egress, the extra fuel enabled fighters to use afterburners to minimize their exposure to enemy defenses. Finally, air refueling permitted the use of secure bases away from conflict areas, which greatly enhanced the entire tactical force operations and contributed to their mission success.

Without tankers, the whole character of the war would have changed. The politically sensitive B-52s would have required much closer basing to Vietnam, which may not have been diplomatically possible. Tactical fighter missions would have been less effective and far more complicated and hazardous. More ground troops would have been necessary to protect additional bases in South Vietnam. Additionally, it is difficult to conceive of any operation on the scale of Linebacker II without air refueling. Vietnam demonstrated the importance of tankers in conventional operations.[20] By the end of 1966, KC-135A tankers were being utilized in Southeast Asia at a rate of over 1,000 sorties per month and increasing.[21] By the end of the war, in slightly more than 9 years, SAC tankers delivered almost 9 billion pounds of fuel, flew 194,687 sorties, and made 813,878 refuelings.[22]

Notes

[1] Casey and Baker, *Fuel Aloft*, 3.

[2] Colonel Samuel G. Porterfield, USAF, *In-flight Refueling Key to an Immediate Intercontinental Air Force,* Air War College Thesis No. 1018 (May 1955) (AU Document M-32983-U P849i), 8.

[3] James H. Straubel, "If you Can't Beat the Law-Skirt It," *Air Force*, Vol 33, No. 5 (May 1950), 40-41.

[4] Memo for Boeing Airplane Company, Wichita, Kansas, from the Acting Chief, Aircraft and Missiles Section, Procurement Division, AMC, Subject: Contract No. AC-20413, Air-to-Air Refueling "Flying Boom;" *Case History Supporting Documents.*

[5] Casey and Baker, *Fuel Aloft*, 16.

[6] Leverett G. Richards, *TAC--The Story of the Tactical Air Command* (New York: The John Day Company, 1961, 30-31.

[7] *The Air Force Blue Book* (New York: The Military Publishing Institute, Inc., 1960), 366.

[8] Swanborough, *United States Military Aircraft Since 1909*, 416.

[9] A. T. Lloyd, ed., "Thirty Years Young," *American Aviation Historical Society Journal 32*, Fall 1987, 172-3.

[10] Martin Caidin, *The Long Arm of America* (New York: E. P. Dutton and Company, 1963), 31.

[11] Martin Caidin, *The Long Arm of America* (New York: E. P. Dutton and Company, 1963), 50.

[12] General Otto P. Weyland, "The Tactical Air Command," *Air Force and Space Digest*, Vol. 42. No 9 (September, 1959), 118.

[13] General Otto P. Weyland, "The Tactical Air Command," *Air Force and Space Digest*, Vol. 42. No 9 (September, 1959), 118.

[14] "The Tactical Air Command," *Air Force and Space Digest Vol. 47*, No. 9 (September, 1964), 76.

Notes

[15] "Hearings on Military Posture," House Armed Services Committee, 1962, 3296.

[16] Maj General Clyde Box, "United States Strike Command--Stateside and Global," *Air University Review*, Vol XV, No 6 (September-October, 1964) 13-14.

[17] Gibson, Major Billy R., "Casey Lowers the Boom," *Aerospace Historian*, Summer 1968, 17.

[18] "The Tactical Air Command," *Air Force and Space Digest*, Vol. 47, No. 9 (September, 1964), 76.

[19] Charles K. Hopkins, *SAC Tanker Operations in the Southeast Asia War*, AUL 959.7 H793s, Office of the Historian, Headquarters Strategic Air Command (Offutt AFB, Nebraska: 1979), 106.

[20] Charles K. Hopkins, *SAC Tanker Operations in the Southeast Asia War*, 106.

[21] Project CHECO Southeast Asia Report, *Aerial Refueling in Southeast Asia, 1964-1970* (Headquarters, Pacific Air Forces, 17 June 1971), p 39. CHECO Report, *USAF SAC Operations in Southeast Asia. Special Report* (HQS, PACAF, 17 Dec 1969), 47.

[22] Carl Berger, ed., *The United States Air Force in Southeast Asia, 1961-1973: An Illustrated Account* (Washington: U.S. Government Printing Office, 1984), 209.

Chapter 5

Air Refueling Enhances Airlift

Operation Nickel Grass: The 1973 Israeli Airlift

The 1973 Arab Israeli conflict demonstrated the need for refuelable airlift aircraft. After just a few days of intense combat, Israel was running low on air to air missiles and spare parts. Israel needed resupply very quickly, but did not possess the necessary airlift to handle the resupply tonnage. Sealift would have taken about 30 days to generate the necessary lift, with an additional 12 to 14 days transit time. Israel needed the equipment much faster. United States strategic airlift was the only viable alternative. Due to the political nature of the war, the only European country to allow en route basing was Portugal. The other NATO countries feared the Arab nations would cut off their oil supplies. This left the US with only one en route base, Lajes Field, Azores, in the middle of the Atlantic. Lajes could only handle 25 C-141 and 5 C-5 aircraft on the ground at the same time. The lack of additional en route bases created a significant bottle neck in the resupply effort.

Operation Nickel Grass highlighted a shortfall in United States strategic airlift capability— dependence on en route basing. Air refueling could have alleviated this shortfall to a degree. At the time Military Airlift Command's C-5 aircraft were air refuelable; however, there was concern whether the C-5 wing could handle the aerodynamic stress of heavyweight air refueling. Studies completed after Nickel Grass, demonstrated air refueling would have actually been less stressful than the maximum gross weight takeoffs accomplished instead. Additional studies showed that air refueling would have increased the tonnage per sortie, reduced the number of missions required, and delivered the cargo faster.

Table 1. Potential Airlift Enhancement Using Air Refueling in the 1973 Israeli Airlift

En route Bases	C-5 Payload (Tons)	C-141 Payload (Tons)	C-5 Missions Required	C-141 Missions Required	C-5 Hours En Route	C-141 Hours En Route
No en route bases	33.5	0	659	0	12.0	12.0
Lajes only	74.3	27.6	145	421	16.0	16.0
Air Refueling	107.4	32	101	364	12.0	12.0
Potential Savings	33.1	4.4	44	57	4.0	4.0

The table above demonstrates the force multiplying effect of air refueling on payload and speed. Together these savings produce a dramatic difference in airlift effectiveness and efficiency. By combining the increased tonnage per sortie and reduced transit time, C-5 efficiency is increased by 93 percent and the C-141 by 55 percent.[1] During the latter 1970s, Military Airlift Command modified all C-141s for air refueling. Today all of Air Mobility Command's strategic airlifters are air refuelable.

Operation Restore Hope and Support Hope

Air Force tankers and airlifters teamed up during Operation Restore Hope, the US led United Nations marathon relief mission to Somalia, in an unparalleled partnership that proved reassuring to US military planners. It marked the first time new Air Mobility Command was able to take advantage of the synergy between tankers and strategic airlifters.[2] Restore Hope's collaboration of tankers and airlifters is seen as the prototype for future expeditionary force operations. The tanker bridge for Somalia extended nearly halfway around the world and demonstrated that air refueling is a greater force multiplier than previously realized.[3]

During Operation Support Hope, a humanitarian mission to help millions of dying Rwandan refugees in Central Africa, KC-10s ferried jet fuel to replenish ground fuel tanks at Entebbe, Uganda, because the airport's fuel capacity was too small to accommodate around-the-clock airlift operations.[4]

Nickel Grass, Restore Hope, and Support Hope all demonstrated the tremendous force multiplication possible using air refueling. Besides the dramatic increase in airlift speed and efficiency, air refueling can alleviate political basing issues, shortages of in-theater fuel supplies, limit the impact of C-5 maintenance reliability, and reduce dependence on en route support facilities.[5]

Notes

[1] *[(Payload per sortie air refueled) x (hours en route/24)] - [(payload per sortie unrefueled) x (hours en route/24)]* (payload per sortie unrefueled) x (hours en route/24)

[2] James W. Canan, " Model for Mobility," *Air Force Magazine*, September 1993, 34.

[3] James W. Canan, " Model for Mobility," *Air Force Magazine*, September 1993, 34.

[4] Vago Muradian, "Tankers. . . Why They're So Important--and So Unappreciated, *Air Force Times*, 6 February 1995, 12.

Notes

[5] Lt Gen Charles T. "Tony" Robertson, USAF, Air Mobility Command, Vice Commander stated in a lecture to Air War College, 5 Apr 1996, the C-5's takeoff reliability rate is less than 70 percent. By eliminating just one en route stop, efficiency increases by over 30 percent.

Chapter 6

Desert Storm

Air refueling facilitated two aspects of the Gulf War—the speedy deployment of large air forces to the region and the employment of these forces in large and complex air combat operations. US tankers included approximately 260 USAF KC-135s and KC-10s—almost half of the US fleet.[1] In addition, 20 Marine Corps KC-130 tankers and 15 carrier-based Navy KA-6 tankers were used in theater. Coalition allies provided an additional 40 tankers from the United Kingdom, Saudi Arabia, Canada, and France. Together these tankers provided a ratio of about one tanker for every six receivers and averaged 360 tanker sorties per day. SAC tankers refueled an average of 1,433 aircraft a day. The coalition offloaded over 700 million pounds of fuel during roughly 50,000 refuelings to about 2,000 receiver aircraft during the 43 days of combat.[2] Of the total number of Desert Storm sorties by category, air refueling ranked third, behind attack and airlift, and USAF tankers accounted for 90 percent of that number.[3]

Air refueling enabled fighter and bomber squadrons to deploy non-stop from the US to the Southwest Asia theater, many loaded with munitions; more than a thousand US aircraft were deployed this way. It took nearly 100 tankers, operating out of en route bases, to create the Atlantic and Pacific air refueling bridges. Fighters deploying to Saudi

Arabia from the US flew 6,900 nautical miles, took 15-16 hours to get there, and required from 7 to 15 refuelings en route.[4]

Operation Desert Shield/Storm involved the largest airlift in history over a short period of time.[5] To get everything to the Persian Gulf quickly, airlift planners used tankers to refuel the continuous stream of strategic airlifters en route to the region.[6] Airlift transported the first combat forces and initial cargo non-stop to Saudi Arabia, demonstrating US resolve. Tankers supported this continuous air flow to Saudi Arabia from August to November 1990, refueling an average of 65 airlift missions per day until hostilities began, and then refueling approximately 125 airlift missions per day until the cease fire.

During the war, USAF tankers flew "...almost 14,000 combat sorties while transferring about 725 million pounds of fuel to roughly 50,000 receiver aircraft."[7] Nearly 60 percent of all employment sorties required tanker support.[8] Tankers increased both speed and mass of the attacks and provided a margin of safety.[9] Air refueling not only extended the range of attack aircraft, it permitted formation of large strike packages, and continuous airborne control and surveillance of battle areas. The distances to some Iraqi targets required many US aircraft to refuel at least twice—once en route to the target and again on the return leg to home base. To get an appreciation for the war's dependence on air refueling, the following table lists representative aircraft and their respective target areas:[10]

Table 2. Aircraft Target Areas

Aircraft	Combat Radius	Target Distance
F-117	550nm	to Baghdad—905nm
F-15E	475nm	to Western Scud areas—680nm
F/A-18	434nm	Red Sea Carrier to Kuwait City—695 nm
B-52G	2,177nm	Diego Garcia to Kuwait—2,500nm

Without extensive tanker support, the character of the entire war would have been different. Initial deployments to the theater would have been delayed, placing an increased burden on en route bases and logistical support, and delaying force closure by up to three months. F-117s could not have attacked Baghdad on the opening night without air refueling. Every dimension of the air campaign would have been altered, from the number of sorties per day to the operating bases used. In short, this air campaign was clearly tanker dependent.

After the war, the Air Force Chief of Staff, General Merrill A. McPeak noted that "the tanker contribution to Desert Storm is what made [the air campaign] work."[11] "...no tankers...no Desert Storm."[12] Without the significant level of air refueling support provided during Desert Storm, the tempo and intensity of the air campaign would have been substantially diminished. Air refueling was the limiting factor for air operations and the key Coalition air capability without which, the Gulf War Airpower Survey concluded "...the air campaign could not have been conducted successfully."[13] While available combat aircraft could have generated more sorties, the number of tanker aircraft in theater could not be increased because both bases and airspace were saturated with aircraft.[14] As a result, the CENTAF Deputy Chief of Staff for Operations was forced to cancel some strike packages and decrease the size of others to match the tanker sorties available. In the judgment of CENTAF officials "...tankers were the most critical limitation."[15]

Paradoxically, tankers often returned to base with a large amount of unused fuel. Almost 40 percent of the fuel available for offload went unused.[16] "Throughout the war, more fuel was requested [by tactical mission planners] than was actually required, as evident in the large number of aircraft that failed to show up for their post-strike refueling or needed much less fuel exiting Iraq than had been estimated."[17] Planners often based receiver fuel estimates on "...a worst case scenario—factoring in low-altitude operations, battle-damaged fuel tanks, threat evasion, and extra time over the target."[18] The excessive fuel requests by some users, limited the fuel available to generate additional combat missions.[19] To prevent reoccurrence in the future, an audit process should be instituted to validate receiver fuel requirements to improve tanker utilization efficiency and maximize combat sortie generation.

Tanker planners were also limited to the number of fighters each tanker could handle at one time. Usually no more than six F-16s were assigned to one tanker, and never more than eight. Six F-16s taking gas both pre and post-strike were normally scheduled for 60,000 lbs (only half of the available offload for a KC-135R).[20] Refueling time—not quantity is frequently a limiting factor during tactical fighter employment, since fighters require small offloads in a compressed time period.

To improve the efficiency of refueling operations air-refuelable tankers could be used as fuel depositories. By consolidating extra fuel on to an air-refuelable tanker, non-refuelable tankers can "bingo" and return to base.[21] The air-refuelable tanker can then loiter on station providing unscheduled opportune refuelings to accommodate unforeseen requirements like combat search and rescue support. This technique was used on a limited basis with KC-10 tankers during Desert Storm.

Notes

[1] Thomas A. Keaney and Elliot A. Cohen, *Gulf War Air Power Survey Summary Report*, Air University, Maxwell AFB, AL, 1994, p. 190. United States General Accounting Office, *Report to Congressional Requesters: Operation Desert Storm--An Assessment of Aerial Refueling Operational Efficiency*, GAO/NSIAD-94-68 Operation Desert Storm (Washington: General Accounting Office, 15 November 1993), 2. The US total included 260 KC-135 and KC-10 tankers. This figure includes all tankers situated in theater, including those at Diego Garcia; tankers at Incirlik, Turkey, supporting air strikes against northern Iraq; and tankers supporting
B-52 attacks from European bases.

[2] United States General Accounting Office, *Report to Congressional Requesters: Operation Desert Storm--An Assessment of Aerial Refueling Operational Efficiency*, GAO/NSIAD-94-68 Operation Desert Storm (Washington: General Accounting Office, 15 November 1993), 1.

[3] Thomas A. Keaney and Elliot A. Cohen, *Gulf War Air Power Survey Summary Report*, Air University, Maxwell AFB, AL, 1994, p. 190.

[4] Thomas A. Keaney and Elite A. Cohen, *GWAPS Summary Report*, 190-1.

[5] *Desert Shield/Storm, Air Mobility Command's Achievements and Lessons for the Future*, US Congress, Senate, Report to the Chairman, Committee on Armed Services, Junuary 1993, 3. Airlift flew a total of 15,800 missions and carrying 544,000 tons of cargo--about 15 percent of the total dry cargo--and 501,000 passengers to the theater of operations.

[6] Vago Muradian, "Tankers. . . Why They're So Important--and So Unappreciated, *Air Force Times*, 6 February 1995, 12.

[7] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), 4.

[8] Thomas A. Keaney and Elite A. Cohen, *GWAPS Summary Report*, 228.

[9] Thomas A. Keaney and Elite A. Cohen, *GWAPS Summary Report*, 228-9.

[10] Thomas A. Keaney and Elite A. Cohen, *GWAPS Summary Report*, 228

[11] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), 4.

[12] General Merrill A. McPeak, USAF, *Selected Works 1990-1994* (Maxwell Air Force Base, Alabama: Air University Press, August 1995), 148.

[13] The SAC tankers utilized included 29 KC-10's, and 193 KC-135's deployed in the area of operations (AOR) at the peak of DESERT STORM with another 17 KC-10's and 69 KC-135's operating in direct support from outside the AOR. *Gulf War Air Power Survey, Vol IV: Weapons, Tactics and Training* (Washington: U.S. Government Printing Office, 1993), p 361, fn3. The problem was not lack of tankers but congested airspace that precluded establishing more tanker refueling orbits. *GWAPS, Vol III: Logistics and Support*, 179.

Notes

[14] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), p 11, fn 11. Although a shift to an orbit structure was considered during the first week of the war, the track structure was kept largely intact due to concern over congestion near the Saudi-Iraq border and the F-16s' need for fuel soon after takeoff (the F-16 was trading weapons for fuel). Some officials argued that greater reliance on orbits would have reduced the serious airspace congestion, made it easier to respond to the fluid battlefield environment, and probably have allowed requirements to be met with fewer tankers.

[15] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), 4. Early in the war, the CENTAF commander suggested that tankers stay on station longer if they still had a considerable amount of fuel available. This option was opposed by tanker planners because if a tanker delayed his return to base, it might not be available for its next scheduled mission. The snowball effect from numerous such changes was deemed unmanageable.

[16] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), 5.

[17] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), 7.

[18] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), 7.

[19] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), 16.

[20] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), 9.

[21] "Bingo" refers to the minimum fuel necessary to return to base with sufficient fuel reserves.

Chapter 7

US National Military Strategy

> *"Any time we have to take an action, we will have to move a force very, very quickly. From a strategy standpoint, I see transportation being of increased importance...our nation must be prepared with little or no warning to project significant US forces great distances to areas that may have little or no infrastructure."*
>
> —General Hansford T. Johnson, CINC, USTRANSCOM [1]

History has demonstrated since World War II, a growing dependence on air refueling. During the Cold War, the US national military strategy was based on nuclear deterrence and the United States' ability to attack, with nuclear weapons, strategic targets deep within the Soviet Union using intercontinental bombers. The Soviet Union's immense size, in addition to the cost of maintaining overseas bases, dictated the requirement for US-based very long-range aircraft. The Strategic Air Command used in-flight refueling to provide the necessary range extension for its bomber and escort fighter aircraft to reach targets within the Soviet Union.

During the Cold War, USAF tankers were assigned the primary mission of supporting SAC's strategic bombers, and gradually were made available for tactical missions as strategic bomber requirements were reduced. Beginning in the early 1960s, the Defense Department began diversifying the nuclear force structure into a mix of bombers, land based missiles, and submarine launched missiles. This force mix, called the Triad, ensured the survivability and effectiveness of US nuclear retaliatory strike capability to accomplish the US national military strategies of massive retaliation and later mutual assured destruction. As the number of nuclear missile warheads on alert increased, the number of bombers required was reduced. This freed up aerial tankers for fighter deployments and regional contingencies. The Strategic Arms Limitations Treaties (SALT I and SALT II), in conjunction with the more recent Strategic Arms Reduction Treaty (START) have resulted in a continued bomber drawdown, freeing up more tankers for fighter and now airlift support, as well as utilizing the KC-135 in its airlift role.[2]

Following the dissolution of the Soviet Union, the collapse of the Berlin Wall, and the end of the Cold War, the US national security strategy changed dramatically. During the Cold War, threats to America's vital interests were easily defined in the context of a bipolar world. Today, America lives in a multipolar world, where the existence of the United States is not directly threatened, however widespread regional disputes and ethnic rivalries threaten the security of our economic trading partners. These indirect threats are menacing yet less predictable and cover a wide spectrum, from regional instabilities like Bosnia, to transnational threats like illegal drug trafficking.

At the same time, the shrinking defense budget necessitated the closure of expensive overseas bases and a drawdown in military force structure. Since Operation Desert Storm in 1991, 867 overseas bases have closed and 12 more will close by the end of 1996.[3] Today, less than 10 percent of the active military force is stationed overseas, compared to over 30 percent in 1988. In addition, the total force size has been reduced over 25 percent since 1990, and budget estimates predict a continued reduction in force size. The importance of rapid strategic mobility as an instrument of national power is apparent, particularly as the overall size of US military forces decrease, and the availability of forward bases become less certain. To project US forces rapidly, aerial refueling has become a necessity. In fact, aerial refueling may be the only means of deploying tactical aircraft or providing the necessary range to airlift forces if access to en route bases is denied.[4] As a result the United States has adopted a military strategy based on two strategic concepts, overseas presence and power projection.

Power projection is accomplished by the rapid deployment of military forces in response to a military contingency or as a show of force. Future conflicts will require the simultaneous deployment of several tactical fighter squadrons. The ability to deploy these forces quickly remains directly dependent on aerial refueling. Strategic mobility has emerged as the critical component of America's national security strategy.[5] Additionally, a flexible, mobile, rapidly deployable military force is closely aligned with the American defensive ethos and how Americans respond to aggression. Americans ". . . react to aggression; we respond to attack; if the United States goes into military action, we do so as a result of an alien initiative. It is this fundamental characteristic of our national policy which. . .establishes the requirement for global mobility of our military forces."[6] American economic prosperity depends on regional stability and the unimpeded access to global markets. Today, responsive Global Reach—Global Power enables the US to help friends and subdue enemies within hours.

Notes

[1] Steven M. Powell, "They Deliver," *Air Force Magazine*, August 1991, 52.

[2] "Roll 'Em On In!" *Air Mobility Forum*, July-August 1993, 9. Since the Gulf War, AMC's KC-135s are relieving a tired C-5 and C-141 fleet of some of its airlift missions with the command's initiative to make loading cargo less arduous. The addition of a snap-on pallet roller system in 1993 made this possible. This system opened more airlift

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possibilities for the tankers by allowing them to interface with other cargo aircraft of the AMC fleet. Tankers have been using their roller system to fly selected channel missions throughout the world.

[3] Lieutenant General Charles E. Wilhelm, US Marine Corps Forces Atlantic Commander, Lecture on "Marine Expeditionary Forces," Air War College, Maxwell AFB, Alabama, 29 March 1996.

[4] Thomas C. Reed, "Secretary of Air Force Authorization Request," *Air Force Policy Letter for Commanders*, Supplement No. 3-1976 (Washington: Internal Information Division SAFOII, Pentagon).

[5]Lt Gen Charles T. "Tony" Robertson, USAF, Air Mobility Command, Vice Commander stated in a lecture to Air War College, 5 Apr 1996. Since 1990, Air Mobility Command has operated at or near its wartime tempo, currently operating at an 85 percent commitment rate.

[6] Lt Gen James Ferguson, USAF, "U.S. Is Dependent On Global Military Mobility," *Supplement to the Air Force Policy Letter For Commanders*, No. 12 (November, 1964), 14.

Chapter 8

Ten Propositions Regarding Air Refueling

This examination of air refueling in the context of air power theory, history, and strategy, has set the stage for presenting ten propositions, or ten "central beliefs," regarding air refueling doctrine.[1] To date, very little has been written on air refueling doctrine, even *AFM 1-1, Vol. I, Basic Aerospace Doctrine,* March 1992, devotes only one short paragraph to air refueling:

> "**Sufficient air refueling capability must be available to exploit aerospace power's unique flexibility**. The ability of aerospace power to concentrate force anywhere against any facet of the enemy may depend on sufficient air refueling capability."

AFM 1-1, Vol. II, a 300 page companion to Vol. I, provides clarity and support for the doctrinal statements in Vol. I, yet devotes less than a page to air refueling doctrine buried within an essay on "Aerospace Force Enhancement." Much work needs to be done in codifying air refueling doctrine. The ten propositions presented in this paper are not intended to be a complete list, but rather a stimulus for further study and codification by others.

1. Air refueling enhances air power's inherent strengths.
2. Air refueling mitigates air power's inherent weaknesses.
3. Air refueling serves as a force multiplier.
4. Air refueling aircraft are high value strategic assets.
5. Air refueling operations require local air superiority.
6. The number of tankers required depends on theater basing, tempo, and threat.

7. Tanker assets should not be based near the forward edge of the battle area (FEBA).
8. During air bridge operations, "fuel in the air" is the limiting factor.
9. During tactical aircraft employment "booms in the air" becomes the limiting factor.
10. Air refuelable tankers enhance air refueling efficiency..
    a. Air refueling enhances air power's inherent strengths.

1. Air refueling enhances air power's inherent strengths.

Speed, range, flexibility, and versatility are the inherent strengths of air power.[2] Air refueling increases speed by eliminating en route stops during deployment missions and by permitting the extended use of high power settings by tactical aircraft during employment missions. Air refueling extends range to the limit of the aircrew. Air refueling enhances flexibility a number of ways: by increasing loiter time over the target; by increasing tactical options for ingress and egress; by permitting large formations to mass in the air without sacrificing range; by expanding in-theater basing options for tactical aircraft; and by reducing the dependence on en route and forward bases. Air refueling enhances versatility by making strategic targets accessible to tactical aircraft.

2. Air refueling mitigates air power's inherent weaknesses.

Air power is inherently non-persistent in the battle space as compared to land, sea, and geosynchronous space forces.[3] Aircraft expend energy just to stay airborne as opposed to surface forces which expend little or no energy when stationary in the battle space. It could be argued that a nuclear alert bomber exerts a persistent threat of force from a continent away, however, the persistence quality referred to here, is the ability to occupy territory or control a geographic area. Using air refueling, aircraft can loiter longer increasing their persistence in the battle space.

3. Air refueling serves as a force multiplier.

Air refueling serves as a force multiplier by expanding the reach and combat power of air forces. Without air refueling, a combat air patrol can stay on station approximately one to two hours. During Desert Storm, F-15s used air refueling to stay on station for eight hours, that is a four fold increase. The combat power of one squadron of F-15s with air refueling is roughly equivalent to four squadrons of F-15s without air refueling. Additionally, air refueling increases combat lethality. For example, one aircraft with a maximum weapons load in conjunction with air refueling, can produce the same combat power as two fighters with maximum fuel loads and reduced weapons loads attacking the same distant target.

4. Air refueling aircraft are high value strategic assets.

As a force multiplier, the tanker's value may best be described by its absence. Without air refueling, overseas deployments would take days rather than hours. Tactical fighters would be based closer to enemy territory and most likely within easy reach of enemy air power. Enemy offensive counter air attacks would likely degrade friendly sortie production. Four squadrons of F-15s would be needed to provide the same defensive counter air coverage as one squadron with tanker support. F-117s would not be able to reach deep strategic targets. Instead, these deep targets would be assigned to vulnerable, unescorted, long range bombers. Weapon loads would be reduced to extend aircraft range. Airborne warning and control aircraft would be unable to provide a continuous air picture. These examples illustrate how the loss of tanker assets, would mean a dramatic reduction in mobility and combat capability. Air refueling definitely multiplies combat reach and power, sometimes exponentially.

5. Air refueling operations require local air superiority.

KC-135s and KC-10s are extremely vulnerable to enemy air attack, since neither possess onboard sensors to detect an attack, or active self-defense equipment to thwart an attack in progress. Additionally, air refueling operations normally require straight and level flight, shallow turns, and precision flying to maintain contact. Maintaining contact while taking evasive action is extremely hazardous. If the air refueling formation breaks up due to attack, reforming the flight would require extensive time, and may require the receivers to abort their missions.

6. The number of tankers required depends on theater basing, tempo, and threat.

Theater tanker requirements depend on several issues. Tanker basing is dictated by available airfields and the threat. The air refueling track location is dictated by the threat, the mission, and receiver basing. Receiver fuel requirements, receiver/tanker ratio, time on station, and distance to the air refueling track are necessary to determine tanker requirements. Theater operations tempo may also dictate additional tankers. For example, if refueling requirements are spread around-the-clock, tanker airframes maybe able to fly more than one sortie per day. However, if only night operations or surge operations are conducted, it maybe impossible for a tanker to fly one mission, regenerate, and launch on a second mission within the surge window.

7. Tanker assets should not be based near the forward edge of the battle area (FEBA).

The tanker's value as a strategic asset and force multiplier make it a high value target. Basing tankers near the FEBA exposes them to degraded operations or physical destruction by surface or air threats, while only marginally improving their offload potential. Degraded tanker sortie production will significantly degrade the overall combat reach and power of theater air forces. The risk/reward tradeoff of exposing long-range, high-value assets to attack, for an insignificant increase in offload capability is normally unwarranted. Additionally, maximum "fuel in the air" is rarely the limiting factor in tactical fighter employment operations, rather "booms in the air" is normally the limiting factor.

8. During air bridge operations, "fuel in the air" is the limiting factor.

When conducting air bridge operations, receiver aircraft stay with the tanker for multiple refuelings during the entire mission. Refuelings are not time constrained. Receivers cycle through the boom, topping off their tanks throughout the flight. These small offloads accumulate into a large total offload for each receiver. If one tanker cannot offload sufficient fuel, an additional tanker will be added to the formation to increase "fuel in the air."

9. During tactical employment "booms in the air" becomes the limiting factor.

During tactical fighter employment missions, refueling time is constrained, because fighters normally want to depart with full tanks in formation. During Desert Storm, large fighter force packages were used to overwhelm and penetrate enemy air defenses, gain local air superiority, and attack ground targets during a short period of time.[4] Because of refueling time constraints and safety considerations, receiver/tanker ratios limit the number of receivers per tanker. For example, normally only 4 F-16s can safely share the same tanker at one time during night operations. If the force package size exceeds the maximum receiver/tanker ratio, an additional tanker will be necessary to increase the "booms in the air." Multi-point drogue tankers can alleviate this problem for probe equipped receivers. For example, the KB-50 could refuel three probe equipped fighters simultaneously.

10. Air refuelable tankers enhance air refueling efficiency.

Air refuelable tankers dramatically enhance force extension operations and employment operations. During Operation Desert Storm, limitations on receiver/tanker ratios caused KC-135 tankers to return to base on average with almost 40 percent of their available offload unused.[5] Tankers could not delay on station, because the airframes were needed to generate follow on missions.[6] In some cases, tankers with excess available offload, passed it to air refuelable KC-10s, which normally had longer loiter times, and the KC-10s could then cover for a no-show tanker or pass it on to unscheduled receivers. Consolidating excess available offloads on to one tanker maximizes the fuel available on station, greatly enhancing the efficiency of tanker operations.

Air refuelable tankers also increase the efficiency of air bridge operations through force extension. For example, one deploying escort tanker can be refueled by a round-robin tanker, permitting the air refuelable tanker to satisfy the receivers' total offload, enabling the other tanker to return to base for regeneration. Without an air refuelable tanker, the same mission would require three tankers instead of two. These examples demonstrate how air refuelable tankers can add considerable efficiency to tanker operations.

Notes

[1] The idea of presenting Ten Propositions Regarding Air Refueling comes from a similarly titled book, *Ten Propositions Regarding Air Power*, by Col Phillip S. Meilinger, USAF. A well written, pocket size guide to the central beliefs of air power doctrine.

[2] AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force,* Vol. 1, March 1992, 5.

[3] Geosynchronous space forces are artificial satellites orbiting 24,000 miles above the equator traveling at the same speed as the earth rotates so that the satellite seems to remain in the same place above the earth. Satellites at other altitudes and declinations will not remain stationary over the same point on earth.

[4] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), 9.

[5] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), 5.

[6] GAO, *Aerial Refueling Operational Efficiency*, (GAO/NSIAD-94-68), p 4, fn 6.

Chapter 9

Conclusion

"As the defense budget comes down, we have to remember that our new strategy will not be worth the paper it's written on without mobility." [1]

—General Ronald Fogleman, USAF Chief of Staff

Air power theory, history, strategy, and doctrine, demonstrate the strength global mobility offers America. Responsive global reach—global power is vital to the national military strategy of the Unites States and made possible through air refueling. Air refueling enhances America's ability to rapidly respond to any contingency across the spectrum of conflict. As a force multiplier, tankers provide speed, range, flexibility, and versatility to airlifters, fighters, and bombers. Air refueling extends the range and presence of Air Force assets, while at the same time reducing reliance on forward basing and overflight rights.

The tanker force provides rapid power projection to fighters and bombers, and force extension to tankers and airlifters. This capability enhances strategic flexibility by decreasing reliance on overseas staging bases, host nation support, and reduces the time necessary to deploy combat forces into theater. Additionally, air refueling increases payload capability for long-range missions by minimizing the trade-off between weapons and fuel, or cargo and fuel.[2] As was demonstrated in Operations Desert Shield and Storm, air refueling served as a force multiplier, expanding both the combat reach and combat power of US and coalition forces. This support included long-range air refueling support of strike forces coming from outside the theater or even from the US mainland. The continued emphasis on rapid conventional force projection to subdue regional threats will continue to place a high demand on America's air refueling assets.

There is much work to be done in the area of tanker doctrine. The ten propositions regarding air refueling presented in this paper, require further study and codification within Air Force Basic Doctrine or Air Mobility Operational Doctrine. When airmen understand how best to employ air refueling assets, the result will be an exponential increase in combat reach and power. Tanker aircrew members and maintainers can be proud of their heritage, their mission, and their impact on national military strategy. Air refueling is the cornerstone of Global Reach—Global Power.

Notes

[1] Steven Watkins and Vago Muradian, "Will Airlift Missions Wear Out the Force?" *Air Force Times*, 15 August 1994, 16.

[2] *Air Mobility Master Plan*, HQ AMC/XP, 1995, Air Refueling Mission Area Plan, 1-7.

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