The Death of "Superman": The Case Against Specialized Tanker Aircraft in the USAF

BY

THOMAS L. GIBSON

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ABOUT THE AUTHOR

Major Thomas L. Gibson is a 1988 graduate of the United States Air Force Academy, Colorado Springs, Colorado. Graduating from Undergraduate Pilot Training in 1989, he was selected to return to Columbus Air Force Base, Mississippi flying T-37s as an instructor pilot. In 1992 he transitioned to C-5s flying out of Travis AFB, California as a first pilot, aircraft commander, and instructor pilot. In 1999, following a tour flying gliders and motorgliders at the Air Force Academy, he was selected for the Air Mobility Command crossflow program and was stationed at McConnell AFB, Kansas. Major Gibson upgraded to instructor pilot and was qualified in the Special Operations Air Refueling program. He attended the US Army Command and General Staff College, graduating in 2001. Major Gibson is a senior pilot with over 2,600 flying hours. He holds a bachelor's degree in English from the Air Force Academy and a master's degree in Management from Colorado Christian University. In July 2002, Major Gibson was assigned to the Headquarters Air Combat Command.

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ABSTRACT

This thesis analyzes the need for a comprehensive recapitalization of United States Air Force air refueling capabilities. The end of the Cold War resulted in an uncertain international security environment devoid of a monolithic threat. While adjusting to its role as the world's sole superpower, the United States adopted an attitude of global responsibility, resulting in increased commitment of military forces. Subsequent deployments have taxed the core USAF tanker, the KC-135, to near critical levels, generating the recapitalization need. Conclusions are based on the synthesis of historical trends, organizationally endorsed material, and a feasibility-acceptability-adequacy model. Five options, including staying with the current tanker force, modifying commercial aircraft, acquiring an all-new tanker, civilian contract refueling, and unmanned aerial tankers are assessed. The resulting combination of dynamic and static analysis reveals the need for a paradigm shift regarding the USAF tanker fleet. The USAF should not acquire specialized tanker aircraft to meet its needs. There has been a migration away from specialized tanker platforms to multi-role aircraft for decades. Future concepts of operations will continue to demand a robust, capable tanker fleet. In order to meet future needs, the USAF should continue to maintain its current fleet, despite unplanned maintenance delays, acquire an interim capability in the form of a commercially modified tanker, and begin the acquisition process on a KC-X next generation tanker. This study concludes, however, that each of these steps should occur within the context of the new paradigm such that the aircraft are employed as communications relays, reconnaissance platforms, or any number of other primary roles and perform the refueling mission secondarily.

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Chapter 1

Introduction

The end of the Cold War found the United States struggling to define its role as the world's sole superpower. In the process, the American military became a victim of its own success.[1] The size and composition of the armed forces had been predicated on the Soviet threat. With that once formidable menace effectively overcome, the Defense Department (DoD) undertook a series of reviews in search of an appropriate force structure for a wholly uncertain international security environment.

The first comprehensive review took place in 1991, amid the aftermath of the Gulf War.[2] This Base Force Review was a cautious step toward drawing down military force levels, but remained focused on a resurgent Russian threat. It stayed with the extant forward basing policies designed to contain regional crises and effected little change in defense spending. Next, in 1993, the DoD initiated the Bottom-Up Review (BUR), but it too was based on cold war assumptions. The concept of fighting two almost simultaneous Major Theater Wars was introduced, but the BUR also failed to adjust the defense spending bottom line. It did, however, call for significant force reductions. In May 1995 the Congressionally mandated Commission on the Roles and Missions of the Armed Forces attempted to address concerns over infighting among the uniformed services. Some force reductions were recommended, but again, Cold War paradigms refused to be thrown off. The final manifestation is the current Quadrennial Defense Review, mandated at the beginning of each Presidential administration to establish a comprehensive blueprint for America's military. Although there have only been two, one in 1997 and another in 2001, the DoD appears to be making inroads toward change. With continual reductions recommended by each study, the end result of this series of reviews is a significantly smaller US military.[3]

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[1] Dennis M. Drew, "The Essence of Aerospace Power." *Aerospace Power Journal,* 15, no. 2 (Summer 2001): 23.

[2] "The Quadrennial Defense Review: A Sense of *Déjà vu,"* (Washington, D.C.: Center for Defense Information 25, no. 2 March 1997), on-line, Internet, 17 June 2002, available from http://www.cdi.org/dm/1997/issue2/index.html.

[3] In *NATO's Air War for Kosovo,* RAND author Benjamin Lambeth writes, "During the initial post-cold war decade of the 1990s, the US active-duty force in all services shrank by 800,000 personnel to 1.4

Despite this draw down of forces, the 1990s were a time of almost continual commitment for the US military.[4] From major theater war efforts in Southwest Asia to peacekeeping in the Balkans to disaster relief efforts around the globe, the US military deployed more in the eight years from 1993 to 2001 than at any other time in its history.

Reflecting the wide variety of circumstances in which it was called to participate, the US Air Force struggled to establish a consistent vision for itself. In the decade of the 1990s three different Air Force vision statements appeared: "Global Reach, Global Power" in 1990; "Global Engagement" in 1996; and "Global Vigilance, Reach, and Power" in 2000.[5] While the language continually changed, the one consistent focus was the global nature of the USAF mission.

Regardless of the nature of the tasking, US forces were predominantly employed from bases in the continental United States (CONUS). The substantial deployment requirements in support of military operations overseas weighed especially heavy on the USAF. This meant that airpower--with its unique ability to be engaged in a matter of hours rather than days, reduced probability of US casualties and equipment losses, and sheer effectiveness--had become the instrument of choice for defending US interests abroad.

Although it has many advantages, there are limitations on airpower that must be taken into account for its effective employment. First, airpower is expensive. The aircraft, munitions, and logistic support required for effective employment are costly – targets engaged are often less valuable in economic terms than the munitions selected to destroy them. Moreover, airpower cannot hold ground, often necessitating the commitment of land forces to insure desired end conditions are achieved. Finally, and most significantly, despite claims of long-range operations, no fighter, bomber, or airlifter can remain airborne indefinitely. They all require substantial tanker support to satisfy their potential. Regardless of the type of operation, from major theater war to

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million, a reduction of more than one-third. The Army was cut from 18 to 10 active divisions, the Navy diminished in size from 567 ships to just over 230, and the Air Force lost half of its 24 fighter wings." Benjamin S. Lambeth, *NATO's Air War for Kosovo: A Strategic and Operational Assessment*, RAND Report MR-1365 (Santa Monica: RAND, 2001), 170.

[4] For a listing of military deployments contrasted with declines in military expenditures, see Bradley Graham and Eric Pianin, "Military Readiness, Morale Show Strain; Budgets Contract; Deployments Expand," *Washington Post*, 13 August 1998, final ed., A1, on-line, Lexis-Nexis, 10 June 2002.

[5] Drew, "The Essence of Aerospace Power," 24.

humanitarian relief, tankers have been – and *increasingly will be* – required to accomplish the USAF mission.

The US began experiments with the transfer of fuel from one aircraft to another in flight with daring attempts made by two enterprising Lieutenants. Noting that nothing in regulations explicitly prohibited the activity, Lieutenants John Richter and Lowell Smith conceived the idea, built the equipment required, and soon thereafter tested their idea in flight.[6] From these humble beginnings the concept of air refueling has grown to a point that it is no longer a novelty, but is perhaps *the* key enabler of the American way of war.[7] Each of the US service branches rely on air refueling, directly or indirectly; the USAF to meet the needs of strike and airlift platforms, the Navy and Marines to extend the range of its size-limited carrier aviation, and the Army to have consistent fire support and transportation of personnel and equipment. Air refueling is thus ubiquitously relevant, so much so that the United States military has come to take its ability to refuel aircraft at any time, in any place, completely for granted.

In September 1991, President George Bush officially terminated the requirement for the USAF to maintain bombers and their supporting tankers on nuclear alert.[8] America's tanker forces had been designed from the beginning specifically to meet the needs of the nuclear-capable bomber fleet of the Strategic Air Command (SAC). Fully one third of the available fleet of KC-135 Stratotankers sat alert alongside the bombers, ready to launch almost immediately.[9] Without them, the airborne element of America's nuclear deterrent triad would have been useless. KC-135s weathered the years well while sitting alert, lulling the USAF into a false sense of complacency regarding the dependability of its core tanker. However, once relieved of the alert commitment, KC-135s flew much more. The quickened pace of 1990s operations occurred as the youngest KC-135 turned twenty-five years old. Increased flying hours conspired with the aging of

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[6] Bradley Jones, "The Questions Are Answered," *U.S. Air Services* 14, no. 2 (1929): 19.

[7] Writing on the topic of air refueling includes a diverse taxonomy, including flight refueling, in-flight refueling, and aerial refueling. In order to be consistent with current USAF doctrine, the term air refueling will be used throughout this paper.

[8] Robert S. Hopkins, III, *Boeing KC-135 Stratotanker: More Than Just a Tanker* (Leicester, England: Midland Publishing Limited, 1997), 65.

[9] The ground alert requirement began on 1 October 1957, just over three months after the USAF took deliver of its first KC-135 on 28 June 1957. Hopkins, 51 – 54.

the fleet to generate unexpected wear in the skin and wings of the aircraft, as well as corrosion throughout its airframe.

While the USAF takes great pains to perform needed preventative maintenance on its aircraft, the overall capability to conduct air refueling has been neglected to the point that it may become a crisis if left uncorrected. The unexpectedly high maintenance needs of aging tanker aircraft have brought the problem to light. Yet little is being done to address the problem. This inattentive attitude has resulted in a predictable degradation of air refueling capabilities. It is only logical that if a capability becomes critical enough, it must be insured through investment and sustainment. Wishful thinking aside, aircraft can only be flown so long before they simply must be replaced, regardless of the number of upgrades and enhancements made.

Methodology

This thesis incorporates two base assumptions. The first is that the air refueling capability of the US military is a critical component of its overall success, and will be increasingly relevant to the conduct of future US military action. Second, that capability is in decline.

Chapter 2 presents the history of air refueling development from its earliest inception, through its glory days of strategic bomber support, to a description of the fleet the USAF flies today. This history review shows the emergence of three trends. First, tankers have always been designed to meet the needs of their planned receivers. Second, the security environment drove tanker employment from a nuclear attack support force to one engaged routinely in conventional conflicts. Third, tanker capabilities have slowly shifted away from a purely tanker mission to a multi-role platform. These trends must be considered in any recommendations for the future of the tanker fleet.

Chapter 3 examines salient organizationally sanctioned material, beginning with doctrine, emerging concepts of operations (CONOPS), and concluding with an analysis of planned budgetary expenditures through fiscal year 2005. Three significant findings emerge from this review. Tanker missions can be summarized as deployment, employment, and penetrating roles. Future CONOPS affirm the underlying assumption

of tanker relevancy. Despite this relevance, significant budgetary investment in tanker recapitalization is nonexistent.

Chapter 4 offers five possible options for meeting the required recapitalization needs. First, maintaining the current force structure is considered. Next, two civilian aircraft suitable for conversion to tankers, the Boeing 767 and Airbus A310, are discussed. The third option is to build an entirely new aircraft, the KC-X, specifically designed to meet future tanker needs. Civilian contract air refueling is an option recently made available by Omega Air, Inc., and its capabilities are discussed next. Finally, unmanned aerial vehicle (UAV) options are presented, focusing specifically on the penetrating tanker role.

Chapter 5 compares each option to criteria taken from US Joint doctrine. Each option is grossly assessed on the merits of its feasibility, acceptability, and adequacy. After the options are evaluated independently, the results are summarized in tabular format for comparison.

Chapter 6 draws together the trends of history, sanctioned material, and the assessments in Chapter 5 to establish recommendations. Not all of the options have a role to play in the future of air refueling. The major finding of the thesis is that the USAF has experienced a de facto shift away from a using its tanker aircraft in purely air refueling roles. The USAF should accept and capitalize on this move toward multi-role platforms in order to increase the versatility of tankers.

Conclusion

In Homer's epic, *The Iliad,* the mighty warrior Achilles is struck down by Paris, who mortally wounds the hero in the one spot he is vulnerable; his heel. The complexity of the US military today suggests that it may suffer from numerous vulnerabilities, however few would merit consideration as potential Achilles' heels. One exception to this generalization lies in the area of air refueling.

The apparently robust nature of the USAF refueling capability is an assumption almost unquestioned by current planners.[10] Yet assuming unconstrained tanker support is potentially reckless in light of the current state of our tanker force. Inherently

[10] Major General David A. Deptula interview with author, 7 February 2002.

unglamorous, the USAF's ability to conduct air refueling anywhere in the world in support of national objectives is, nonetheless, one of America's unique contributions to international stability. In order for it to maintain its vitality, certain investments are necessary.

Some authors assert that the current state of the USAF air refueling capability constitutes an "air refueling emergency."[11] Like the military overall, USAF tankers may be victims of their own success. Air refueling mission reliability rates for the Operation DESERT STORM, for example, exceeded 90 percent.[12] During Operation ALLIED FORCE, tanker reliability was over 97 percent.[13] It seems difficult to declare a state of emergency when the tanker force is capable of supporting real world operations at such levels. Nonetheless, the relative decline of the overall USAF air refueling capability necessitates a dedicated recapitalization effort in order to maximize its future potential. This thesis is an attempt to go beyond identifying the problem, and to extend an analysis to possible solutions. The overarching question is uncomplicated. How should the USAF recapitalize its air refueling capability, insuring its dependability for the foreseeable future?

[11] Major Mark D. Camerer, "Civilian Contract Air Refueling: Innovative or Insane?" Research Report no. 2001-04 (Maxwell AFB, AL: Air Command and Staff College, 2001), 11-20.
[12] Hopkins, *Boeing KC-135,* 65.
[13] General Charles T. Robertson, Commander in Chief, US Transportation Command speech to the Air Force Association Air Warfare Symposium 2000, 24 February 2000, on-line, Internet, 17 June 2002, available from http://www.aef.org/pub/rob200.asp.

Chapter 2

History of Air Refueling Development

The United States has historically enjoyed the luxury of being a geographically insular nation. While there are certainly defensive benefits to such a buffer, there are also constraints. The same barriers that have discouraged large-scale assault on American soil acted to restrict the employment of US military power abroad when the need arose to use force to defend its interests. Flexing its emerging great power status in the late nineteenth and twentieth centuries, the United States endeavored to overcome the distance constraint by increasing the effective range of its water and aircraft. One extremely effective method was the employment of air refueling.

The advent of powered flight in the twentieth century offered seemingly endless potential, sparking imaginations throughout the world. Following the Wright brothers' lead, other intrepid airmen began a series of conquests, each more spectacular than the last. On 25 July 1909, Monsieur Louis Blériot piloted the first powered aircraft across the English Channel.[14] When one considers that mankind's first flight occurred less than six years earlier, this was truly a remarkable accomplishment, demonstrating significant increases in both range and endurance of early aircraft. This flight heralded the end of Britain's security based on geographical isolation. It also served to portend not only the coming demise of the insularity of other nations, but the rapid pace at which advances in aviation technology would bring about those changes.

The potential consequences of this cross channel accomplishment were not lost on one future US aviation leader. Looking at a display of Blériot's aircraft in Paris in late summer 1909, Second Lieutenant Henry "Hap" Arnold thought, "If one man could do it once, what if a lot of men did it together at the same time? What happens then to

[14] "Bleriot Flies Over Channel," *New York Times*, 25 July 1909. Blériot's aircraft weighed 700 pounds loaded, was equipped with a 20 horsepower, three-cylinder engine, and had a top speed of 45 mph. Subsequent two-seat versions were flown as combat reconnaissance aircraft by both British and French aviators in World War I. "Bleriot Monoplane," USAF Museum, Wright-Patterson Air Force Base (WPAFB), on-line, Internet, 6 June 2002, available from http://www.wpafb.af.mil/museum/early_years/ey1a.htm.

England's Splendid Isolation?"[15] Several years later Arnold would serve in key positions in the US Air Corps that gave him unambiguous answers to his questions.

Aviation continued to improve and airplanes saw widespread use on the battlefield during World War I. These early war fighting aircraft were fragile and possessed limited range and endurance. In turn, these limitations necessitated airfields near their intended targets. Without nearby landing fields, the impact of airpower was minimal. US Army Service pilot Lieutenant John Richter, referring to events of September 1918, said, "I had to fly nine sorties on the day the St Mihiel offensive started...We all wished we could refuel somehow without having to return to our bases just when the action got interesting."[16]

Even before the close of World War I, airmen continued attempts to stretch the burgeoning capabilities of their machines. In October 1918, a Navy Reserve pilot, Lieutenant Godfey Cabot, conducted experiments designed to increase the range and endurance of aircraft by positioning cans of gasoline on ships that could be snagged without landing. Although never seriously adopted as a means of refueling, this method was employed for several years to snag mail on delivery flights without landing.[17] World War I ended before the full potential of the aircraft in war was thoroughly explored. But man's quest for higher, faster, and farther flight had just begun.

In May 1919, Lieutenant Commander Albert Read and crew completed the first transatlantic flight.[18] Read and his crew began their voyage on 8 May and finally reached Plymouth on 31 May. Although their flying boat landed several times for fuel en route, the accomplishment was nonetheless daring and praiseworthy, hinting that America's "splendid isolation" may be coming to its end, as well.

The earliest fuel transfer between two aircraft in flight occurred in November 1921 when wing walker Wesley May carried a five-gallon can of fuel from a Lincoln

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[15] Henry H. Arnold, *Global Mission* (New York: Harper & Brothers, 1949), 2.
[16] Quoted in Air Force Doctrine Document (AFDD) 2-6.2, *Air Refueling*, 19 July 1999, 47. The St. Mihiel Offensive began on September 12, 1918. Brigadier General William "Billy" Mitchell mustered 1,481 aircraft to support General Pershing's advance. Bernard C. Nalty, ed., *Winged Shield, Winged Sword: A History of the United States Air Force, Volume I, 1907 – 1950* (Washington D.C.: Air Force History and Museums Program): 65-66.
[17] Vernon B. Byrd, *Passing Gas: The History of Inflight Refueling,* (Chico, CA: Byrd Publishing Company, 1994), 17.
[18] "NC-4, Rockaway to Plymouth, Flew 3,925 Knots In 57 Hours, 16 Minutes, Actual Time in Air." *New York Times,* 1 June 1919.

Standard to a JN-4 before a Long Beach, California crowd.[19] While the onlookers were amazed, this early air refueling was clearly a daredevil stunt rather than a militarily viable solution to range and endurance challenges. It was not until two years later that air refueling was seriously considered as a means of extending the flight time of aircraft.[20] Perhaps motivated by his Mihiel experience, John Richter was instrumental to the effort.

After witnessing an endurance flight by two other US Army Air Service pilots, Lieutenants Oakley Kelly and John Macready, Richter was convinced that engineering improvements to increase the time aircraft could remain aloft had reached a plateau.[21] Sensing that available engines, airframes, and crews were capable of remaining airborne for extended periods, Richter decided that replenishing consumables such as fuel and oil was the issue to be overcome. With the support of his commander at Rockwell Field, Major Hap Arnold, Richter began efforts that resulted in the first air refueling in a form familiar to that still in use today.[22]

On 27 June 1923 Richter and Captain Lowell Smith were the crew of the first aircraft to be refueled in flight.[23] Their air refueling system was the picture of simplicity, little more than a hose dangled behind the tanker aircraft, grabbed by a crewmember aboard the receiver, and then placed into the fuel tank. Gravity moved the fuel from one plane to the other. Although their first flight was modest, Richter and Smith quickly capitalized on their initial success, setting several world records during a thirty-seven hour, fifteen minute flight on August 27 and 28 the same year.[24] Two months later they flew non-stop from the Canadian border to the Mexican border with two refuelings.[25] This 1,280 mile nonstop flight prompted Brigadier General William "Billy" Mitchell, one of the most outspoken airpower advocates of the time, to comment in a remarkably contemporary statement, "Using the new technique, bombers could now depart on long-

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[19] Dennis Casey and Bud Baker, *Fuel Aloft: A Brief History of Aerial Refueling* (US Army Military History Institute, n.p., n.d.), 1.
[20] "Plane Refueled in Flight," *Aviation* 15, no. 2 (9 July 1923): 51.
[21] "Smith and Richter Up 37 hr. 15 min.," *Aviation* 15, no. 11 (1923): 316.
[22] Arnold was enthusiastic enough about the flight that he took to the air himself and flew formation with the intrepid pair on the final two laps of their sortie. "The New World's Duration Record," *Aviation* 15, no. 23 (1923): 716.
[23] Richard K. Smith, *75 Years of Inflight Refueling: Highlights, 1923-1998*, Air Force History and Museums Program, 1998, 1.
[24] "New World's Records," *Aviation* 15, no. 18 (1923): 580.
[25] "Border to Border Refueling Flight," *Aviation* 15, no. 25, (1923): 752-753.

range missions with lighter fuel and heavier bomb loads. Experimental, advanced, or secret aircraft could be used and concealed from foreign eyes. Aircraft could be flown from protected home bases to project US air power, with its defensive and offensive potential, anywhere on the earth without depending upon other countries to grant landing rights."[26]

Mitchell's comments notwithstanding, the periodicals of the time are replete with stories on the thriving inter-service rivalry between the US Army Air Service and the US Navy air components rather than serious discussion on the pragmatic uses of air refueling in war.[27] Thus, the support Arnold gave Richter and Smith probably stemmed more from a desire to highlight aviation rather than to develop a new war fighting technique. Unfortunately, the momentum built up by the string of successes came to a tragic halt on 18 November 1923. Performing before a crowd attending the Army Relief Fund Air Carnival at Kelly Field, Texas, tanker pilot Lieutenant Paul T. Wagner was killed when the hose he lowered to his receiver became entangled with his right wing, sheering it from the airplane.[28] This was certainly not the kind of publicity the Army Air Service wanted and considering the lack of a military necessity for air refueling it is not surprising that this tragedy effectively ended experimentation in the US for almost five years. Despite the hiatus, Major Arnold published an article entitled, "Practical Value of Refueling Airplanes in Flight" in which he describes not only military advantages to the technique, but civilian uses as well.[29] Although US military experiments with air refueling stopped, the quest for increased range persisted.

In May 1927, a mere 24 years after Kittyhawk, Charles Lindbergh made history by completing the first non-stop solo crossing of the Atlantic.[30] America's insular boundary had been overcome in a non-stop flight, albeit by a single machine carrying little more than its pilot and fuel, and flying from west to east in order to take advantage

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[26] Quoted in Lane Spencer, *First World Flight: The Odyssey of Billy Mitchell* (Daytona Beach, FL: US Press, 2001): 161-162.

[27] For example, beginning with the 3 April 1922 edition of *Aviation* magazine, the editors dedicated a regular column entitled "Army and Navy Air News." The title of the column was changed to "US Army and Navy Air Forces" in the 18 June 1923 issue, but its purpose remained unwavering: to highlight accomplishments of the two air arms side by side.

[28] "Refuelling in Air not without Danger," *Aviation* 15, no. 25, (1923): 753.

[29] "Practical Value of Refueling Airplanes in Flight," *Aviation* 17, no. 2, (1924): 750-751.

[30] Charles A. Lindbergh, *Autobiography of Values* (New York: Harcourt Brace Jovanovich, Inc., 1977): 79.

of prevailing winds. Lindbergh took off from Roosevelt Field, New York and landed more than thirty-three hours later in Paris, France. Unfortunately for its advocates, a surprisingly long flight had been made without the aid of air refueling. Amid the celebration of "Lone Eagle's" accomplishment, the US aviation community deferred interest in air refueling until the following year, spurred in part by a European response to Lindbergh's flight.

In April 1928, a German Junkers aircraft attempted the first non-stop east to west crossing of the Atlantic, but the *Bremen* landed short of the intended destination due to unexpected headwinds.[31] Her crew landed safely on Greenly Island, just off the coast of Labrador, and the Junkers Company asked the US Army Air Corps for help retrieving the aircraft and crew. The mission to recover the *Bremen* was successful, however, during the return trip, two US pilots, Captain Ira Eaker and Lieutenant Elwood "Pete" Quesada, almost ran out of gas near Portland, Maine because an overcast deck prevented them from seeing their intended destination.[32] That evening over a card game, Quesada, Eaker, and Chief of the Army Air Corps, Major General James Fechet, mentioned Richter and Smith while contemplating how helpful a flying gas station would have been in their situation. Eaker ran with the idea and approached Fechet requesting permission to pursue air refueling experimentation.[33] Fechet's decision to allow the testing put into motion the most well known event in the American development of air refueling, the flight of the *Question Mark*.

Determined to demonstrate that air refueling should be viewed as more than an aerial stunt, the receiver aircraft chosen, an Atlantic-Fokker C-2A trimotor monoplane,

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[31] "First East-West Non-Stop Atlantic Flight: The 'Bremen'." On-line. Internet, 16 May 2002, available from http://www.celtic-connection.com/lit/aviation-04-00.html; "The *Bremen* Episode Inspires Notion of Air Refueling." On-line, Internet, 16 May 2002 available from http://www.bolling.af.mil/organizations/wing/welcome/bolling_history/history/BREMEN.HTM

[32] James Parton, *"Air Force Spoken Here": General Ira Eaker and the Command of the Air*, (Bethesda MD: Adler & Adler Publishers Inc., 1986; reprint, Maxwell AFB, AL: Air University Press, 2000), 70.

[33] Lieutenant General Elwood R. Quesada, transcript of oral history interview by Dr. Edgar F. Puryear, Jr., June 22, 1977, United States Air Force Historical Research Agency (AFHRA), Maxwell AFB, AL. Fechet may have been more willing to authorize the testing as Quesada served as Fechet's aide-de-camp during this time and had tremendous respect for Major Spatz, whom Eaker recommended as the mission commander. Quesada and Spatz subsequently served as crewmembers aboard the *Question Mark* during the record flight.

was much larger than previous aircraft used for similar roles.[34] Mrs. Ira S. Eaker, Captain Eaker's wife, suggested the aircraft's name. In an Associated Press interview she told reporters, "that since it might prove anything, or nothing, the logical name was *Question Mark*."[35] On 1 January 1929, in the same vicinity as both Wesley May's 1921 wing walking stunt, and several successful 1923 air refueling flights by Richter and Smith, the *Question Mark* departed the Van Nuys Metropolitan Airport carrying a crew of five: Major Carl "Tooey" Spatz, (as he spelled his name at that time), Captain Ira Eaker, Lieutenants Harry Halverson and Pete Quesada, and Staff Sergeant Roy Hooe.[36] Although the event was not principally designed as a publicity stunt, one of the pervasive goals of the period was to keep aviation in the public eye and provisions for

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[34] The "tanker" used by Wesley May was a Lincoln Standard J-1 biplane, weighing 1,557 pounds. "Standard J-1," National Air and Space Museum, on-Line, Internet, 6 June 2002 available from http://www.nasm.si.edu/nasm/aero/aircraft/standard.htm. The "receiver" was a JN-4 biplane weighing 1,430 pounds, a top speed of 75 mph, and approximately 2½-hour endurance. "Curtiss JN-4D 'Jenny'," USAF Museum, WPAFB, on-line, Internet, 6 June 2002, available from http://www.wpafb .af.mil/museum/early_years/ey2b.htm. In the 1923 Army Air Service experiments at Rockwell Field flown by Richter and Smith both tanker and receiver aircraft were de Havilland DH-4Bs. The DH-4B was a single engine biplane with a gross weight of 3,557 pounds. Its cruising speed was 90 mph with an unrefueled range of 400 miles. DH-4s were the only US built airplanes to see combat on the Western Front during World War I. First flown in combat by the 135th Aero Squadron in August 1918, they were employed as bomber, observation, and artillery spotting aircraft. Available in large numbers in the acutely fiscally constrained post-war environment, these stalwart machines were pressed into service in many roles, including transport, air ambulance, photographic plane, trainer, target tug, forest fire patroller, and air racer. "De Havilland DH-4: Air Service Workhorse," USAF Museum, WPAFB, on-line, Internet, 6 June 2002, available from http://www.wpafb.af.mil/museum/early_years/ey8a.htm. For more on the post-World War I demobilization see Maurer Maurer, *Aviation in the U.S. Army: 1919 – 1939* (Washington, D.C.: US Government Printing Office, 1987): 3-15. By contrast, the Atlantic-Fokker C-2A, *Question Mark,* was a transport aircraft powered by three 220 horsepower radial engines, had a gross weight of 10,395 pounds, cruised at approximately 100 mph, and had an unrefueled range of 350 miles. "Atlantic-Fokker C-2A 'Question Mark'," USAF Museum, WPAFB, on-line, Internet, 6 June 2002, available from http://www.wpafb.af.mil/museum/research/cargo/c1/c2aqm.htm. See also "Atlantic-Fokker C-2A," USAF Museum, WPAFB, on-line, Internet, 6 June 2002, available from http://www.wpaft.af.mil/ museum/research/cargo/c1/c2a.htm. The two tankers used to refuel the *Question Mark* were Douglas C-1 single engine biplanes, which weighed 6,445 pounds, cruised at 85 mph, and had a range of 385 miles. "Douglas C-1," USAF Museum, WPAFB, on-line, Internet, available from http://www.wpafb.af.mil/ museum/research/cargo/c1/c1.htm.

[35] "How the Plane Was Named,*" New York Times*, 5 January 1929.

[36] Carl A. Spatz, "Report of the Flight of the Question Mark, January 1-7, 1929," Carl A. Spaatz Papers, Library of Congress, Manuscript Div, Box 110, 2. Spatz is correctly pronounced "spahtz," but was often mispronounced "spats." Spatz changed the spelling of his name to Spaatz in 1937 at the behest of his family, particularly his daughter Tattie who was off to college that year. See David R. Mets, *Master of Airpower: General Carl A. Spaatz* (Novato, CA: Presidio Press, 1988): 104. Two members of the crew of the Question Mark are enshrined in the Airlift/Tanker Hall of Fame. Lt Gen Ira Eaker was inducted in October, 1993, and Master Sergeant Roy Hooe was inducted in October, 2001. "Master Sergeant Roy W. Hooe: 2001 Airlift/Tanker Hall of Fame Inductee," *Airlift/Tanker Quarterly* 9, no. 4 (Fall 2001): 10-13. Biographies of the crew can be found in "Personnel of Army Air Corps Endurance Flight," *U.S. Air Services* 14, no. 2 (February, 1929): 24 – 27.

communicating with the press were carefully planned.[37] Consequently, Spatz, as the mission commander, agreed to refuel over the Rose Bowl as requested by Pasadena officials.[38]

Throughout the next six plus days, the flight gained prominence in the media as the *Question Mark* broke every endurance record of any kind in existence at the time. Failing engines forced the *Question Mark* to finally land at 2:07 P.M. on January 7.[39] The flight lasted for 150 hours, 40 minutes, and 15 seconds, during which the *Question Mark* was refueled 43 times by two Douglas C-1s, dubbed RP (refueling plane) #1 and RP #2. These tanker aircraft transferred 5,760 gallons of fuel and 202 gallons of oil to Spatz and his crew.[40] In Spatz's words, "As the crew understood it, the mission of the *Question Mark* was to determine the practicability of refueling in flight and to find out whether or not refueling had any reasonable application to commercial and military flying. It is believed that the Question Mark accomplished its mission."[41]

Spatz was so encouraged by the results of the flight that in his, "Report of the Flight of the Question Mark" he recommended tests "whereby refueling shall be applied to bombardment, pursuit and observation aircraft." [42] Although Spatz suggested the *Question Mark* be returned to its original condition, he intended for RP #1 to remain

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[37] Spatz, "Report of the Flight of the Question Mark," 158.

[38] "Army Plane Begins Endurance Flight," *New York Times*, 2 January 1929. Flying overhead Pasadena was a deviation from the planned route. The *Question Mark* flew predominantly near the coast in order to take advantage of smoother air. "Showing off" may have been a mistake for Spatz as he was drenched in aviation fuel when the refueling hose was ripped from his grasp during the refueling above the Pasadena stadium due to turbulence in the area.

[39] Spatz, "Report of the Flight of the Question Mark," 8. An example of media coverage of the flight is found in a series of articles published in *The New York Times*. The *Times* initially reported the flight on 2 January 1929, the day after it took off. The article, "Army Plane Begins Endurance Flight," appeared on page 22, buried behind the Sports section. The following day, "Endurance Plane Passes One Record," appeared on page 7. On 4 January 1929, the *Question Mark* made the front page in the article, "Army Refueled Plane Beats Belgian Record; Remains Up to Pass German Endurance Time." On 5 January "Plane Up 87 Hours, Still Going Strong," appeared on the front page accompanied by a picture showing the *Question Mark* during a refueling. 6 January was a Sunday, and news of the flight remained on the front page in "Army Plane Still Up; Completes 111 Hours in Refueling Flight." The Sunday issue also included excerpts of the logs dropped by the crew under, "*Question Mark's* Log Tell of the Flight." A special picture section of the paper also included a photograph of the plane in flight, albeit without a tanker. Finally, on 7 January, the final article appeared entitled, "Plane Past 134-hour Mark, Beats All Flight Records; Crew Get Sleep, All Well," accompanied by a picture of the aircraft and a separate picture of the crew.

[40] *History of Aerial Refueling,* USAF Audio Visual Presentation, Aerospace Audiovisual Service, Military Airlift Command, AVR 467, n.d.

[41] Spatz, "Report of the Flight of the Question Mark," 152.

[42] Ibid., 163.

modified in order to conduct the recommended testing.[43] Despite the achievements of the personnel and equipment involved with the endurance flight, the Army Air Corps peevishly chose not to pursue air refueling. Civilian aviators, on the other hand, quickly bested the *Question Mark's* world record endurance flight.[44]

It is oddly curious that American military interest in air-to-air refueling waned in the early 1930s. This seeming retrenchment was due to a number of factors. First, the very success of the mission may have worked against continued development. The team involved in the *Question Mark* flight set out to prove the viability of routinely resupplying an aircraft in flight. This was safely accomplished many times over, both day and night and under a variety of weather conditions.[45] Hence it was not crew fatigue or breakdown of the resupply effort that ended the mission; termination was due to engine limitations. Air refueling had indeed been proven viable; therefore, it was logical to Army planners that efforts focus on improving engine reliability, not air refueling.[46]

Additionally, the international security environment of the time did not seem to warrant continued air refueling development. Although tensions with both Germany and Japan were evident, it was believed that sufficient plans existed to deal with either.[47] Aeronautics made great strides in 1933 with the advent of the DC-1 and DC-2 aircraft, both of which were all metal, low-wing monoplanes sporting controllable pitch propellers

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[43] RP #1 was christened *Asterisk* following a particularly harrowing landing at the fog-bound Rockwell Field subsequent to a refueling rendezvous with the *Question Mark*. Ross G. Hoyt, "Reflections of an Early Refueler," *Air Force Magazine* (January 1974): 58.

[44] In July 1930, the Hunter brothers raised the world record for endurance flights to 553 hours. In 1935, the Keyes brothers stayed airborne for 27 straight days. Andrew Parr, "The History of Fuelling in Flight," *Aeronautics* (March 1947): 48.

[45] Twelve of the 43 contacts between the *Question Mark* and the tankers occurred at night. On 3 January the resupply effort had to be relocated inland over the Imperial Valley because of deteriorating weather forecasts along the coastal area. While low clouds and fog were problematic near the coast, the crews had to overcome dust and strong winds in the vicinity of the mountains. See Hoyt, "Reflections of an Early Refueler," 58-59.

[46] Using the term "air refueling" to describe the effort to keep the *Question Mark* aloft is somewhat understating the actual accomplishments. Much more than fuel and oil were passed to Spatz and his crew. Nineteen warm meals, including a New Year's Day turkey dinner prepared by ladies from a local church, two dozen quarts of ice cream, telegrams, letters, a collapsible bath tub, a supply of bath towels, woolen underwear, a rubber suit for Major Spatz, and a window for the cabin to replace one lost during the flight were among the many items transferred from these early "full service" tankers. See Charles F. McReynolds, "The Refueling Flight of the 'Question Mark'," *Aviation* 26, no. 3 (1929): 158.

[47] For a discussion of US war plans during this time, see Edward S. Miller, *War Plan Orange: The US Strategy to Defeat Japan, 1897-1945* (Annapolis, MD: Naval Institute Press, 1991).

that essentially doubled speeds and ranges of the planes.[48] With these advances, Germany was well within the unrefueled range of bombers operating out of the United Kingdom (U.K.). US bombing doctrine at the time called for massive, self-protecting formations.[49] Refueling support for these formations would have been too complex to orchestrate safely given the rendezvous technology of the day as well as pragmatic constraints imposed by available airspace. Escort fighter support was not anticipated, but even if it had been, the existing equipment was too large to be practical for installation on fighter aircraft.[50] In the Pacific theater, the US envisioned war with Japan as primarily a naval engagement. Plans were based primarily on decisive surface encounters between battleships, in which aircraft flew reconnaissance missions and as spotters for naval gunfire. Hence, air refueling was an interesting sideshow, but not a serious part of US defense needs.

Consequently, the US Army Air Corps rested on its laurels. The British, however, continued maturing the concept of range extension via air refueling. Like their American counterparts, military interests were not the driving factors; commercial interests motivated the efforts.[51] In 1930, Lieutenant Commander Atcherly patented a system by which two aircraft could make contact by trailing long cables fitted with grappling hooks.[52] In 1936, Sir Alan Cobham acquired the patent for Atcherly's system and incorporated Flight Refueling, Limited (FRL).[53] Cobham modified the Atcherly system somewhat by equipping the tanker aircraft with a harpoon, (Figure 1), which fired

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[48] Smith, *75 Years of Inflight Refueling*, 11.

[49] For a discussion of the Air Corps Tactical School and development of daylight precision bombing doctrine prior to World War II see Michael S. Sherry, *The Rise of American Air Power: The Creation of Armageddon* (Binghamton, NY: Vail-Ballou Press, Inc., 1987): 50 – 59. See also Robert T. Finney, *History of the Air Corps Tactical School: 1920 – 1940* (Original imprint by the Research Studies Institute, USAF Historical Division, Air University, 1955): 62 – 67.

[50] For a thorough explanation of the development, equipment, and employment of the Cobham system see C.M. Poulsen, "Fuelling in the Air: Sir Alan Cobham's System Explained," *Flight and the Aircraft Engineer* 25, no. 6 (1939): a – d. Schematics of individual components and the complete systems for both tanker and receiver aircraft can be found in C.M. Poulsen, "Payload and Long Range: How Refuelling in the Air Can Help," *Flight* 68, no. 1913 (1945): 200 –204.

[51] Anticipated commercial advantages can be found in "Range and Payload by Refuelling in the Air," *The Aeroplane* (September 28, 1945): 362 – 364.

[52] Brian Gardner, "Skytanker: The Story of Air-to-Air Refuelling," *Air Extra* no. 49 (August-September 1985) 18 - 19.

[53] Andrew Parr, "The History of Fuelling in Flight," *Aeronautics* 16, no. 2 (1947): 48. For more detailed information on the business plan see Sir Alan J. Cobham, K.B.E., A.F.C., "Flight Refueling" *Shell Aviation News* no. 95 (May, 1939): 14 – 16.

a line across that trailed by the receiver. Atcherly's system depended on a less reliable crossover maneuver flown by the tanker pilot to snag the receiver's line. In 1939, this improved hose and reel system was employed successfully on cargo flights sixteen times during Atlantic crossings, both east to west and west to east.[54] Further development stopped due to the outbreak of World War II in August that year. Until the Boeing Company developed the flying boom system in 1947 FRL's hose and reel system was the only viable foundation for air refueling.[55]

[54] Andrew Parr, "The History of Fuelling in Flight," *Aeronautics* 16, no. 2 (March 1947): 48.
[55] Byrd, *Passing Gas*, 50.

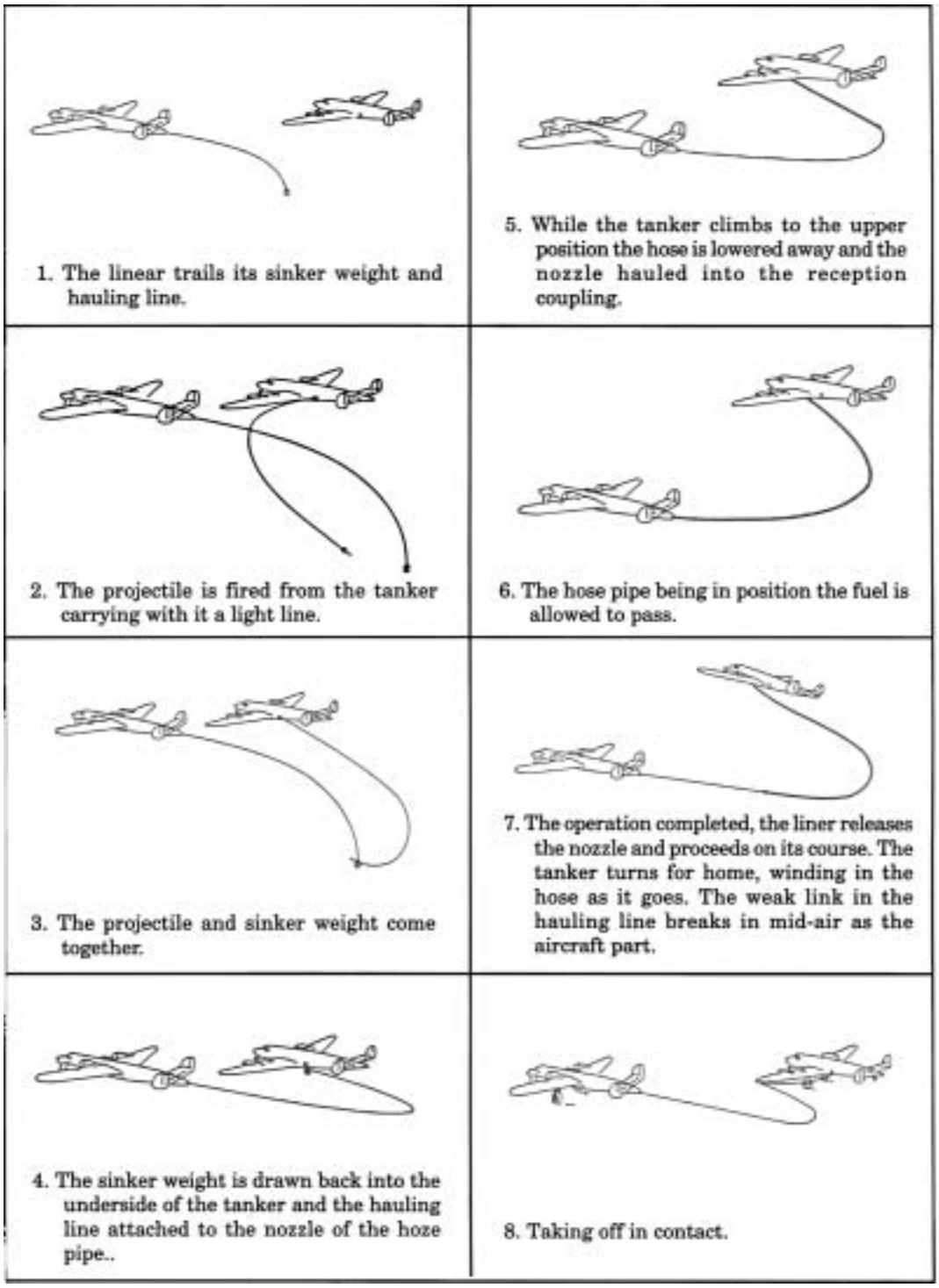

Figure 1 – Cobham Refueling System

Source: Byrd, *Passing Gas*, 73.

The US Army Air Corps was aware of Cobham's efforts, but gave them only cursory consideration. In an August 1939 letter, Shell Oil Company executive Jimmy Doolittle answered a inquiry made by Major General "Hap" Arnold, now Chief of the Army Air Corps, regarding the British method of "Flight Refueling."[56] Doolittle reported on the aircraft, equipment, and procedures employed by Flight Refueling Limited, citing claims of the advantages offered by refueling in flight using civilian passenger carrying examples. Regrettably, with no American experimentation and British efforts cut short by the outbreak of World War II, air refueling development stopped completely.

It was during World War II that air forces were first capable of significantly influencing ground warfare. Even with the aeronautic advances up to 1939, however, an aircraft's combat payload was limited by several factors, none more significant than the amount of fuel carried. Thus, military strategists in World War II, like their predecessors in World War I, were burdened with the operationally hazardous need to establish airfields in relative close proximity to their intended targets.

In the European theater of war, the October 1940 victory in the Battle of Britain essentially secured British airfields for the remainder of the war, however, the great distances in the Pacific made range more of a problem than ever for American planners. A deep felt desire to retaliate directly against Japan, whose December 7, 1941 attack on Pearl Harbor was the proximate cause of US entry into the war, prompted a fresh investigation of means to extend aircraft range.[57] In the early months of 1942, US military planners met to discuss plans to attack Tokyo using B-17s flying out of Midway Island or the Aleutians.[58] Air refueling was but one avenue explored to affect the retaliatory strike. The US Army Air Corps contracted FRL to modify a B-24D Liberator

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[56] J.H. Doolittle, Shell Oil Company, to Major General H.H. Arnold, Chief of the Air Corps, letter, subject: Flight Refueling, August 23, 1939, in Case History of Air-to-Air Refueling, Appendix, AFHRA. Arnold first met Second Lieutenant Doolittle when the latter performed a dangerous stunt riding between the wheels of an aircraft as it landed at Rockwell Field. Over the years that followed, Arnold developed a close working relationship with Doolittle. See Dik Alan Daso, *Hap Arnold and the Evolution of American Airpower* (Washington, D.C.: Smithsonian Institute Press, 2000): 102 – 105. At the time of Arnold's request to Doolittle on the refueling system Shell Oil Company owned a 60 percent share of FRL. Smith, *75 Years of Inflight Refueling,"* 25.

[57] Brian Gardner, "When You Need A Buddy: The Development of Air Refueling in the United States Navy," *The Hook* (Bonita, CA: Tailhook Association) Fall 1983: 12.

[58] Hopkins, *Boeing KC-135,* 17. Thomas A. Julian, "The Origins of Air Refueling in the United States Air Force," in *Technology and the Air Force: A Retrospective Assessment,* ed. Jacob Neufeld, George M. Watson, Jr., and David Chenoweth. (Washington, D.C.: Air Force History and Museums Program, 1997) 80-81.

as a tanker and a B-17 Flying Fortress as a receiver. Testing was conducted at Eglin Field, Florida, but not completed until July 1943. In the meantime, now Lieutenant Colonel Jimmy Doolittle led a flight of B-25 aircraft on a raid against targets in Tokyo on 18 April 1942. The bombers launched from the deck of the aircraft carrier USS. *Hornet* and planned to land in China following their attack. This fulfilled America's desire to strike back, and the FRL system was considered too difficult to install or employ in mass numbers of aircraft, despite successful tests.[59] The feasibility of the actual plan for the attack was suspect, considering "the relative improbability of ever overcoming the continuous sequence of miracles that would confront such a mission."[60] These factors, combined with the promise of greater range and bomb load of the B-29 Superfortress, meant that, once again, air refueling capabilities were allowed to whither in the US. While the Doolittle raid was an important moral victory for the United States, the physical damage inflicted was minimal. Other methods for extending the range of America's bombers were needed, and the war would not wait. Thus, traditional methods were continued.

If the drama of the Battle of Britain secured forward airfields in Europe, its counterpart in the Pacific was General Douglas Macarthur's island hopping campaign. Macarthur's men fought heroic battles to secure airfields within the unrefueled range of the Japanese homeland. Perhaps one of the best known was the fight for the small island of Iwo Jima. In February and March 1945 during a 36-day siege, more than 26,000 US Marines were killed or wounded and nearly all of the 21,000 Japanese defenders perished.[61] Iwo Jima was needed initially as a base from which to launch P-51 escorts supporting B-29 bombers en route to Japan. Over the next several months more than 2,400 bombers diverted to Iwo Jima because of emergencies, the most common of which was insufficient fuel.[62] Although amphibious assaults are not habitually related to the concept of air refueling, in this case they are inexorably linked. The sad result of Iwo Jima came because air refueling development had been allowed to languish. Thus,

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[59] Byrd, Passing Gas, 60.
[60] Gardner, "When You Need A Buddy," 12.
[61] James Bradley, *Flags of Our Fathers*, New York, 2000, 246.
[62] "Epilogue," on-line, Internet, 5 December 2001, available from http://www.iwojima.com/battle/battled.htm.

thousands of lives were lost in the quest for airfields within the operating range of aircraft.

US airpower came of age during World War II and the Axis powers were not the only ones noticing its increased effectiveness. In 1943 a new fight began, this time within US military ranks. Late that year, Army Chief of Staff General George C. Marshall submitted a paper to the Joint Chiefs of Staff on "A Single Department of War in the Post-War Period," which called, in part for an independent air equal to those of the Departments of the Army and Navy.[63] US naval leaders loathed the idea, however. When England formed the Royal Air Force in 1918 she chose to consolidate all army and navy aircraft into the fledgling service. Within naval ranks was, "the realistic concern of many senior naval officers that under such a department of war, the new air component would either absorb naval aviation entirely or deprive it of most of its funding."[64] The dispute lasted several years eventually ending, at least on paper, with the National Security Act of 1947, which codified Marshall's vision for the services and Department of Defense.

World War II ended with the Japanese surrender on the deck of the battleship USS *Missouri* on 2 September 1945. The war was a victory for the Allies, but there were obvious tensions between them. As the world polarized, the US recognized an on-going need to maintain a substantial and capable air force. Ironically, range became more of a problem for strategic planners in the post-World War environment. A variety of innovative solutions were attempted. In 1946 the US initiated the Nuclear Propulsion for Aircraft Program (NEPA).[65] The program founders were lured by the promise of flight time measured in days or weeks rather than hours. Despite daunting technical challenges, NEPA viewed nuclear-powered flight as feasible and nuclear-powered solutions to the range problem were pursued in various forms.

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[63] Jeffrey G. Barlow, *Revolt of the Admirals: The Fight for Naval Aviation, 1945 – 1950* (Washington, D.C.: US Government Printing Office, 1994): 23.
[64] Ibid., 24.
[65] Barton C. Hacker. "Nuclear-Powered Flight" in *Technology and the Air Force: A Retrospective Assessment*, ed Jacob Neufeld, George M. Watson, Jr., and David Chenoweth. Air Force History and Museums Program, Washington, 1997. p.192. The Kennedy administration cancelled the last remaining nuclear propulsion programs in 1961.

In February 1946 the US Joint Strategic Survey Committee published their view of the roles, functions, and missions of the US military branches.[66] These were revised several times over the next two years and tensions regarding the roles of the services persisted. Eventually, Secretary of Defense Forrestal convened a conference at Key West Naval Air Station from 11 – 14 March 1948 to discuss and clarify primary missions for each branch.[67] One of the major issues settled during this conference and reinforced several times thereafter was the establishment of responsibility for "strategic air warfare" given to the United States Air Force (USAF).[68] At that time, most interpreted this mission as synonymous with nuclear bombardment. While the Key West Agreement identified the USAF as holding primary responsibility for strategic air warfare, it was not made solely responsible for this mission area. Thus, the US Navy chose to pursue systems that could support employment of nuclear weapons from its aircraft carriers. This was interpreted by many Air Force officers as an encroachment on their area of responsibility and therefore perpetuated the dissention between the services.[69]

Internationally, too, tensions mounted. President Harry S. Truman, in a statement to a joint session of Congress 12 March 1947 laid out his view, "that it must be the policy of the United States to support free peoples who are resisting attempted subjugation by armed minorities or outside pressures."[70] This statement, combined with a July 1947 *Foreign Affairs* article entitled "The Sources of Soviet Conduct," authored by "X," later revealed to be State Department planner George Kennan, set the stage for the US position in the Cold War. In his article, Kennan stated that, "Soviet society may well contain deficiencies which will eventually weaken its own total potential. This would of itself warrant the United States entering with reasonable confidence upon a policy of firm containment, designed to confront the Russians with unalterable counter-force at every

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[66] Barlow, *Revolt of the Admirals*, 32-33.
[67] Ibid., 123.
[68] Air Force Bulletin No. 1 (Washington, D.C.: Department of the Air Force, 21 May 1948) 1.
[69] James Forrestal, Secretary of Defense, memorandum to General Spaatz and Admiral Towers, subject: Fundamental Concept of Strategic Warfare, August 9, 1948. General Spaatz, Chief of Staff of the Air Force and Admiral Towers, Chief of Naval Operations, Undated memorandum for Secretary Forrestal, subject: Your Memorandum of 9 August 1948.
[70] Harry S. Truman, Special Message to the Congress on Greece and Turkey: The Truman Doctrine. 12 March 1947. *Public Papers of the Presidents of the United States: Harry S. Turman.* United States Government Printing Office, Washington. 1963.

point where they show signs of encroaching upon the interests of a peaceful and stable world."[71]

In November 1947, the newly formed USAF convened the Heavy Bombardment Committee with the express purpose of reporting to the USAF Aircraft and Weapons Board concerning "methods and instrumentalities required for aerial delivery of individual and mass atomic attacks against any potential aggressor nation from bases within the continental limits of the United States."[72] This report may rightly be called the seminal event in the development of air refueling in the US Air Force.[73] Although the committee's topic was explicitly heavy bombardment, their first priority recommendation for research and development was the development of, "air-to-air, high capacity, single point, refueling systems and evolve a method of satisfactory rendezvous and refueling under all-weather conditions."[74] Their second and third priorities also dealt with air refueling. The number one tactics recommendation concerned refueling bombers en route or departing their target areas. Additionally, the top two interim solutions recommended also dealt with air refueling. Thus, of the four areas of recommendations in the report, Tactics, Research and Development, Alteration of the Present B-52 Program, and Interim Solutions, three of them identified air refueling as the top priority.

Although these recommendations were crucial, they could not be acted upon until endorsed by the USAF Aircraft and Weapons Board, convened in January 1948, and approved by the Chief of Staff of the Air Force. The USAF Aircraft and Weapons Board was established with the responsibility to "determine the aircraft and weapons development and procurement program for the armed forces which comes within the jurisdiction of the USAF."[75] Several of the board's decisions affected the development of air refueling in the USAF as well as addressed the range extension problem in more imaginative ways.[76] The board agreed that strategic bombers used for more than 4350-

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[71] X, "The Sources of Soviet Conduct," *Foreign Affairs* 25, no. 4 (1947): 581.
[72] Report on Heavy Bombardment by Heavy Bombardment Committee Convened to Report to the USAF Aircraft and Weapons Board, 7 November 1947, 2.
[73] Julian, "The Origins of Air Refueling," 85.
[74] Report on Heavy Bombardment by Heavy Bombardment Committee, 6.
[75] AF Regulation 20-10, *USAF Aircraft and Weapons Board*, 29 September 1947, 1.
[76] Some of the other methods of range extension included development and testing of several systems that would allow landings in unimproved areas, such as track landing gear, skate gear, etc. Aviation engineers also experimented with catapults in order to overcome the initial inertia. These experiments later led to the development of Jet Assisted Takeoff bottles that could be temporarily mounted on aircraft as required.

nautical mile radius missions would be refueled in flight. They ordered Air Materiel Command to begin development of air-to-air, high capacity, single point, refueling systems and associated rendezvous equipment as their first priority. The board went on to incorporate in-flight refueling provisions in the B-52 program. Finally, the board directed Air Materiel Command to expeditiously modify B-29 and B-36 aircraft as tankers. The USAF Aircraft and Weapons Board forwarded these findings to the Chief of Staff of the Air Force for final approval. The Chief of Staff at the time was none other than General Carl A. Spaatz, the mission commander for the *Question Mark* endurance flight nineteen years earlier. Perhaps not surprisingly, air refueling was judged superior to other forms of range extension and all the USAF Aircraft and Weapons Board recommendations were adopted by the Air Force, which meant air refueling was no longer a sideshow.[77]

As a result, in March 1948 tanker development in the US began in earnest. It was further accelerated in July of that year as tensions in Berlin escalated.[78] In short order the first B-29 Superfortress was modified as a tanker aircraft with the British hose and reel system. The codename given the modification program was "Superman." Once modified, the aircraft were redesignated KB-29s, and were first activated with the 43rd

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Finally, the board requested the feasibility be determined of towing bombardment aircraft closer to their targets, and specified that, "other means of range extension should also be considered." "Summary Minutes of Second Meeting of the USAF Aircraft and Weapons Board," convened on 27 January 1948. Washington, D.C.: Headquarters USAF, 2-4. National Archive, College Park, MD. Box 183. Civilians were also busy experimenting with "other means," including developing a technique by which the aircraft would receive its fuel by picking up cans of gasoline from a speeding car. The most noteworthy use of this method was by Robert Timm and John Cook, who, in 1959, stayed airborne for over 1,500 hours in a Cessna 172 in the vicinity of Las Vegas. See Brian Gardner, "Skytanker: The Story of Air-to-Air Refuelling," *Air Extra* no. 49 (August-September 1985): 17-18.

[77] Secretary of War Robert Patterson nominated Spaatz as the commander of the Army Air Forces on 12 December 1945, despite the fact that General George Kenney outranked Spaatz by a few days. Spaatz served as the first Chief of Staff of the Air Force until his retirement in the spring of 1948 when he turned over command to Hoyt S. Vandenberg. Mets, *Master of Airpower,* 311 – 312, 331.

[78] On 24 June 1948 Stalin ordered a blockade of all western access to Berlin via land or water. Air corridors could not be cut off because they were guaranteed by treaty. Thus, two days later, the US and UK began aerial resupply efforts into the city which became known as Operations VITTLES for the Americans and Operation PLAINFARE for the British. Colonel Gail S. Halvorsen, *The Berlin Candy Bomber* (Bountiful, UT: Horizon Publishers & Distributors, Inc., 1997) 28. In response to the mounting tensions, beginning on 4 July 1948, the Boeing Company conversion facility in Wichita, Kansas went to 84-hour workweeks for all personnel involved with the "Superman" program. Case History of Air Refueling, Historical Office, Wright-Patterson AFB, March 1949: 21. AFHRA, Maxwell AFB.

and 509th Air Refueling Squadrons.[79] While effective, the hose and reel system had limitations. There was tremendous drag created by the hose when it was deployed between aircraft that limited the allowable airspeed to 216 nautical miles per hour.[80] Also, an extended period of time was required once the tanker and receiver aircraft rendezvoused to get the hose in position to transfer the fuel. The transfer rate of fuel was too slow to meet the needs of large aircraft, and the equipment needed was simply too large to fit in fighter aircraft, as previously mentioned. Concerns also centered on the serious fire hazard present should the aircraft be attacked while refueling.

To solve the problem regarding fighter aircraft, a system employing a conical basket trailing behind the tanker, known as a drogue, was developed for use with smaller receivers. Designed by FRL in 1949, Cobham's engineers fielded a system very similar to that in use today by many fighter aircraft.[81] The receiver aircraft was fitted with a probe that plugged into the basket receptacle and allowing the fuel transfer to take place. Although this solved the problem of in-flight refueling for fighter aircraft, it had the conspicuous disadvantage of a slow transfer rate. Large aircraft would take inordinate amounts of time to refuel from such a system.

Figure 2 – Hose and Drogue Attachment

Source: E. E. Stein, "The Development of the Boom to Drogue Adapter at Wright-Patterson Air Force Base," Wright Air Development Center (WADC) Technical Note WADC-TN-56-343 (WPAFB: WADC, Air Research and Development Command, 1956), Exhibit D.[82]

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[79] Case History of Air Refueling Appendix, item 104, memorandum entitled, "Installation of 'Superman' and 'Ruralist' Modifications in B-29 and B-50 Airplanes," 30 March 1948. Hopkins, *Boeing KC-135*, 18.
[80] Casey and Baker, *Fuel Aloft,* 16.
[81] Hopkins, *Boeing KC-135*, 19.
[82] This illustration conveys the concept of the drogue refueling system, although it depicts a boom to drogue adapter developed for the KC-135. While the adapter is an effective solution to the problem of making the KC-135 compatible with drogue receivers, the hose length is shorter than that of the KC-10 integral drogue. The shorter length makes the KC-135 drogue less forgiving for the receiver pilot, earning the adapter the nickname "Iron Maiden" among receiver pilots. Gale Matthews, president Omega Air, Inc., interview with the author, 10 June 2002.

To solve the problem, in 1949, the USAF ordered 40 KB-29s from the Boeing Company modified with a system known as the flying boom.[83] The flying boom employs a hydraulically extended refueling nozzle that mates with a receptacle on the receiver aircraft. It is equipped with "ruddervators" that allow the boom to be precisely positioned by specially trained boom operators aboard the tanker aircraft. The primary advantage of the flying boom is a tremendous increase in the rate at which fuel can be transferred. Using a probe and drogue, a tanker can offload approximately 1700 pounds of fuel per minute, compared to approximately 6000 pounds per minute with a boom.[84] While it addressed several limitations of the drogue system, adopting the flying boom meant the USAF now had two completely incompatible refueling systems, a situation that resulted in repercussions still not completely corrected today.

The Soviet Union exploded its first atomic device in 1949, followed less than two years later by a nuclear test. These explosions meant the US was no longer the world's sole nuclear power, and US strategies had to be adjusted to account for the emerging balance.[85] Long-range bombers capable of attacking targets deep in the heart of the Soviet Union were the earliest delivery systems available to strategic planners; consequently, they received top priority for the next several years. Under General Curtis LeMay, commander of Strategic Air Command (SAC) for an unprecedented nine years, from 19 October 1948 through 30 June 1957, the US tanker fleet expanded into a massive force hundreds strong.[86]

On 25 June 1950, communist North Korea invaded South Korea beginning the Korean War. Although most tankers were dedicated to the national priority of nuclear war, the US policy of containment compelled it to respond in Korea. A small number of tankers were included in the forces deployed. On 14 July 1951 the first combat refueling using the flying boom was conducted by a KB-29P with an RB-45C receiver.[87] Tactical

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[83] Byrd, *Passing Gas*, 80.
[84] Air Force Technical Order (T.O.) 1C-135(K)R-1, "Flight Manual – USAF Series KC-135R/T Aircraft," Change 46, 15 August 1998, 1-63.
[85] For early nuclear strategy development see Lawrence Freedman, "The First Two Generations of Nuclear Strategists," in *Makers of Modern Strategy from Machiavelli to the Nuclear Age*, ed. Peter Paret (Princeton, NJ: Princeton University Press, 1986): 735 - 778.
[86] Norman Polmar and Timothy M. Laur, ed. *Strategic Air Command: People, Aircraft, and Missiles.* Baltimore, MD: The Nautical & Aviation Publishing Company of America, Inc., 2nd ed, 1990, 4. LeMay's time in command of SAC is the longest tenure of any US military force commander.
[87] Hopkins, *Boeing KC-135*, 20.

Air Command (TAC) also employed tankers in theater both during combat operations and in the deployment of squadrons to the theater, and on 29 May 1952 performed the first US fighter air refueling over enemy territory.[88] At the time, little was made of these seemingly minor events. In reality, however, they were the first glimpses of the future of tanker employment. Slowly, tankers migrated to conventional employment over nuclear support missions.

During this same time period there was concern in the USAF about the challenges of having two mutually exclusive air refueling systems. Beginning in early 1952, SAC held demonstration flights intended to evaluate which system, the drogue or the boom, would better meet the needs of the USAF.[89] The result of these tests would establish the equipment installed on all future tanker aircraft. Much to General LeMay's chagrin, the drogue was deemed the better system, and on 13 August 1952 the Undersecretary of the Air Force approved it as the USAF standard. However, because the drogue could only achieve offload rates of 250 gallons per minute versus the 600 gallon per minute rate of the boom system, and the tanker's primary mission was to refuel his bomber, LeMay saw to it that more than two-thirds of the tankers had the flying boom installed. Six years later, a year after LeMay's retirement, the USAF formalized what already existed in fact. On 14 July 1958 the boom was designated the USAF standard for air refueling. Thus, the de facto system held sway over the policy in the end.

As potential enemies matured their air defenses, faster bombers were required to ensure they could penetrate successfully to their targets. The increased speeds of jet-powered bombers meant enemy interceptors would be forced into "tail chases," since weapons shots from anything other than behind the bomber were likely to miss. In order to insure a better chance of penetration to the target, the USAF sought fast, high-flying bombers like the B-47 and subsequent B-52. The acquisition of jet-powered bombers meant much greater payloads as well as increased speed. However, the price of these payload and speed increases was increased fuel consumption. The KB-29 was too slow to effectively refuel the B-47 Stratojet, which was the most modern bomber at the time.

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[88] USAF Museum, Wright-Patterson Air Force Base, http://www.wpafb.af.mil/museum/history/korea/kc6.htm. There is some disagreement between sources on this event. Compare, for example, with Byrd, *Passing Gas*.
[89] Hopkins, *Boeing KC-135*, 21 – 23.

In an attempt to service the needs of the B-47 and follow on bombers like the B-52, the USAF modified several C-97 Stratofreighters into KC-97 Stratotankers.[90] The KC-97 was much more effective than the KB-29, however, it still could not offer offloads in the amounts needed by the thirsty bombers, and that only at an altitude much lower than the bomber's cruising altitude. Consequently, the six-engine B-47 had to descend to meet its tanker and subsequently burned the majority of the fuel on-loaded simply returning to its cruising altitude. The same situation would ensue with the Boeing B-52 Stratofortress; however, the B-52's eight engines would further exacerbate the problem.[91]

To match the performance of the B-52, the USAF needed an all jet tanker. The solution was found in a derivative of the Boeing 367-80.[92] The "Dash 80," as Boeing insiders knew it, with its radical wing sweep, represented a significant departure from previous designs. Boeing, in anticipation of the USAF jet-tanker requirement, took a considerable risk by funding its development in house before the USAF made known its intention to acquire a jet tanker.[93] When the USAF eventually invited entrants for a jet tanker competition, Boeing was the only company that could boast a flying prototype. Despite the head start, the aircraft did not fare well. In fact, the Dash 80 finished fourth of four entries. However, because Boeing had begun development before the other manufacturers, they could deliver a production aircraft sooner. That was enough of an advantage given the perceived need for Boeing to be awarded a contract that eventually led to a production run of 930 airplanes. This marked the second time that extant events trumped intentions in tanker development. The aircraft first flew on 15 July 1954 and was deployed operationally for the first time in 1956.[94] The KC-135 Stratotanker was

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[90] Hopkins, *Boeing KC-135,* 22. The USAF selected the C-97 in December 1950.
[91] David R. Mets, interview with the author, 24 April 2002. Smith, *75 Years of Inflight Refueling,* 38.
[92] A persistent myth is that the KC-135 is simply a militarize version of the Dash 80, and the civilian variant is the Boeing 707. In reality, however, they are three distinct designs. The fuselage of the 367-80, is 132 inches in diameter, the KC-135 is 144 inches, and the 707 is 148 inches. While the difference in these measurements may not appear significant to the layperson, they have substantial impacts that cascade throughout the aerodynamic design of the remainder of the aircraft. Ultimately, the KC-135 shares less than 22 percent commonality with the Boeing 707. John E. Steiner, "Jet Aviation Development: A Company Perspective," in *The Jet Age: Forty Years of Jet Aviation,* ed. Walter J. Boyne and Donald S. Lopez (Washington, D.C.: National Air and Space Museum, Smithsonian Institution Press, 1979), 141.
[93] John E. Steiner, "Jet Aviation Development: A Company Perspective," in *The Jet Age: Forty Years of Jet Aviation,* ed. Walter J. Boyne and Donald S. Lopez (Washington, D.C.: National Air and Space Museum, Smithsonian Institution Press, 1979), 153.
[94] Hopkins, *Boeing KC-135*, 25-28.

specifically built to meet the demands of supporting SAC bombers in the event of nuclear war.[95]

National war plans went though tremendous changes in the years following World War II. As new technologies matured and the geopolitical environment shifted, their impacts were accounted for, culminating in "Single Integrated Operations Plan (SIOP) 62."[96] Effective as of 1 April 1961 under President Kennedy, the SIOP took great pains to match tankers with specific bomber missions in case of a nuclear exchange. As previously mentioned, the tankers sat alert alongside the bomber force, which had the unintended consequence of allowing the aircraft to weather the years remarkably well. Its predecessor, however, the KB-50, was becoming frail. Following a crash in 1964, the entire fleet was grounded because of widespread corrosion.[97]

1962 also saw the KC-135 used as a CONUS communications relay node under the SAC Post Attack Command and Control System (PACCS).[98] Designed to ensure communications capability existed following a nuclear exchange, three KC-135s were modified for this duty. These measures succeeded in establishing reliable air refueling support and national command and control in case of a nuclear exchange.

Not all tankers sat alert, however. During the decade-long Vietnam conflict, KC-135s were employed in several ways. As in Korea they ferried fighters to the theater and supported them on combat missions from within the theater. B-52s were used on "Arc Light" missions, which involved conventional bombing of suspected enemy strongholds.[99] Arc Light missions, too, were refueled by KC-135s. In addition, TAC modified seven KC-135s to act as airborne radio relay platforms. These KC-135 Combat Lightening aircraft were still available to meet emergency air refueling needs, however, their role was primarily to extend the radio range of the USAF Tactical Air Control System.[100] Although the KC-135 was originally intended to support refueling needs of

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[95] "KC-135 Stratotanker," USAF Fact Sheet, on-line, Internet, 19 November 2001, available from http://www.af.mil/news/factsheets/KC_135_Stratotanker.html.
[96] Douglas Lawson, "Historical Summary of US War Plans," NationalWarPlansAndPolicies.xls, CD-ROM, 15 January 2001. The SIOP is updated annually and remains a vital pillar of US national defense.
[97] Hopkins, *Boeing KC-135,* 56.
[98] Ibid., 115.
[99] Major George R. Fessler, Jr., *Aerial Refueling in Southeast Asia, 1964 – 1970* Project Contemporary Historical Examination of Current Operations (CHECO) Report (Headquarters Pacific Air Force, June 17, 1971): 22.
[100] Hopkins, *Boeing KC-135,* 132; Fessler, *Air Refueling in Southeast Asia*, 25.

the SIOP, some were extensively modified for other purposes and many others were employed in a major conventional conflict. KC-135s in South East Asia flew 194,687 sorties, offloading 8.96 billion pounds of fuel.[101] Doctrinally, this weight of effort signaled a de facto shift toward substantial support for tactical operations.[102]

The other major development in the field of air refueling to come out of the Vietnam conflict was the requirement to refuel helicopters in flight. USAF studies concluded that a downed airman had a reasonably good chance of being recovered if reached within the first 15 minutes following the ejection.[103] Chances of recovery drop steeply thereafter. In order to meet this response time, however, the rescue helicopters would have to be airborne. This, in turn, led the Air Recovery Service (ARS) to forward a requirement for helicopter air refueling in August 1964.[104] In December 1965 the first contact between a CH-3 helicopter and a Marine Corps KC-130 tanker was completed, although no fuel was passed. In December the following year the first fuel transfer took place and by June 1967 KC-130P tankers were refueling search and rescue helicopters in combat in Southeast Asia.[105]

October 1973 marked another major event in air refueling development. Egypt and Syria attacked Israel on 6 October that year, which was Yom Kippur, a Jewish holiday. Although caught off guard, Israel turned the tide by 10 October, prompting a Soviet airlift to both Cairo and Damascus. Again compelled by Cold War concerns, the United States responded with an airlift of its own, Operation NICKEL GRASS.[106] While primarily an airlift operation, the USAF learned lessons regarding its air refueling capabilities as well.

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[101] Hopkins, *Boeing KC-135*, 60.
[102] Despite the amount of conventional combat SAC forces saw during this period, the SIOP remained the primary concern. Studies were carefully conducted month to month assessing SEA operation on SAC's SIOP capability. See "SEA Impact on the SAC SIOP Forces," Project CORONA HARVEST, 5 December 1968 and subsequent report by the same title, 10 March 1969. AFHRA, Call numbers K416.03-5 and K416.03-4. Similar studies were conducted during Operation DESERT STORM, but remain classified as of this writing.
[103] Major Tracy W. Colburn, "Running On Empty: The Development of Helicopter Aerial Refueling and Implications for Future USAF Combat Rescue Capabilities," (Research paper, Maxwell AFB, AL: Air Command and Staff College, March 1997), 7.
[104] Ibid., 7.
[105] Ibid., 9 - 10.
[106] Keith Hutcheson, *Air Mobility: The Evolution of Global Reach* (Vienna, VA: Point^{One}VII, Inc., 1999), 22-23.

Mitchell's words were seemingly prophetic as several nations refused landing rights to US cargo aircraft during the crisis. Unfortunately, the massive C-5 Galaxy aircraft used during the airlift required multiple tankers each to support their operations.[107] Additionally, C-141s, the other major airlift asset employed, were not equipped with air refueling receptacles. Thus, Operation NICKEL GRASS highlighted two major shortfalls in required capabilities and resulted in motivating the USAF to acquire a larger tanker better able to support the needs of large mobility aircraft and fitting all C-141 aircraft with receptacles for boom refueling.[108]

While lessons of the 1973 war were the proximate cause for acquiring the new airplane, the need for an advanced tanker had actually been identified much earlier.[109] In testimony before a 1974 House of Representatives Committee on Appropriations, Lieutenant General William J. Evans stated that the requirement had been identified as early as 1967, but had not been sufficiently high on the USAF funding priorities relative to other programs. During General Evans' testimony, Representative John J. Flynt of Georgia clarified the intent of the Advanced Tanker/Cargo Aircraft (ATCA) acquisition, stating that the "objectives of this program are (1) to enhance the Air Force's *strategic airlift capability* by augmenting the current cargo/transport force, and (2) to assure adequate aerial refueling support for the Air Force airlift, Strategic and General Purpose Forces' mission by eliminating the inherent deficiencies in the current tanker force."[110] Thus, the aircraft was originally envisioned primarily as an airlifter, not a tanker. Unwittingly, Arabic nations set the conditions prompting the USAF acquisition of its ATCA. By declaring an oil embargo, the Organization of Petroleum Exporting Countries (OPEC) drove fuel prices up. This resulted in a slump in new aircraft sales and an opportune market for the USAF to acquire its ATCA, which was derived from the DC-10

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[107] Hutcheson, *Air Mobility,* 24.
[108] Walter J. Boyne, "NICKLE GRASS," (Air Force Association: December, 1998) 81, no. 12, on-line, Internet, 5 December 2001, available from http://www.afa.org/magazine/Dec1998/1298nickel.html.
[109] Lieutenant General William J. Evans, Deputy Chief of Staff, Research and Development, Headquarters USAF, testimony before the House of Representatives Committee on Appropriations, 29 April 1974. *Department of Defense Appropriations for 1975* (Washington D.C.: US Government Printing Office, 1974), 884.
[110] *Appropriations for 1975,* 883.

commercial airliner.[111] The USAF added 60 McDonnell-Douglas KC-10 Extender aircraft to its fleet.

The KC-10 was first deployed in 1981. The USAF saw definite advantages in purchasing an aircraft based on a commercial wide-body design rather than one specifically built to military specifications. First and foremost, the airplanes would be available quickly. It would have the higher payload required to support large mobility receivers. Moreover, a commercial derivative avoided developmental costs and exploited the worldwide logistics support system already in place. The KC-10 also has the airlift capacity to carry the necessary cargo required for fighter deployments.[112] Finally, the KC-10 has additional advantages in its ability to refuel both boom and drogue receivers on a given sortie.[113]

The fall of the Berlin Wall in November 1989 marked the end of the Cold War, but certainly not the end of the tanker's relevance. On 2 August 1990, Iraq invaded neighboring Kuwait, sparking an international response to their aggression. The US-led coalition ousted Iraq during a six-week air campaign followed by a four-day ground assault. In all, 262 KC-135s flew close to 17,000 sorties, offloading some 812 million pounds of fuel.[114] 46 KC-10s flew almost 3,300 sorties and offloaded approximately 284 million pounds of fuel.[115] Those figures are approximately equal to a year's worth of effort in South East Asia. Reflecting their three and a half decades of alert status, the KC-135 mission reliability rate was over 90 percent.[116] On any given day almost a fifth of all DESERT STORM sorties were tankers.[117] Interestingly, the number of tankers available was not an issue. Rather, due to the employment of a massive armada of aircraft designed to overwhelm Iraqi defenses, airspace congestion was the critical

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[111] Robert F. Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force 1961-1984, Volume II*, (Maxwell Air Force Base, AL: Air University Press, 1989), 656.
[112] 1976 Carter Presidential Transition Briefing, "Tanker Requirements and the Advanced Tanker/Cargo Aircraft," n.p., n.d.
[113] "KC-10A Extender," USAF Fact Sheet, on-line, Internet, 19 November 2001, available from http://www.af.mil/news/factsheets/KC_10A_Extender.html. While the KC-135 can employ a drogue, it does so by attaching the apparatus to the end of the boom, rendering the aircraft unable to refuel receptacle equipped receivers.
[114] Eliot A. Cohen, *Gulf War Air Power Survey (GWAPS), Volume III, Logistics and Support* (Washington, D.C.: Government Printing Office, 1993), 180-181.
[115] Ibid., 180-181.
[116] Hopkins, *Boeing KC-135,* 65.
[117] Cohen, *GWAPS*, 200.

limiting factor during DESERT STORM operations.[118] This experience heralded the next shift in the development of air refueling. While tanker planning was previously viewed essentially as a "numbers game" of supplying sufficient numbers of tankers for a given number of receivers, airspace now became a constraint to air refueling employment.

Nuclear alerts stopped on 27 September 1991 when President George Bush officially ended the alert posture.[119] Shortly thereafter, on 1 June 1992, SAC, TAC, and Military Airlift Command (MAC) stood down in a massive USAF reorganization. Fighter and bomber aircraft were transferred to the newly formed Air Combat Command (ACC) while the majority of SAC tankers were moved to Air Mobility Command (AMC), along with the majority of MAC's former airlifters. With this reorganization, AMC became the single source manager for tanker support. Absent the Cold War nuclear requirement, there seemed little need of maintaining a massive tanker fleet. Consequently, beginning on 7 July 1992 and continuing for two years, several dozen KC-135s were placed into storage at the Aerospace Maintenance and Regeneration Center at Davis-Mothan Air Force Base, Arizona.[120]

While the KC-10 could refuel probe or receptacle receiver on any given flight, KC-135 was still limited to one or the other. Noting that, "Currently, over half of the air refuelable aircraft in the free world require a hose/drogue system for air refueling," Air Mobility Command set out to address this limitation.[121] In 1997, the USAF Air Mobility Warfare Center at Fort Dix, New Jersey undertook a Qualification Operational Test & Evaluation of the KC-135 Multipoint Refueling System (MPRS). The main components of MPRS include an under-wing store mounted near the KC-135 wingtips. The store contains a hose and drogue assembly that can be extended or retracted in flight by the tanker crew. This system would make the KC-135 compatible with all receiver aircraft and has the additional advantage of allowing multiple receivers to refuel simultaneously. Due to aerodynamic interaction that caused damage to the KC-135 during the retraction sequence this system was not adopted.

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[118] Ibid., 206.
[119] Hopkins, *Boeing KC-135*, 65.
[120] Ibid., 193-195.
[121] "KC-135 Multi-point Refueling System Qualification Operational Test & Evaluation Test Plan," (Fort Dix, NJ: Air Mobility Warfare Center, June 1997), v, 2-3.

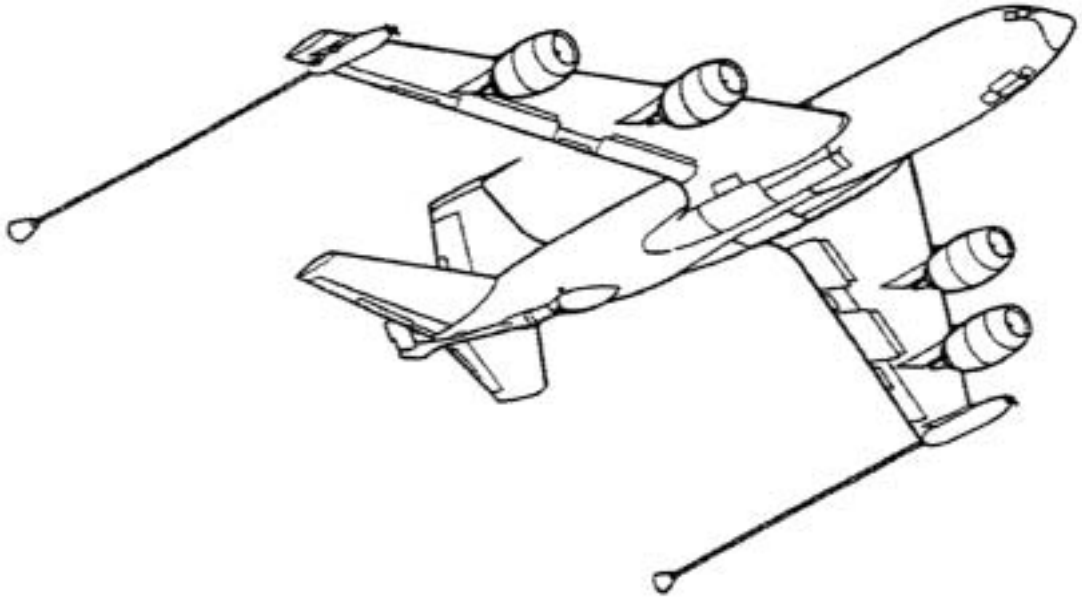

Figure 2.3 – KC-135 with MPRS Installed
Source: "KC-135 Multi-point Refueling System Qualification Operational Test & Evaluation Test Plan," 5.

In March 1999, in response to repression of ethnic Albanians by Yugoslav President Milosevic of Serbia, the North Atlantic Treaty Organization (NATO) initiated Operation ALLIED FORCE. Following a 78-day bombing campaign, Milosevic agreed to NATO's terms, and withdrew from Kosovo. During the conflict, NATO employed some 200 tankers operating out of eight countries, effectively making it a major theater war level of effort for the tanker force.[122] As in DESERT STORM, allied tankers were limited by the amount of available airspace between Italy and the Balkans, not the amount of tankers that were available to be committed.[123]

Following attacks on the World Trade Center and Pentagon on 11 September 2001 the US is again leading a coalition, this time in a global war on terrorism. According to Washington Democrat Senator Patty Murray, Operation ENDURING FREEDOM is America's first "tanker war" because each strike sortie, without exception

[122] General Charles T. Robertson, Jr. Commander in Chief United States Transportation Command, testimony to the House Armed Services Committee, 26 October 1999.
[123] Benjamin S. Lambeth, *NATO's Air War for Kosovo: A Strategic and Operational Assessment* (Santa Monica: RAND, 2001), 161.

requires air refueling support.[124] Contrary to expectations of a decade earlier, and without doubt, in the post-Cold War environment the need for a robust and versatile tanker fleet is increasing. In the decade of the 1990s and into the twenty-first century, airpower has been selected over and again as the means by which America chooses to defend its interests. US and allied airpower simply cannot complete the job it is called to do without robust refueling support.

From inauspicious beginnings as an air show stunt, air refueling gained credibility with the flight of the *Question Mark*, but lacked a relevant military requirement to drive its development. The Cold War and the constraints imposed by US geographic isolation provided the necessary stimuli to mature the capability. Originally designed to support the nuclear-armed bomber fleet, the tanker steadily saw use in conventional conflicts.

To date, tanker aircraft characteristics have consistently been driven by receiver needs. Its employment has been in concert with national priorities established by political leadership and expressed in doctrine. The on-going US commitment to international security has resulted in a large number of military deployments, each of which has required significant tanker support. Providing this support shifted the emphasis of the US air refueling fleet away from the purely tanker role to multi-role utilization. Today, tankers are a necessary element of almost any effective US airpower employment. Chapter three surveys current USAF doctrine, emerging CONOPS, and future budgets to derive desired capabilities of the US air refueling fleet.

[124] Senator Patty Murray, "Floor Remarks by Senator Murray Supporting the Lease of Boeing Refueling Tankers by the Air Force," on-line, Internet, 6 June 2002, available from http://www.senate.gov/~murray/releases/01/12/2001C07A51.html.

Chapter 3

Doctrine, CONOPS, and Budgets

Begin with the end in mind.

--Stephen R. Covey*, The Seven Habits of Highly Effective People, 1989.*

It is essential to establish the desired capabilities of the air refueling fleet before evaluating potential solutions. The tool should not precede the function, or the analogy of the boy who receives a hammer for his birthday is apparent; suddenly the world is full of nails, and they all need pounding. To accomplish that goal, this chapter covers current USAF air refueling doctrine, current and near-term concepts of operations, and finally budgetary expenditures of the services in order to determine both the ideal and realistically achievable capabilities of America's refueling fleet.

Although doctrine is authoritative, it is not directive,[125] and therefore not binding. In spite of this, a survey of salient USAF doctrine is a logical starting point for an effective examination of air refueling capabilities and needs. Air Force doctrine is organized hierarchically. Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrine* lays the foundation upon which the subsequent documents are built. AFDD 1 establishes, in broad terms, the most fundamental beliefs about US airpower. It establishes USAF support for the principles of war established in joint doctrine, which are "those aspects of warfare that are universally true and relevant."[126] The document introduces the tenets of air power, which are designed to "provide more specific considerations for air and space forces,"[127] and defines the six Air Force core competencies: air and space superiority, precision engagement, information superiority, global attack, rapid global mobility, and agile combat support. These competencies represent the "basic areas of expertise that the Air Force brings to any activity across the range of military operations."[128] The final section of note in AFDD 1 is a list of

[125] AFDD 1, V.
[126] Joint Pub 1, III-1.
[127] AFDD 1, 22.
[128] Ibid., 27-34.

seventeen mission areas. Although air refueling is specifically mentioned in the list of Air Force missions, the reference is intentionally broad.

The AFDD 2-series of documents establish operational level guidance. "Operational doctrine guides the proper employment of air and space forces in the context of distinct objectives, force capabilities, broad functional areas, and operational environments. Basic doctrine and operational doctrine provide the focus for developing the missions and tasks that must be executed through tactical doctrine."[129] AFDD 2, *Organization and Employment of Aerospace Power* is the first of several operational-level doctrinal works. It addresses issues such as command and control of Air Force units during peace and war. Like AFDD 1, it addresses air refueling, but again only in broad mission terms. Importantly for this discussion, AFDD 2 emphasizes the expeditionary nature of the Air Force today.

The US Air Force provides the nation the ability to rapidly project forces anywhere in the world through Air Expeditionary Forces (AEFs) assigned to Air and Space Expeditionary Task Forces.[130] AEFs are tailorable force packages that integrate with air mobility forces to accomplish the commander's objectives. AEFs can be lethal or non-lethal in nature, thereby providing national leadership with a full range of force options. In some cases, an AEF may be comprised principally of Mobility Air Force assets when the operational focus is non-lethal in nature and its success hinges directly on support provided by airlift and air refueling assets. Regardless of the AEF's composition, however, air mobility forces provide an essential capability to project US influence anywhere in the world.[131]

AFDD 2-6 echoes the almost axiomatic Clausewitzian statement that "war is nothing but the continuation of policy with other means,"[132] with the statement, "US national interests drive the national security strategy of 'global engagement.' Our dependence on political, economic, and military partners demands a military capable of operating on a global basis. Rapid global mobility is essential to that capability. This is especially true today where a smaller, increasingly CONUS-based force must be able to

[129] Ibid., 2.
[130] AFDD 2, 35.
[131] AFDD 2-6, 3.
[132] Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton NJ: Princeton University Press, 1976), 69.

rapidly respond to unpredictable threats wherever and whenever they occur."[133] Implicit in the concept of employing from CONUS is the idea that not only must our military be able to respond, but to sustain its operations to the forward location until victory is achieved. This sustainment effort is the bedrock for persistent operations of a CONUS-based force.

AFDD 2-6, *Air Mobility Operations,* addresses both airlift and air refueling in much greater detail. Specifically, air refueling affords a measure of security to US and allied forces by allowing them to be based well outside the range of enemy threats. Some aircraft can participate without having to forward deploy at all. There are logistical advantages realized as well, since CONUS-based operations reduce theater logistics requirements, simplifying sustainment efforts.[134]

Tanker aircraft have inherent airlift capabilities. This affords their use in a dual role as an augmentation to core airlift assets. "Under the dual role concept, tankers can transport a combination of passengers and cargo while performing air refueling."[135] One of the most efficient uses of this dual role concept is during the deployment of assets to a theater. The tanker may be tasked to use their organic cargo capacity to transport unit personnel and support equipment while performing air refueling for the fighter unit being deployed. The Integral Tanker Unit Deployment concept involves tanker units self-deploying, exploiting their intrinsic airlift capabilities by hauling their own personnel and equipment.[136]

AFDD 2-6.2, *Air Refueling* is the most directly salient doctrinal reference for this discussion. The advantages of air refueling listed include: "increasing the range, payload, and flexibility of air forces," resulting in, "increased loiter time for receivers and less dependence on forward staging bases."[137] AFDD 2-6.2 continues the hierarchical structure of Air Force doctrine stating, "The Aerospace Expeditionary Force, airpower's answer to unexpected crises, is predicated on tankers escorting and refueling aircraft en route to the Area Of Responsibility, and air refueling airlift aircraft flying non stop to the

[133] AFDD 2-6, 1.
[134] Ibid., 47.
[135] Ibid., 48.
[136] Ibid., 48; AFDD 2-6.2 58
[137] AFDD 1, 56; AFDD 2-6, 47. Other advantages, not listed in doctrine, include reduced runway lengths required by receivers since they can take off lighter without full fuel loads. In any case, lightweight takeoffs are inherently safer than heavyweight takeoffs, regardless of runway available.

destination with critical personnel, supplies, and equipment."[138] Tankers are employed in six basic mission areas: (1) SIOP support, (2) global attack support, (3) air bridge support, (4) deployment support, (5) theater support, and (6) special operations support.[139]

Air Refueling Missions

The six basic mission areas represent the broad, fundamental, and continuing activities of the USAF's air refueling system. Air refueling forces perform these missions across the spectrum of conflict.

Single Integrated Operation Plan Support

As seen in Chapter 2, supporting the delivery of nuclear munitions was the driving force in the US Air Force's initial procurement of air refueling aircraft. With the advent of the SIOP in 1961, it was codified as the primary mission of the Air Force tanker fleet throughout the Cold War. This mission has been greatly de-emphasized since the break up of the Soviet Union; however, it remains a critical baseline requirement.

Air refueling assets are integrated into the SIOP in support of two critical assets: bombers equipped with nuclear weapons and US Strategic Command airborne command post aircraft. On 2 March 1949, a B-50A named "Lucky Lady II" completed the first nonstop round-the-world flight, supported by four air refuelings.[140] At a press conference following the Lady Luck II's amazing accomplishment, Lieutenant General Curtis E. LeMay, SAC Commander, summed up the flight's significance by saying that the United States Air Force could drop an atomic bomb, "any place in the world that required the atomic bomb."[141] Today, US bombers, one leg of the nuclear triad, supported by air refueling have the potential to deliver their payload to any location in the world and recover to suitable reconstitution bases.[142] During times of increased tensions, they may be launched and proceed to orbit areas well beyond the range of enemy missiles or attack

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[138] AFDD 2-6.2, 6.
[139] Ibid., 14.
[140] Marcelle S. Knaack, *Encyclopedia of U.S. Air Force Aircraft and Missile Systems, Volume II: Post-World War II Bombers,* (Washington, D.C.: Office of Air Force History, 1988), 175.
[141] Quoted in "B-50 Circles Globe Non-Stop in 94 Hours; Refueled in Air at 4 Bases by B-29 Tankers," *The New York Times,* 3 March 1949.
[142] AFDD 2-6.2, 14. The other two legs of the US nuclear triad consist of intercontinental ballistic missiles and submarine launched ballistic missiles. For a thorough discussion of the inception and maturation of triad, see Futrell, Volume II, 375 – 387.

aircraft. They can be maintained in this orbital status until they are directed to fulfill their mission or are recalled. In the same manner, airborne command post aircraft have nearly unlimited flight endurance through air refueling, providing national leadership the ability to continue to direct military action from a relatively secure airborne platform—regardless of the situation.[143]

Global Attack Support

Mitchell's 1923 statement regarding the reach of US bombers is, in fact, reality. Air refueling assets can be employed to give conventionally armed strike platforms the ability to reach any target globally without relying on intermediate basing locations or being subject to politically charged overflight restrictions. This provides the ability to rapidly strike, from CONUS if necessary, targets in distant locations and recover to safe areas.[144]

Air Bridge Support

On December 20, 1928 while deploying for the endurance attempt, the *Question Mark* was refueled overhead Dallas, Texas en route to a landing at Midland Field. Comparing the time required for that air refueling to that of the Midland stop, a commentator estimated that more than thirty minutes were saved by air refueling.[145] Similarly, today's air bridge creates a line of supply linking the CONUS and a theater, or between any two theaters. Air refueling makes accelerated air bridge operations possible since en route refueling stops are reduced or eliminated.[146] Thus, it reduces reliance on forward staging bases, minimizes potential en route maintenance delays, and enables airlift assets to maximize their payloads. This significantly increases the efficiency of airlift operations.[147]

Deployment Support

In May 1951, 48 F-84Es of the 31st Fighter Escort Wing deployed to Korea during Project HIGH TIDE, marking the first fighter unit deployment supported through air

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[143] AFDD 2-6, 52.
[144] Ibid., 52. Examples include: 1986 – Operation ELDORADO CANYON, the US punitive strikes against Libya; 1991 – Operation DESERT STORM; 1999 – Operation ALLIED FORCE; 2001 – Operation ENDURING FREEDOM.
[145] Charles F. McReynolds, "The Refueling Flight of the '*Question Mark*'," *Aviation* 26, no. 3 (1929): 159.
[146] AFDD 2-6, 53.
[147] AFDD 2-6.2, 16.

refueling.[148] Air refueling assets extend the range of deploying combat and combat support aircraft, allowing them to fly non-stop to or between theaters of operation. This capability increases the deterrent effect of CONUS-based forces and allows a rapid response to regional crises.[149] In a more contemporary example, fighters flying from Langley AFB, Virginia can deploy to Dhahran, Saudi Arabia in 15 hours with refueling support as opposed to the 47 hours required if they stop to refuel at intermediate staging bases.[150] The capability of air assets to fly non-stop to a theater may eliminate the need to obtain landing or overflight rights from foreign countries that may want to remain neutral in a given conflict, a circumstance seen during the 1973 Yom Kippur War, in which the United States supported Israel against Arab aggression.

Theater Support to Combat Air Forces

Perhaps the foremost contribution of air refueling to theater operations is bolstered security of combat and combat support air assets. Commanders are free to base assets beyond the range of enemy threats and still have confidence in their ability to strike targets. Air refueling also increases the endurance of air combat support assets, which are often in critically short supply. The Airborne Warning and Control System (AWACS), Joint Surveillance Target Attack Reconnaissance System (JSTARS), Rivet Joint, and airborne battlefield command and control center (ABCCC) are among the many crucial airborne platforms used to help manage, direct, and conduct combat operations.[151] Without air refueling, they have limited endurance and require extensive regeneration periods between sorties. Extending endurance reduces the number of sorties, decreases ground support requirements at forward locations, and may reduce the number of aircraft deployed to an Area of Responsibility.[152]

Special Operations Support

C-130 variants and KC-135R/T tankers enable special operations forces (SOF) to maintain a long range operating capability, increasing their responsiveness.[153] The US

[148] Hopkins, *Boeing KC-135*, 21.
[149] AFDD 2-6.2, 16-17.
[150] Rudolph G. Penner, *Modernizing the Aerial Tanker Fleet: Prospects for Capacity, Timing, and Cost*, Congressional Budget Office, September 1985, 4.
[151] AFDD 2-6, 54.
[152] AFDD 2-6.2, 18.
[153] The KC-135R/T is the designation for the eight KC-135s modified with receptacles allowing them to act as receivers as well as tankers.

Air Force maintains air refueling crews who are trained to air refuel fixed and rotary-wing special operations aircraft. Successful mission completion requires special equipment, specialized crew training, and modified operational procedures.[154]

The six air refueling missions can be summarized into three essential capabilities. First, air refueling allows assets outside a theater to deploy to areas of interest. Second, tankers support aircraft during their employment in theater. Third, specialized tankers penetrate sensitive areas with their receivers. These three capabilities suggest a useful construct encompassing the baseline requirements of a tanker force. Although airframes need not be dedicated to one role only, the US requires tankers for the deployment phase of conflict, the employment phase, and one that penetrates denied airspace alongside its receiver.

While doctrine offers an idea as to how the USAF intends to employ air refueling, it offers little in the way of describing how forces will actually be employed. Concepts of operation (CONOPS) are the next step in discerning the requirements for future air refueling requirements.

GLOBAL STRIKE TASK FORCE

Motivated by the confluence of three factors, the Air Force developed a new concept of operations known as Global Strike Task Force (GSTF) in the late 1990s. The three factors were the upcoming 1997 Quadrennial Defense Review (QDR), the budget for the F-22 Raptor, and the potential of facing "anti-access" strategies employed by potential adversaries.[155]

Quadrennial Defense Review

The Military Force Structure Review Act, included as part of the National Defense Authorization Act for Fiscal Year 1997, established the requirement for the QDR.[156] It is the fourth in a series of comprehensive reviews of the US defense establishment beginning with the 1991 Base Force Review, the 1993 Bottom-Up Review, and the 1995 Commission on Roles and Missions of the Armed Forces. A collaborative effort between the office of the Secretary of Defense and the Joint Staff, the QDR is

[154] AFDD 2-6, 55.
[155] Major General David Deptula, interview with the author, 7 February 2002.
[156] Secretary of Defense William S. Cohen, *Report of the Quadrennial Defense Review* (Washington, D.C.: Government Printing Office, May 1997), 1.

designed to examine America's defense needs well into the future. It includes potential threats, strategy, force structure, readiness posture, military modernization programs, defense infrastructure, and other elements to provide a blueprint for a strategy-based, balanced, and affordable defense program.

Department of Defense organizations at all levels are required to review their strategic plans and mission objectives to ensure that they link to the goals and objectives of the QDR. Thus, it represents the latest evolution of tools through which civilian control of the military is implemented. The importance of ensuring military programs are congruent with QDR guidance is therefore essential.

F-22 Budget Challenges

Springing from the Advanced Tactical Fighter program initiated in the early 1980s, the Lockheed F-22 is the follow-on air superiority fighter to the USAF's current McDonnell-Douglas F-15 Eagle. Although the aircraft is specifically suited to the counter-air role, it also will possess significant ground attack capabilities. However, concerns over the aircraft's cost have driven the planned number of aircraft purchased steadily lower. Initially, the quantity of aircraft in the program was set at 750, however it was reduced to 648 in 1991 during the Base Force Review process.[157] In 1993, during the Bottom Up Review the program was cut again, this time down to 442. Not unexpectedly, the 1997 QDR cut production further to a total of 339 production and 2 development aircraft.

These cuts are over the express objections of both the Joint Chiefs of Staff and each of the Commanders in Chief. Both groups submitted letters voicing their support for the F-22 to the Honorable Trent Lott, the Senate Majority Leader in 1999: "As the Joint Chiefs of Staff, responsible for assuring the most secure environment for the employment of our forces, we speak with one voice on this issue: America needs the F-22 to ensure our military forces always achieve air superiority in any conflict."[158] The Combatant Commanders in Chief wrote, "One of the primary responsibilities we as

[157] Congressional Research Service Issue Brief for Congress, *F-22 Raptor Aircraft Program,* 5 November 2001, 2. Cost concerns were no secret to the manufacturer. In the March-April 2001 issue of the Lockheed Martin internal newsletter, *Mission Brief* Bob Rearden, F-22 Team Program Office General Manager writes, "Technical issues are not the biggest challenge for the F-22 program, affordability is." "The War on Cost," *Mission Brief* 5, no.2 (Lockheed Martin Aeronautics Company, March-April 2001) 3.

[158] Joint Chiefs of Staff, to the Honorable Trent Lott, Senate Majority Leader, letter, subject: F-22 Budget Cuts, 28 July 1999.

warfighters have is the readiness of our forces to fight and win. In looking at future readiness, it is clear the F-22 is an essential part of our modernization requirements."[159]

Anti-Access Strategies

Driven in large measure by the final report of the National Defense Panel (NDP) in 1997, there came increased focus on the likelihood of reduced access to critical areas in which to base US forces. In their assessment, the NDP reported, "Forward bases and forward-deployed forces will likely be challenged and coalition partners coerced. Critical nodes that enable communications, transportation, deployment, and other means of power projection will be vulnerable."[160] Identifying the ability to project combat power rapidly as "the cornerstone of America's continued military preeminence," the NDP stressed the need for means through which to gain access to areas of concern.[161] Specifically, the NDP stated that in the future the US military must be able to deploy "more rapidly, absent forward access, with smaller units and footprint, and with greater lethality."[162] Power projection in the future is not just determined by the military means available, however. "For political (domestic or regional) reasons, allies might be coerced not to grant the United States access to their sovereign territory. Hostile forces might threaten punitive strikes (perhaps using weapons of mass destruction) against nations considering an alliance with the United States. Thus, the fostering and nurturing of allies and alliances, as well as our ability to protect our allies from such threats, will be an important factor in our future ability to project combat power anywhere in the world."[163]

Echoing this concern and emphasizing the joint role tankers play, a Department of the Air Force White paper stated, "Faced with the potential of reduced overseas bases for all US forces, the concept of global reach becomes increasingly important and highlights the aerial tanker as a critical asset in meeting future needs. Air Force tankers refuel Air Force, Navy, Marine and many allied aircraft, leveraging all Service capabilities on land, sea, and in the air. Aerial refueling increases the range, on station times, and ordnance

[159] Combatant Commanders in Chief, to the Honorable Trent Lott, Senate Majority Leader, letter, subject: F-22 Budget Cuts, 28 July 1999.
[160] Phillip A. Odeen, *Transforming Defense: National Security in the 21st Century,* Report of the National Defense Panel, December 1997, i.
[161] Ibid., 12.
[162] Ibid, 33.
[163] Ibid, 12.

capabilities of receiving aircraft —true force multiplication...The increased emphasis on rapid response and global reach will only enhance the value of our tanker force."[164] With the convergence of these factors, Air Force leaders realized they had not well expressed their intentions for the F-22 outside their own organization. Hence, GSTF was born, explicitly addressing each of the three factors driving its birth.[165]

Originally called Global Reconnaissance Strike (GSR), GSTF complements the AEF structure by employing the advanced stealth features of the F-22 to assist the B-2 stealth bomber in defeating enemy anti-access systems. This allows conventional follow on forces to arrive in theater safely and support the Joint Force Commander's campaign. In the words of then Commander of Air Combat Command, General John P. Jumper, GSTF is not a war winning CONOP, but rather a "kick down the door" force.[166] General Jumper unveiled his vision for GSTF in a spring 2001 *Aerospace Power Chronicles* article. In it, General Jumper lays out the history behind GSTF, citing military lessons learned from the 1990s as the driving motivation for the concept.

Thus, the 1997 QDR, the F-22 budget concerns, and the emergence of anti-access strategies employed by potential adversaries combined to highlight the need of the USAF to express a comprehensive explanation of why we wanted F-22.

SERVICE BUDGET PRIORITIES

Relevant USAF doctrine and concepts of operations are necessary determinants of the role of tankers. However, it is clear that one of the truest indicators of intent resides in budget expenditures. The following table summarizes the top twenty-five Defense Programs for fiscal years 2001 through 2005.

[164] Quoted in AFDD 2-6.2, "The Air Force and US National Security: Global Reach – Global Power," Department of the Air Force White Paper, 3.
[165] Deptula interview with author, 7 February 2002.
[166] General John P. Jumper, "Global Strike Task Force: A Transforming Concept, Forged by Experience," *Aerospace Power Journal*, (Spring 2001), on-line, Internet, 19 November 2001, available from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj01/spr01/jumper.htm.

Table 1 – Top 25 Defense Programs, FY01 - FY05

Dollars in Billions	2001	2002	2003	2004	2005	Total
F-22	$3.99	$3.94	$4.70	$4.01	$3.60	$20.24
F/A 18 E/F	$2.94	$2.93	$3.12	$3.19	$3.25	$15.43
JSF	$0.86	$2.65	$3.86	$3.73	$3.92	$15.02
C-17	$3.18	$3.54	$2.70	$1.83	$2.60	$13.85
SSN-774	$2.10	$2.33	$2.34	$2.36	$2.75	$11.88
V-22	$1.84	$2.14	$2.37	$2.30	$2.22	$10.87
CVN-77	$4.21	$0.33	$0.70	$2.14	$1.33	$8.71
LPD-17	$1.58	$1.63	$1.84	$1.78	$0.15	$6.98
SBIRS	$0.81	$0.84	$1.22	$0.99	$0.92	$4.78
Comanche	$0.61	$0.76	$0.74	$0.94	$1.37	$4.42
Longbow Apache	$0.73	$0.85	$0.88	$0.77	$0.44	$3.67
Abrams	$0.65	$0.87	$0.55	$0.84	$0.67	$3.58
FMTV	$0.44	$0.47	$0.70	$0.68	$0.66	$2.95
EELV	$0.62	$0.40	$0.56	$0.52	$0.43	$2.53
C-130J	$0.44	$0.29	$0.39	$0.29	$0.96	$2.37
F-16	$0.37	$0.34	$0.49	$0.50	$0.49	$2.19
Bradley	$0.38	$0.41	$0.41	$0.43	$0.44	$2.07
LHD	$0.02	$0.01	$0.00	$0.17	$1.50	$1.70
JSTARS	$0.56	$0.22	$0.20	$0.36	$0.36	$1.70
C-5	$0.15	$0.27	$0.36	$0.36	$0.49	$1.63
AAAV	$0.14	$0.18	$0.21	$0.46	$0.63	$1.62
F-15	$0.32	$0.35	$0.33	$0.36	$0.19	$1.55
JSOW	$0.28	$0.27	$0.27	$0.30	$0.32	$1.44
JDAM	$0.27	$0.25	$0.28	$0.29	$0.28	$1.37
Crusader	$0.36	$0.45	$0.25	$0.04	$0.17	$1.27

Source: Data compiled from *Program Acquisition Cost By Weapon System*, Department of Defense Budget for Fiscal Year 2003, February, 2002 and Department of Defense Major Defense Acquisition Programs, on-line, Internet, 17 April 2002, available from http://friends.acq.osd.mil/ara/dab.oipt/schedule/mdaplist.html.

Two points are noteworthy. Of the top twenty-five programs, ten require air refueling support to be fully mission effective. These ten programs total $84.85 billion out of the $154.69 billion budgeted. Significantly, almost 55 percent of defense spending for the years shown is dependent on tanker support. The second point to note is that future tanker programs do not appear on this list.

In 1941 the US fully anticipated World War II and was feverishly building aircraft to field against the Axis powers. General Hap Arnold experienced difficulty explaining to his superiors that "money for planes was of no use without operating bases, pilots, and crews" to accompany them.[167] Arnold knew that new weapons would serve little purpose without proper support. Likewise, without recapitalization of US air

[167] James P. Tate, *The Army and Its Air Corps: Army Policy toward Aviation, 1919-1941.* Air University Press, July 1998, 175.

refueling assets, future leaders will find their choices severely limited. The next chapter presents five possible options to meet this recapitalization requirement.

The survey of salient doctrine, examination of current USAF concepts of operations, and budget priorities for each of the services suggests several observations. First, air refueling is a *key* component of how the US has fought and plans to fight in the future. Therefore, maintaining a credible capability or improving it is a must. Second, and closely related to the first, even a cursory review and analysis points to factors suggesting that air refueling will become even *more* relevant than in the past. Third, each of the four branches of service depends on its continued support. Fourth, allies will continue to play a key role in America's employment of military force. Since few of them possess air refueling aircraft, and none in the quantity of the US, it falls to the USAF to meet this requirement.

Chapter 4

Recapitalization Options

Having portrayed the history of air refueling and reviewed doctrinal and concept of operations issues, it is clear that air refueling played and will continue to play a critical role in US military employment. As is true of many military circumstances, there are several options from which to choose when dealing with the issue of recapitalization of air refueling capabilities. Proposed options for meeting the full range of challenges include: (1) continue with the current force structure, (2) modification of commercial variants, (3) production of an all-new tanker from the ground up (KC-X), (4) civilian contract refueling, and (5) employing unmanned aerial vehicles (UAVs) as tankers.

Current Force Structure

One course of action that must be considered is to maintain the current force structure. This is nothing more than the null hypothesis in logical analysis, and is the heuristic starting point for study. The USAF tanker inventory consists of the Boeing KC-135 Stratotanker, the McDonnell Douglas KC-10A Extender, the Lockheed MC-130P Combat Shadow, MC-130E Combat Talon I, and MC-130H Combat Talon II.[168]

The KC-135 is the USAF's core air refueling platform. There are currently 545 KC-135s in the inventory.[169] Of these, 253 are assigned to active duty squadrons, 222 are assigned to Air National Guard (ANG) units, and 70 are in the Air Force Reserve (AFR). The KC-135 carries up to 209,000 pounds of fuel and has six pallet positions. It employs a flying boom to connect to receivers, through which it is capable of offloading fuel at a rate of up to 6,600 pounds per minute.[170] To refuel probe-equipped receivers, the KC-135 is fitted with a drogue assembly attached to the end of the boom, however, this cuts

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[168] "KC-135 Stratotanker," USAF Fact sheet, on-line, Internet, 19 November 2001, available from http://www.af.mil/news/factsheets/KC_135_Stratotanker.html; "KC-10A Extender," USAF Fact sheet, on-line, Internet, 19 November 2001, available from http://www.af.mil/news/factsheets/KC_10A_Extender.html; "HC-130P/N," USAF Fact Sheet, on-line, Internet, 3 May 2002, available from http://www.af.mil/news/factsheets/HC_130P_N.html; "MC-130 E/H Combat Talon" USAF Fact Sheet, on-line, Internet, 3 May 2002 available from http://www.af.mil/news/factsheets/MC-130E-H Combat Talon I-II.htm; "MC-130P," USAF Fact Sheet, on-line, Internet, 3 May 2002, available from http://www.af.mil/news/factsheets/MC-130-P Combat Shadow.htm.

[169] KC-135 Fact sheet.

[170] Air Force Technical Order (T.O.) 1C-135(K)R-1. "Flight Manual – USAF Series KC-135R/T Aircraft." Change 46. 15 August 1998, 1-63.

the offload rate essentially in half. Additionally, the drogue cannot be jettisoned in-flight, making the aircraft incompatible with receptacle-equipped receivers for the duration of that flight. Of the 545 KC-135s, eight are modified as receivers themselves and are employed in support of US Special Operations Command priorities.

The USAF has 59 KC-10s, all of which are assigned to active duty units.[171] The KC-10 is much larger than the KC-135 and is capable of carrying more than 356,000 pounds of fuel, nearly twice the capacity of the KC-135. The KC-10 also serves as an airlift platform and can carry up to 27 pallets of cargo or up to 17 pallets while simultaneously carrying up to 75 passengers. Another advantage of the KC-10 over the KC-135 is that it carries both a boom and drogue on every sortie. Fuel can be offloaded via the boom at rates up to 7,370 pounds per minute and up to 3150 pounds per minute through the drogue.

Finally, USAF employs the Lockheed MC-130P Combat Shadow, MC-130E Combat Talon I, MC-130H Combat Talon II, and HC-130P/N aircraft as tankers for Special Operations helicopters. One significant difference with these aircraft is their primary mission is not air refueling. Each of the MC-130 variants is used chiefly to perform other Special Operations missions with helicopter air refueling support as a secondary mission. There are 28 total Combat Shadow aircraft, 24 of which are assigned to active units and 4 with ANG forces.[172] All 14 MC-130Es are assigned to AFR units while all 24 MC-130H models are assigned to active duty squadrons. 13 HC-130s are assigned to active duty units, 13 with ANG, and 10 with AFR units. These C-130 variants are equipped only with hose and drogue assemblies due to their receiver's needs.

Commercial Variant

The utility of the KC-10 suggests that modifying an existing commercial aircraft may be a reasonable approach to the current recapitalization goal. At least two aerospace companies, Airbus Industrié (France) and Boeing, have considered adapting existing aircraft to the tanker role.

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[171] KC-10 Fact sheet.

[172] USAF Fact Sheet: HC-130P/N available at http://www.af.mil/news/factsheets/HC_130P_N.html; USAF Fact Sheet: MC-130 E/H Combat Talon available at http://www.af.mil/news/factsheets/MC-130E-H Combat Talon I-II.htm; USAF Fact Sheet: MC-130P available at http://www.af.mil/news/factsheets/MC-130-P Combat Shadow.htm.

The Airbus offering is called the Multirole Tanker-Transport (MRTT).[173] Based on the A310 airframe, the aircraft would be capable of carrying up to 170,000 pounds of fuel. The planned conversion would have both boom and drogue systems installed and retain its cargo carrying capacity of up to approximately 110,000 pounds. It is expected to be equipped with a refueling receptacle, allowing it to be refueled itself.

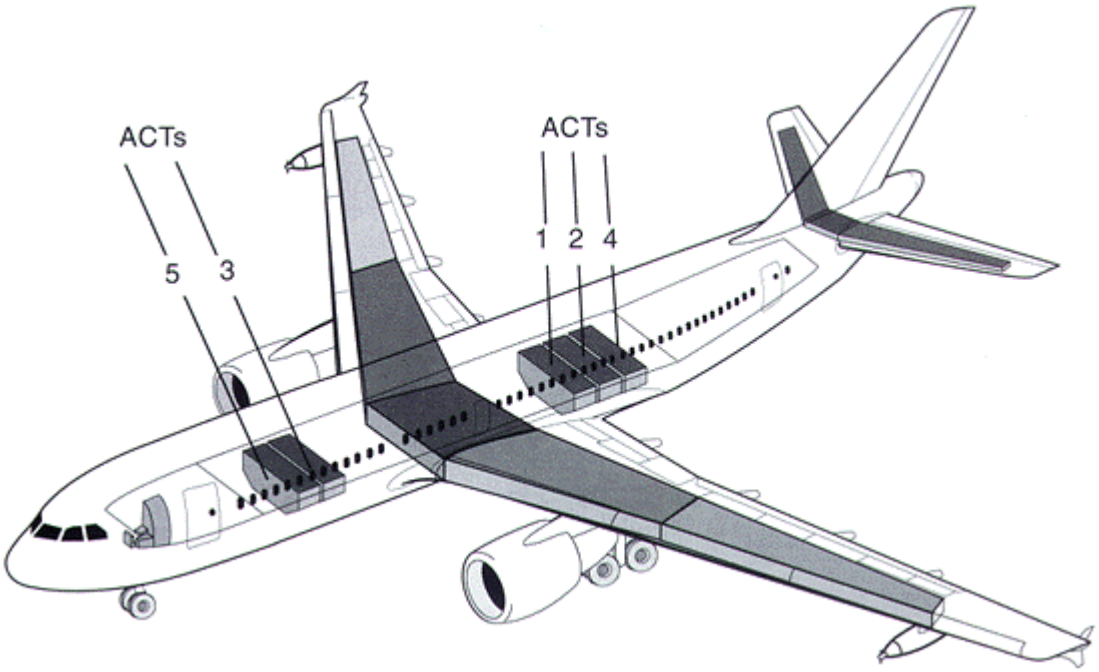

Figure 4 - Airbus Industrie MRTT

Source: Jane's All the World's Aircraft 2002-2003, Jane's Information Group, 2002, on-line, Internet, 16 April 2002, available from http://www.janes.com.

Boeing plans its tanker proposal on the 767 airframe.[174] The aircraft will carry approximately 206,000 pounds of fuel, roughly the same capacity as the KC-135.

[173] "Airbus Multirole Tanker-Transport (MRTT)," Jane's All the World's Aircraft 2002-2003, Jane's Information Group, 2002, on-line, Internet, 16 April 2002, available from http://www.janes.com.
[174] "Boeing 767 Tanker/Transport," on-line, Internet, 3 May 2002, available from http://www.boeing.com/defense-space/military/767t-t/flash.html.

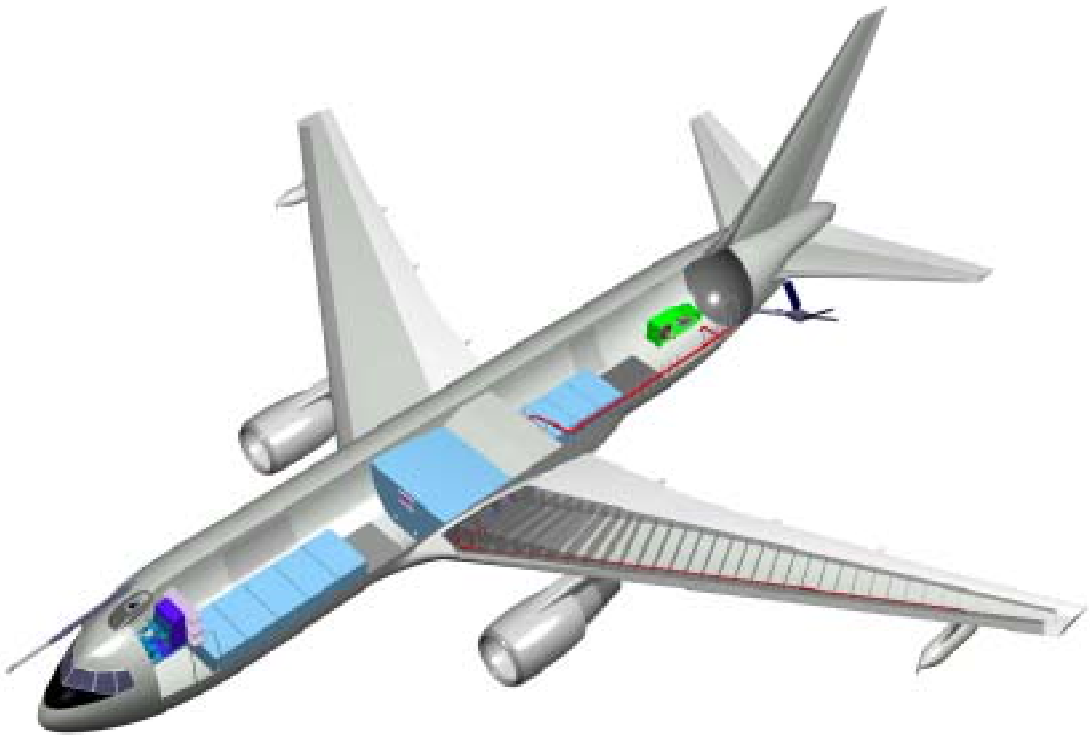

Figure 5 - Boeing KC-767

Source: Boeing 767 Tanker/Transport," on-line, Internet, 3 May 2002, available from http://www.boeing.com/defense-space/military/767t-t/flash.html.

Like the Airbus, the 767 will be equipped with both a boom and hose and drogue refueling systems. It will have its own air refueling receptacle, and be capable of performing as an airlifter while retaining its tanker functionality.

KC-X

Lockheed-Martin's box wing aircraft design is one possible solution to the KC-X. Their Advanced Mobility Aircraft (AMA) incorporates a unique wing configuration designed to enhance aerodynamic properties while reducing the overall size of the aircraft.[175] The junction between the upper and lower wings provides mounting points for left and right booms on the lower surface while mounting drogues on the associated upper joints. Thus, the AMA offers twin-boom/drogue configurations on all sorties. The fuselage cargo area opens to the rear much as the current C-130 Hercules allowing the

[175] "Advanced Mobility Aircraft: Tanker/Transport," Lockheed-Martin, on-line, Internet, 3 May 2002, available from http://www.Imasc.com/ama/tanker.htm.

aircraft to double in the airlift role. In order to be compatible with the digital battlefield of the future, KC-X should include embedded sensors and data relay equipment.

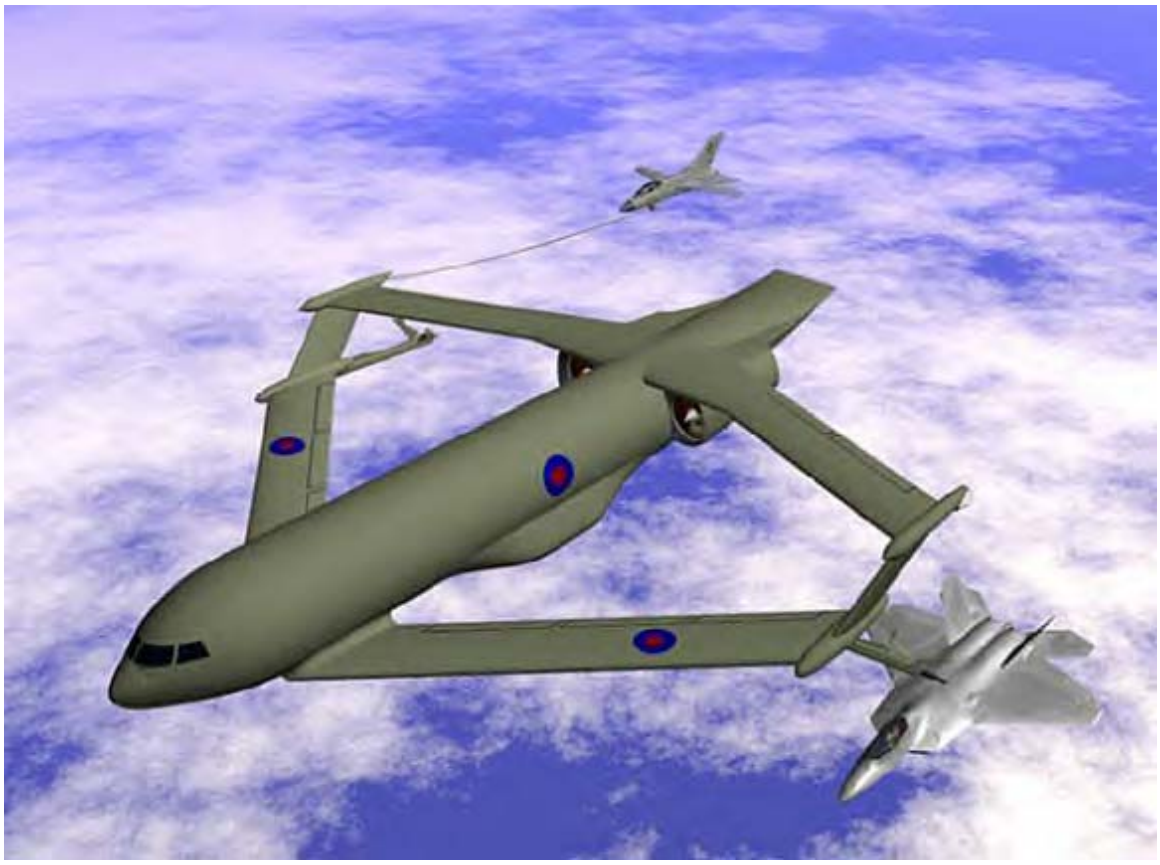

Figure 6 - Box Wing Tanker Proposal

Source: "Advanced Mobility Aircraft: Tanker/Transport," Lockheed-Martin, on-line, Internet, 3 May 2002, available from http://www.Imasc.com/ama/tanker.htm.

Civilian Contract Refueling

The US military regularly contracts with civilian corporations to obtain capabilities they lack or have in short supply. Air Mobility Command maintains a significant airlift capability in the Civil Reserve Air Fleet (CRAF) program, designed to meet airlift shortfalls in times of emergency. For their part, civilian carriers pledge a certain number of aircraft to be made available when called upon while AMC in peacetime awards contracts to participating carriers as an incentive to participate in the program.[176] Similar programs to meet air refueling needs could bring similar benefits.

[176] *Civil Reserve Air Fleet,* USAF Fact Sheet, on-line, Internet, 17 May 2002, available from http://www.af.mil/news/factsheets/craf.html.

Perhaps encouraged by the success of the CRAF, Virginia-based Omega Air, Incorporated offers civilian aircraft modified to provide air refueling.[177] Omega Air is a subsidiary of an Irish firm by the same name that specializes in modifying discarded aircraft for resale or lease. In March 1997, Omega Air contracted with the US Naval Air Warfare Center Aircraft Division establishing a four-phase evaluation of the suitability of retrofitting Boeing 707 aircraft with hose and drogue refueling systems for use with Navy and Marine Corps receivers. In the culmination of the program, from September 2001 through March 2002 Omega Air successfully refueled 825 Navy aircraft including F-14s, F-18s, EA-6Bs, and S-3s.[178] The current Omega Air fleet consists of one KC-707, but they have recently acquired 20 DC-10s from Japan Airlines that are planned for conversion to air refueling platforms.[179] Thus, once the conversions are complete, the Omega Air fleet will consist of airframes substantially similar to those flown by the USAF.

Unmanned Tanker Platform

There are no current plans or systems that are capable of performing the tanker mission from an unmanned aerial vehicle (UAV).[180] However, it is an option often discussed, for the reasons outlined below. Nonetheless, the following is purely hypothetical.

Current aircraft autopilots can easily be programmed to fly from one point to another and to maintain tracks and orbits that would be suitable for air refueling. Tremendous advances in UAV capabilities suggest that they could be modified to perform this mission as well. Although current UAVs such as the USAF Predator system would be too slow and carry insufficient payload to be considered, the Global Hawk and DarkStar high-altitude endurance (HAE) platforms, or derivatives thereof, offer more promise.

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[177] Heather Herod, Naval Air Warfare Center Aircraft Division News release, "Aviation History Underway at NAWCAD," on-line, Internet, 24 April 2002. Available from http://www.nawcad.navy.mil/view_release.cfm?article_id=8.
[178] Ron Laurenzo, "Private Aerial Tanker Earns Navy's Praise," *Defense Week* 23, no. 17 (2002): 1, 15.
[179] Gale Matthews, President, Omega Air, Inc., interview with the author 10 June 2002.
[180] *Unmanned Aerial Vehicles Roadmap: 2000 – 2025*, Office of the Secretary of Defense, April 2001.

Global Hawk operates at ceilings of up to 65,000 feet and can remain airborne for up to 40 hours.[181] It can fly up to 12,000 miles at speeds up to 340 knots, more than adequate to be compatible with the speeds of today's receiver aircraft.[182] The RQ-3A DarkStar was the alternative HAE UAV developed by the Advanced Research Projects Agency joint UAV program office. The system is optimized for reconnaissance in highly defended areas, such as those that may be encountered in an anti-access strategy defended environment. This capability to operate in highly defended areas stems from its low-observable design characteristics. DarkStar has a range in excess of 500 miles at altitudes up to 45,000 feet.[183]

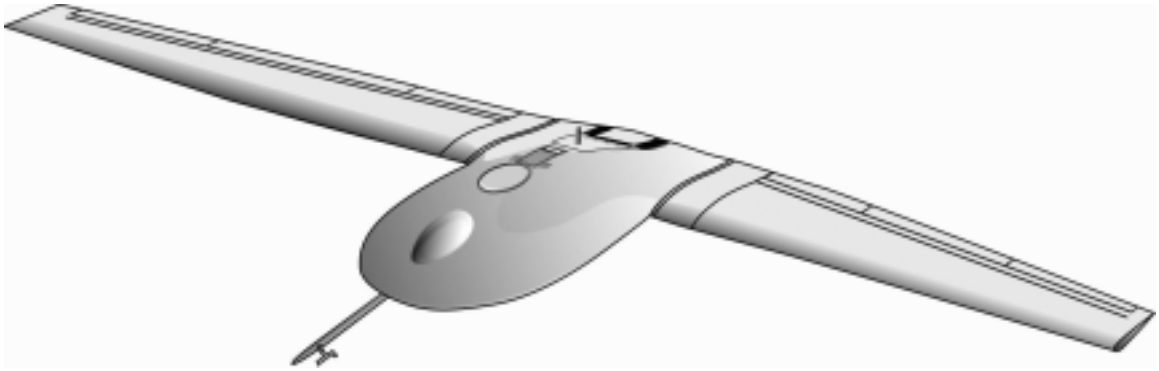

Figure 7 - RQ-3A DarkStar

Source: RQ-3A DarkStar Tier III Minus, on-line, Internet, 19 May 2002, available from http://www.fas.org/irp/program/collect/darkstar.htm.

In order to realistically incorporate UAVs into tanker service, modifications will be required. The primary advantage of UAVs is their potential utility in close combat support in order to limit liability to pilots. Multiple refueling of fighter or helicopter platforms would be especially useful. Accordingly, modifications under consideration for traditional tanker aircraft should be considered for UAVs.

In January 1972, the Boeing Company published the test results of a study undertaken to determine the feasibility of a multipoint aerial refueling boom system for

[181] 1997 United States Air Force Issues Book, Appendix B, Air Force Background Papers, on-line, Internet, 13 February 2002, available from http://www.af.mil/lib/afissues/1997/app_b_16.html.
[182] USAF Fact Sheet. *Global Hawk.* http://www.af.mil/new/factsheets/global.html.
[183] RQ-3A DarkStar Tier III Minus, on-line, Internet, 19 May 2002, available from http://www.fas.org/irp/program/collect/darkstar.htm.

use with the KC-135.[184] The study examined several options, some of which allowed up to four receptacle-equipped fighter aircraft to be refueled simultaneously from a KC-135. The study went as far as a full-scale mockup of a store designed to be mounted on the wingtips of the KC-135, seen in the figure below. Surprisingly, the design incorporates both a boom assembly, shown extended, as well as a drogue. The drogue adapter is located in the aft section of the fairing. The tanker crew could choose the configuration of the boom in flight, allowing this design to be fully compatible with all receivers.[185]

Figure 8 – Full-scale Mockup of Boeing Multipoint Boom Store

Source: *Multipoint Aerial Refueling Boom Feasibility Study,* Technical Report ASD/XR-71-30 (Wichita, KS: The Boeing Company, Wichita Division, January 1972), 497.

[184] *Multipoint Aerial Refueling Boom Feasibility Study,* Technical Report ASD/XR-71-30 (Wichita, KS: The Boeing Company, Wichita Division, January 1972), 3.
[185] Although the US never purchased the system, Iran currently employs one similar to it on both their KC-747 and KC-707 tankers. The system is the Beech 1080 Air Refueling store and is suitable only for probe-equipped receivers. Paul Jackson, ed. *Jane's All the World's Air Forces,* (Alexandria, VA: Jane's Information Group, Limited, 2000), 190-191.

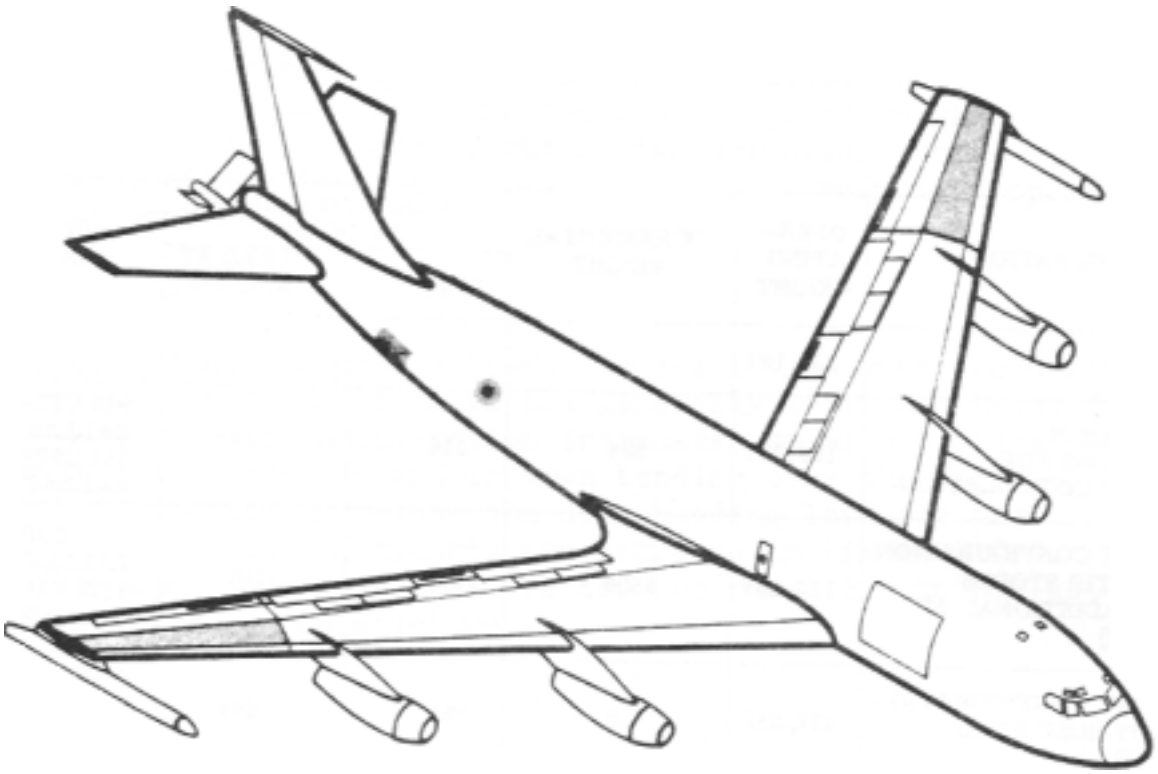

Figure 9 – Multipoint Boom Store Installed on KC-135
Source: *Multipoint Aerial Refueling Boom Feasibility Study,* Technical Report ASD/XR-71-30 (Wichita, KS: The Boeing Company, Wichita Division, January 1972), 37.

This system, or one sufficiently like it, could be adapted for installation on a UAV. This boom could be integrated directly into the fuselage itself rather than mounted on external hard points, as seen in Figure 9, however the issue of developing a boom that could feasibly be installed on a UAV appears to have been solved three decades ago.

Adequately controlling the boom is the next issue that needs to be addressed. A series of Air Force Institute of Technology (AFIT) studies may offer solutions.[186] Between December 1989 and January 1997, AFIT performed studies designed to allow autonomous refueling of aircraft in hazardous ground environments, such as a chemically contaminated area, for example. The studies reviewed various methods of successfully controlling and guiding robotics arms to find and connect with the aerial refueling port of

[186] The studies referred to include: Wade Milholen, *Experimental Evaluation of Impedance Control for Robotic Aircraft Refueling*, 14 December 1989; Clayton M. Anderson, *Three Degrees of Freedom Compliant Motion Control for Robotic Aircraft Refueling,* 13 December 1990; Richard A. Bennett, *Brightness Invariant Port Recognition for Robotic Aircraft Refueling,* December 1990; and Douglas Haanpaa and Mark Drajeske, *Force Feedback, Virtual Fixtures, and Reality Registration for Mid-Air Refueling,* January 1997.

fighter aircraft. Although these experiments are designed for employment on the ground, once a receiver aircraft is in the refueling envelope the relative motion between the tanker and receiver aircraft is static. If these guidance methods could be linked to visual cues provided by the optical cameras mounted on the extension arm of the Boeing Multipoint Boom Store, the necessary adjustments could be made without human intervention. The procedure would be even simpler for a probe-equipped receiver, since the drogue is essentially self-guiding by design. Thus, all of the components necessary to construct a hypothetical unmanned tanker have already been developed.

The most viable options for near and long-term tanker recapitalization have been presented. The remaining tasks are to compare the strengths and weaknesses of each using the criteria of feasibility, acceptability, and adequacy, and to base recommendations upon them.

Chapter 5

Feasibility, Acceptability, Adequacy Comparisons

This chapter focuses on comparisons between the options presented in Chapter 4. The comparison is affected using criteria normally associated with operational combat plan analysis found in Joint Publication 1-02*, Department of Defense Dictionary of Military and Associated Terms.* Although not routinely used in this manner, assessing the feasibility, acceptability, and adequacy of the options clarifies the strengths and weaknesses of each.

As defined in the Joint Pub, **feasiblility** is an operation plan review criterion that establishes "whether the assigned tasks could be accomplished by using available resources."[187] **Acceptability** determines "whether the contemplated course of action is worth the cost in manpower, materiel, and time involved; is consistent with the law of war; and is militarily and politically supportable."[188] **Adequacy** assesses whether the scope and concept of a planned operation are sufficient to accomplish the task assigned."[189]

Using these criteria as a comprehensive functional analysis model, each option can be assessed, first relative to each criterion, and finally in relation to each other. This contextually influenced snapshot will then be combined with implications from history and future conops to establish final recommendations in Chapter Six.

Current Force Structure

Feasibility – Not surprisingly, maintaining the current force structure must be assessed not only as a feasible solution, but also the most feasible of the options presented. By definition the fleet in being has an advantage in feasibility. Evidence presented in Chapter one indicated that the current tanker force is able to consistently conduct real world combat operations with mission reliability rates in excess of 90 percent. Therefore, of the options considered, maintaining the current USAF force structure is the most feasible choice.

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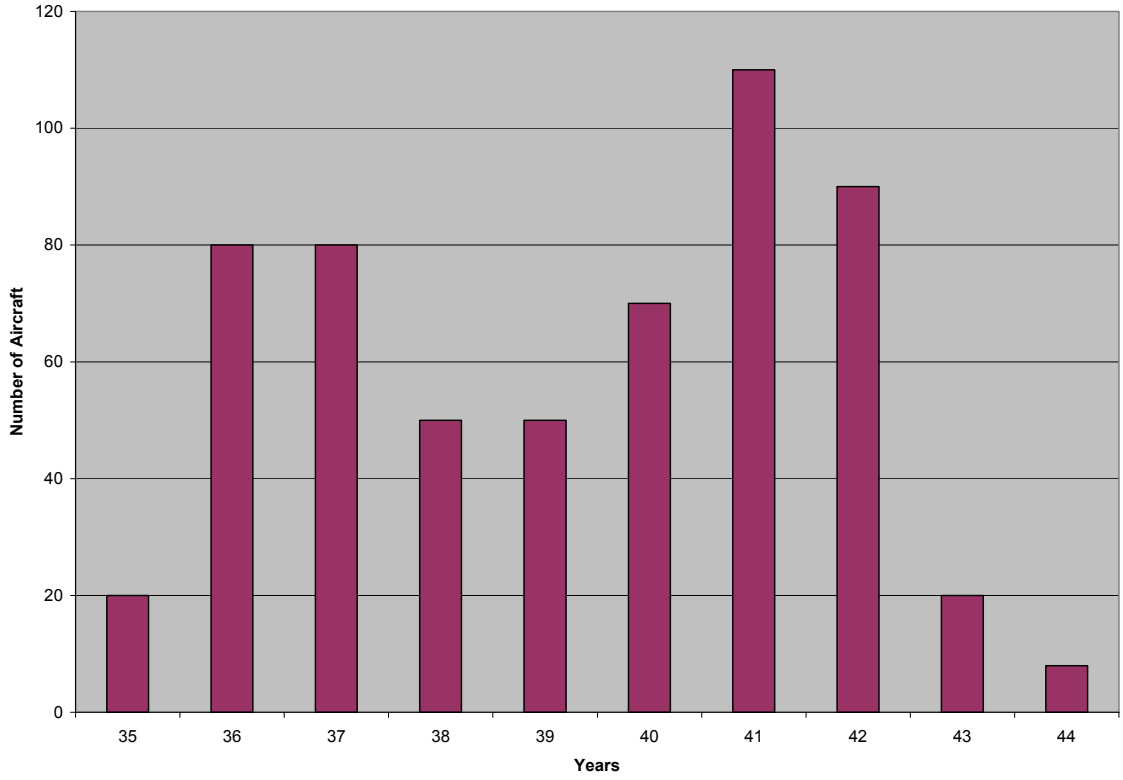
[187] *Joint Pub 1-02, Department of Defense Dictionary of Military and Associated Terms.* 12 April 2001, 156.
[188] *Ibid.*, 1.
[189] *Ibid.*, 4.

Acceptability – The acceptability of maintaining the current force structure is somewhat questionable. Continual upgrades and modification programs have been undertaken in order to prolong the usefulness and relevance of the KC-135 in particular.[190] Originally, the skin of the KC-135 was designed to last for approximately 10,000 flight hours. However, in August 1977, SAC authorized reskinning of the KC-135 fleet with materials in use on the commercial Boeing 707 airframe, which increased the life expectancy to 27,000 flight hours. Beginning in 1981, the Air Force re-engined the KC-135 fleet with the CFM-56 engine, which gives the aircraft more thrust, burns less fuel and is dramatically quieter than the original J57 engines. In the mid-1990's cockpit conversions took place under the Pacer CRAG (Compass, Radar, Avionics and Global Positioning Satellite) program the KC-135 cockpit is substantially modernized. Flight tests have been attempted with a Multi-Point Refueling System that would allow the KC-135 to add one hose and drogue pod to each wing tip allowing it to refuel both boom and probe receivers on each sortie, thereby increasing its versatility. The system has experienced several challenges both in budgeting and functionality and therefore has not fully matured.

Despite these wide-ranging modifications, as of this writing the average age of the KC-135 is 38.7 years (see Figure 10 below), and the increase in flying has created concurrent increases in maintenance requirements.

[190] For a detailed discussion of modifications to various systems see Hopkins, *Boeing KC-135,* particularly chapter 5.

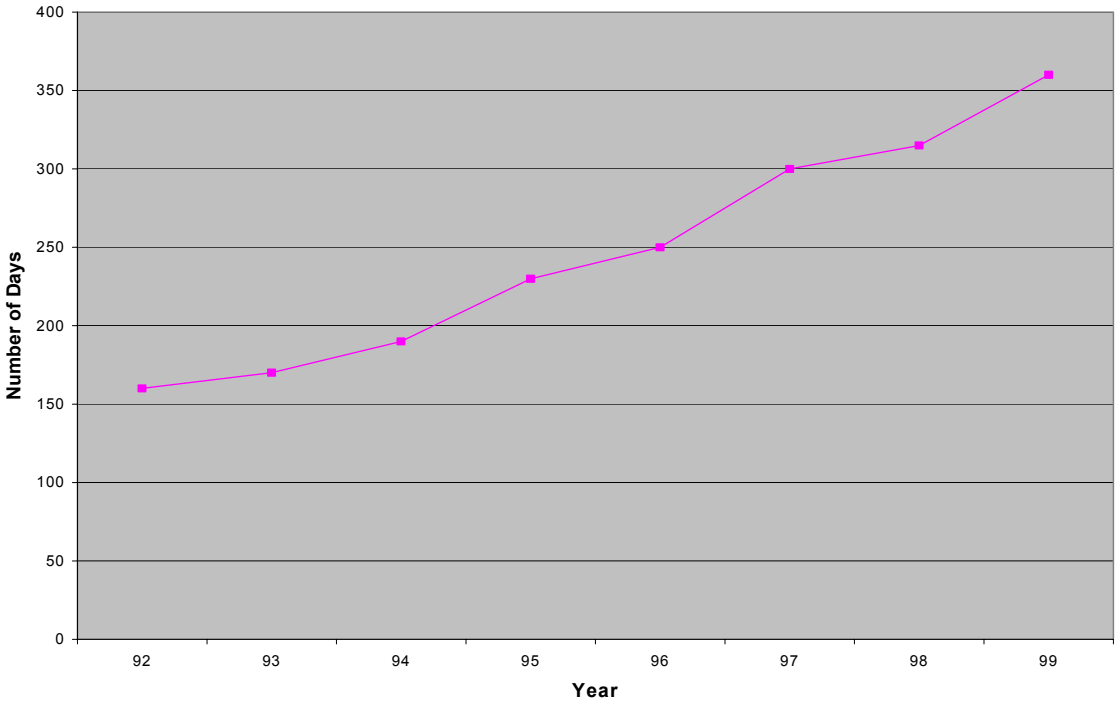
Figure 10 - Age of the KC-135 Fleet as of September 1999



Source: Oklahoma City Air Logistics Center, Tinker Air Force Base, OK, quoted in United States General Accounting Office Report to the Chairman, Subcommittee on Military Readiness, Committee on Armed Services House of Representatives GAO/NSIAD-00-135, *Air Transport Capability Falls Short of Requirements,* 38.

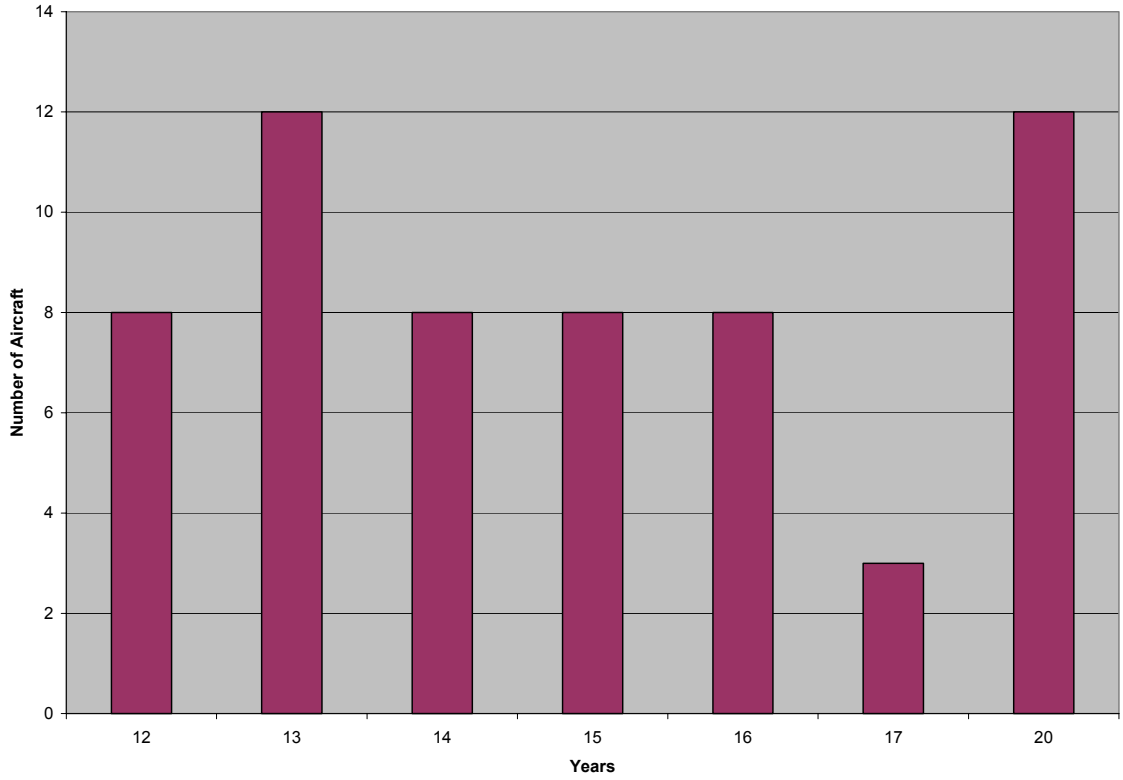
Inspections based on hours flown are coming due sooner and taking longer than forecast because of the increased strain on the aircraft. Most notably, the depot inspection, which is scheduled to take 120 days per aircraft, is now taking an average over 400 days and has increased 288 percent over the last 10 years (see Figure 11 below). This increase in downtime is due to unanticipated airframe corrosion and puts the USAF's core air refueling capability at risk. While the USAF is dealing with the corrosion on an aircraft by aircraft basis, the KC-135 fleet as a whole finds itself in a situation jarringly similar to that of the KB-50 in 1964 just before the entire KB-50 fleet was grounded due to widespread corrosion.

Figure 11 - KC-135 Average Depot Maintenance Days Fiscal Years 1992-99



Source: Oklahoma City Air Logistics Center, Tinker Air Force Base, OK, quoted in United States General Accounting Office Report to the Chairman, Subcommittee on Military Readiness, Committee on Armed Services House of Representatives GAO/NSIAD-00-135, *Air Transport Capability Falls Short of Requirements,* 41.

Figure 12 - Age of the KC-10 Fleet as of January 2000



Source: Oklahoma City Air Logistics Center, Tinker Air Force Base, OK, quoted in United States General Accounting Office Report to the Chairman, Subcommittee on Military Readiness, Committee on Armed Services House of Representatives GAO/NSIAD-00-135, *Air Transport Capability Falls Short of Requirements,* 39.

Thus, due to the limited number of KC-10s available, the specialized roles of the C-130 variant tankers, and KC-135 maintenance requirements, the United States' current force structure is not an acceptable solution.

Adequacy – A June 2000 General Accounting Office report on military readiness concluded that the DoD is 19 percent short of the air refueling capability required to execute wartime plans.[191] Their findings were based on the same two major theaters of war assumptions as the 1997 QDR, thus the report's findings must be reviewed in accordance with the capabilities based model of the 2001 QDR. There can be little doubt, however, that the maintenance trends and age of the KC-135 fleet in particular will continue to negatively impact the air refueling capacity the USAF can bring to bear.

[191] United States General Accounting Office. *Air Transport Capability Falls Short of Requirements,* June 2000, 29.

Based on the QDR findings and empirical trend, the current force structure will be inadequate to meet future needs.

Commercial Variant

Feasibility – Adapting commercial aircraft currently in production to execute the air refueling mission is feasible, as demonstrated on by the KC-10, for example. As mentioned in a previous chapter, both Airbus Industrié and Boeing have approached the USAF with preliminary proposals to convert the Airbus A310 or the Boeing 767 into tanker platforms. Advantages of this course of action include the avoidance of airframe certification by the Federal Aviation Administration, and compliance with equipment requirements specified by the International Civil Aviation Organization under the future Global Air Traffic Management airway structure.[192]

Acceptability – Developmental costs would be minimal for a conversion of an existing airframe. The Airbus A310 is currently flying in the German Air Force as a transport aircraft with conversion to the tanker role scheduled for 2004.[193] The Boeing 767, for example, is planned to enter service as a tanker with the Italian Air Force and Japanese Air Forces.[194] Another advantage enjoyed by commercial derivative aircraft is the commonality of parts and maintenance needs with their civilian counterparts. For example, 88 percent of the parts on the KC-10 are common to both the military and commercial aircraft.[195] Because of this commonality, when the USAF purchased the KC-10, it also bought into the worldwide maintenance pool of parts used by commercial

[192] The International Civil Aviation Organization (ICAO) sprung out of meetings held in Paris in 1910. Its evolution paralleled that of aircraft development and travel leading to the Chicago Conference in November 1944. It was during this conference that the ICAO was formally established, "as a means to secure international co-operation and highest possible degree of uniformity in regulations and standards, procedures and organization regarding civil aviation matters." Source, "Foundation of the International Civil Aviation Organization." http://www.icao.org/cgi/goto.pl?icao/en/history/htm. The Global Air Traffic Management (GATM) program is designed to increase the safety and visibility of air traffic, particularly in remote areas where ground-based radar monitoring is impossible, such as over oceanic regions. In order to meet GATM requirements, aircraft must be equipped to capitalize on emerging technological improvements in communications, navigation, and traffic avoidance. Source: "Global Air Traffic Operations" http://www.hanscom/af.mil/esc-gat/. The majority of USAF aircraft are currently not GATM compliant. The alternative is to avoid GATM airspace, however this is costly due to circuitous routing and inefficient altitude restrictions that cause increased fuel consumption.

[193] *Jane's All the World's Air Forces* (Alexandria, VA: Jane's Information Group, Limited, 2001), 148.

[194] As of this writing, Italy will be the first country to fly the KC-767 with deliveries beginning in 2004-2006. Japan will begin receiving their KC-767s in 2008. *Jane's All the World's Air Forces* (Alexandria, VA: Jane's Information Group, Limited, 2001), 165, 221.

[195] "KC-10A Extender," USAF Fact Sheet.

airlines, which helps avoid maintenance delays.[196] Similar arrangements could be made today. This option is inherently politically sensitive, however, and subject to manipulation based not on rationally assessed needs, but rather subjectively motivated interests. Following the attacks on the United States of 11 September 2001, several aircraft buyers cancelled orders, resulting in aircraft that were in the process of being built, but without buyers to take delivery. This is reminiscent of the situation following the 1973 oil embargo, when the USAF purchased the KC-10. Addressing the ATCA purchase at the time, Secretary of the Air Force Orr, commented that rather than wait for an entirely new tanker to be constructed, "a good program soon was chosen over a somewhat better program later."[197]

Adequacy – There are several tradeoffs to consider when assessing the adequacy of a commercial variant. Of those aircraft currently under study, there is slightly more information available on the 767. The airframe is essentially the same size as the KC-135, but has a somewhat smaller fuel capacity than the KC-135R.[198] It will have the capacity to be configured to carry eighteen pallets or up to 216 passengers.

The A310 also has roughly the same dimensions as the KC-135.[199] Converted as a tanker, the aircraft will have a fuel capacity in excess of 170,000 pounds. It will be able to carry up to 214 passengers and a payload up to 110,231 pounds. The inherent benefits of either the 767 or A310 are that both take advantage of modern construction methods, avionics, and materials. This modern equipment is fully compliant with current GATM requirements as well as those planned in the foreseeable future. Clearly, either of the commercial aircraft discussed are adequate to the USAF needs.

Both aircraft have smaller offload capacities than the KC-135s they are intended to replace. Also, it is likely that defense spending will not result in the purchase of sufficient new tankers to support a one for one replacement of new tanker for KC-135. Thus, the overall refueling capacity will be less than the current capacity, which has already been shown to be 19 percent below that required. Therefore, this option, while it does offer some interim value, falls short of an adequate long-term solution.

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[196] Futrell, *Ideas, Concepts, Doctrine,* Vol II, 656.
[197] Quoted in Volume II, Futrell, *Ideas, Concepts, Doctrine,* 665.
[198] *Jane's All the World's Aircraft*, 588.
[199] *Ibid.,* 185.

KC-X

Feasibility – Due to the tremendous expense and extended time required by the current acquisition process, this is the least feasible of the five options considered. The USAF's most recent purchase of a large aircraft specifically designed for military uses was the Boeing C-17 Globemaster III. In September 1986 the Congressional Budget Office published a report entitled *Improving Strategic Mobility: The C-17 Program and Alternatives.*[200] The report states that the complete C-17 program is estimated to cost $29.3 billion, a figure that does not include an additional $600 million dollars for research and development that was conducted before 1987. These figures establish the fly-away cost (which includes research and development, initials spares, training equipment, required ground support equipment and other nonaircraft expenses) of the C-17 at $103 million per plane. By comparison, the fly-away cost for the KC-10 was $63 million per aircraft. These figures are intended merely to demonstrate the significant difference between developing an entirely new aircraft versus modifying existing airframes. Obviously the figures will be different for the KC-X, however, the scope of differences is instructive.

Acceptability – It is axiomatic that political pressures are a influential factor in the development of any major defense acquisition program. One need only witness current debate surrounding the lease or buy decision the USAF faces with the KC-767 for ample evidence of the role played by various interest groups.[201] Consideration must be given to U.S. versus international manufactures, as well as balancing the needs of other defense spending programs.[202] While these considerations do not preclude the possibility of such an aircraft being developed, they are liabilities in this assessment.

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[200] Rudolph G. Penner, *Improving Strategic Mobility: The C-17 Program and Alternatives* (Congressional Budget Office, September, 1986) 16 – 21.

[201] Examples of the issues surrounding the plan can be found in: Ron Laurenzo, "Air Force Wants 767 Tankers ASAP" *Defense Week Update* 1 February 2002; "Roche, DOD Would Need Legislative Changes To Lease Boeing 767s" *Aerospace Daily,* 22 January 2002; Gail Kaufman and Amy Svitak, "Lease Vexes Senators" *Defense News* 16, no. 49: 8.

[202] For an example of international concerns influencing US military acquisition programs, see Amy Svitak, "Boeing's Aircraft Conversion Plan Bumps Into Security Rule" (*Defense News*, 7 – 13 January 2002), 3; David A. Fulghum "Allies Call for U.S. Tanker Competition" *Aviation Week & Space Technology,* 21 January 2002; Marc Selinger "Air Force Secretary Says He Would Welcome Airbus Bid On Tankers" *Aerospace Daily,* 12 February 2002.

Adequacy –Properly configured, KC-X could easily be the most adequate solution of the options considered. For example, equipping the KC-X with multiple booms would reap benefits in both the deployment and employment phases. In the deployment phase, multiple booms would provide the advantage of a built-in backup in case of a boom failure, alleviating some planning restrictions.[203] During employment, the KC-X would be able to off-load fuel to both members of two-ship fighter formations, enhancing formation integrity and decreasing the amount of time required for formations to perform their primary missions. The aircraft should also have the means through which to refuel probe receivers on every sortie. Another benefit could be realized by maximizing the aerodynamic properties of the KC-X in the lower altitude regime normally used for air refueling rather than for the higher altitudes used for fuel-efficient cruising operations. Most civilian airline designs are most aerodynamically efficient at these higher altitudes, so modifying a civilian design results in less efficient operations during refueling.

Civilian Contract

Feasibility – Based on the four-phase project conducted between Omega Air, Inc. and the Naval Air Warfare Center Aircraft Division, civilian contract air refueling is feasible for probe receivers. The successes experienced during the months mentioned indicate that, like its military counterpart the KC-135, the KC-707 is capable of refueling a variety of receiver aircraft.[204] However, the majority of USAF receivers require a boom-equipped tanker. Until a civilian concern makes the necessary modifications, this in not a feasible option for directly meeting USAF needs. Indirectly, however, USAF tanker planner would realize benefits stemming from reduced requirements for USN and USMC training and deployment.[205]

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[203] Whenever the F-117 Stealth fighter is ferried, for example, current tanker planning factors call for a ratio of no more than two F-117s per tanker, for example. A multi-boom tanker would presumably rid planners of this hindrance. For the restriction, see Air Force Pamphlet 10-1403, *Air Mobility Planning Factors*, 1 March 1998, Table 11 "KC-135 Tanker Aircraft Required," Note 4, 19.

[204] Omega Air, Inc., has also made inroads with US allies in NATO. The Omega Air, Inc. KC-707 is listed among approved tankers in Annex 10U to the NATO Air to Air Refueling Document, ATP 56(A).

[205] The burden will not be totally relieved, however. Before being designated fully qualified for a deployment USN and USMC pilots are required to conduct at least one refueling with the tanker used to support them in combat. Thus, KC-135s and KC-10s will still be required to conduct some minimal level of training with these aircraft, but a much-reduced level, presumably. Gale Matthews, President Omega Air Inc., interview with the author, 10 June 2002.

Acceptability – Comparing operating costs of civilian contract refueling is straightforward. During the months of September 2001 to March 2002, Omega Air, Inc. charged the Navy $5995 per KC-707 flying hour for air refueling. This falls between the operating expenses of the KC-135 and KC-10, which are $3, 673 and $7,527, respectively.[206] Currently, there is only one source for civilian contract air refueling, Omega Air Inc., thus eliminating competition between contractors that may result in better pricing for users.

Adequacy – Civilian air refueling is inadequate to meet the majority of USAF needs. Currently there is only one company that offers this capability and they have only one modified aircraft. The modifications provide only for hose and drogue refueling, which precludes compatibility with the majority of USAF receiver aircraft. Additionally, Omega Air, Inc. does not see itself supporting combat operations, regardless of the receiver involved. "The tanker fleet would be available to support test centers, training missions, depots, and ranges and selected fleet operations."[207] Changes to their equipment, fleet size, and employment concepts would significantly affect this assessment, but at the time of this writing, civilian air refueling is inadequate for USAF needs.[208]

Unmanned Aerial Vehicle

Feasibility – There are several successful versions of UAVs currently in production, thus it seems reasonable to consider the potential of adapting them to perform as tankers, particularly as penetrating tankers. Flight testing has demonstrated the effectiveness of the propulsion, guidance, and aerodynamic designs. Programming the UAV to fly an established track suitable for air refueling is well within the current capabilities and allowing the receiver aircraft to do the majority of maneuvering simplifies the UAVs task load significantly. Certainly combining the various components required for a successful UAV tanker will entail some research and development investment, however, the fact that viable UAVs are currently operational

[206] AFI 65-503. *US Air Force Cost and Planning Factors*, 4 February 1994, Table A15-1, 3.
[207] Heather Herod, Naval Air Warfare Center Aircraft Division News release, "Aviation History Underway at NAWCAD," on-line, Internet, 24 April 2002, available from http://www.nawcad.navy.mil/view_release.cfm?article_id=8.
[208] For an opposing few on the topic of civilian contract air refueling see, Major Mark D. Camerer, "Civilian Contract Air Refueling: Innovative or Insane?" Research Report no. 2001-04. Maxwell AFB, Ala: Air Command and Staff College, 2001.

offsets these concerns somewhat. Thus, a UAV tanker for use as a penetrating tanker is essentially neutral in relation to feasibility.

Acceptability – UAVs are clearly an acceptable method of performing airborne duties previously dedicated to manned platforms. While there would be some development necessary to mature an unmanned tanker, the potential tradeoffs are significant. First, by its nature, the vehicle would serve well in the role of penetrating tanker in hostile areas, reducing the number of manned platforms at risk. Incorporating low observable elements such as those in the DarkStar UAV would enhance this capability. Second, UAVs could be programmed to loiter high above an area of interest waiting to be called upon for emergency air refueling needs. This "reliability tanker" role is normally performed by KC-10s, however, UAVs could function in this capacity significantly closer to hostile environments than the KC-10. Finally, UAVs have shorter turn around times that would allow them to fly more sorties per day than manned aircraft.

Adequacy – The adequacy of an unmanned tanker rests heavily on the number purchased. UAVs themselves have no crew rest limitations and could therefore fly more sorties and sorties of longer duration than manned tankers. Therefore, while individual airframes may have lower offload capacities, on the whole their total offload capacity would be increased due to these factors. During the deployment phase, UAV tankers could be programmed to fly as part of the deploying formation, increasing the offload available, as well as the number of booms en route. During the employment phase, these same UAVs would be available to employ in theater. Unless large numbers of UAV tankers are purchased, however, the severe restrictions imposed by their individual offload capacities prevent them from consideration as an adequate solution. The following table summarizes current fuel capacities and payloads of both the Global Hawk and DarkStar UAVs.

Table 2 – UAV Weight Comparisons

UAV	Payload Capacity (Pounds)	Fuel Capacity (Pounds)	Total Potential Offload (Pounds)
Global Hawk	2,000	14,210	16,210
DarkStar	1,000	3,000	4,000

Source: Compiled from Kenneth Munson, ed., *Jane's Unmanned Aerial Vehicles and Targets*, (Alexandria, VA: Jane's Information Group, Limited, 1996), n.p.

The information in the table clearly indicates that the available offloads from UAVs are significantly less than those available from other options considered. In the words of a USAF Headquarters Operations Analysis Working paper, "The most important tanker characteristic is its fuel off-load capacity."[209] Additionally, the UAV with the most offload available is the one least suited to the penetrating tanker role. Therefore, based on the extremely limited offloads, UAVs cannot be considered an adequate alternative to meet USAF recapitalization needs.

The results of the above analysis are summarized at Table 3. A "+" indicates that the option rated well relative to the criterion. A " – " indicates the option performed negatively with regard to the criterion. An "O" is an indication that the option is neutral, neither good, nor bad regarding the criterion.

Table 3 - Criteria Results Summary

	Current Force Structure	Commercial Variant	KC-X	Civilian Contract	UAV
Feasible	+	+	_	_	O
Acceptable	_	+	_	+	+
Adequate	O	_	+	_	+

[209] William T. Shuler, Operations Analysis Working Paper No. 63, "Some Effects of Tanker Performance Characteristics on Range of B-47E and B-52 Aircraft," Headquarters, USAF, Washington, D.C., May 1956, 1.

The results in Table 3 were not compared relative to each other, but rather independently within each option. They are crude evaluations, to be sure, meant to be holistic synopses only. The summary table is intended as an easy reference for the results of the analysis of each of the five options discussed given the feasibility, acceptability, and adequacy framework as a control.

This analysis is necessarily static in nature. As factors considered on each criteria change, this would signal the need to reaccomplish the assessment in order to maintain its relevancy. For example, an option's feasibility should be reassessed based on significant technological breakthroughs, such as engine improvements, or construction material changes. The acceptability of non-lethal airpower is less susceptible to concerns originating from the laws of armed conflict, but is clearly affected by treaties and political interests. Adequacy should be reevaluated based primarily on two criteria, total fuel capacity and the number of booms available, but may be influenced by emerging CONOPS should air refueling requirements change. This model is not intended as the definitive verdict on the topic, but rather on passes at a point in time, which must be rebuilt as relevant factors vary.

The following chapter presents conclusions and recommendations based in part on conclusions reached in each of those previous. The holistic integration of the lessons of air refueling history, the future USAF needs, and the static analysis results above determine the form for one proposal to meet the USAF's air refueling recapitalization needs.

Chapter 6

Conclusions and Recommendations

> *Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur.*
>
> --Giulio Douhet, *The Command of the Air*

Readers of AFDD 1 are reminded, "The overriding objective of any military force is to be prepared to conduct combat operations in support of national political objectives—to conduct the nation's wars."[210] It is this standard that must be the ultimate measure of merit when judging between possible courses of action.

Commanders know that criteria are simply tools and not all criteria are equally important at all times; their application requires judgment based on context. As with many military endeavors, effectiveness is more important than efficiency when determining a solution to the issue of recapitalizing the USAF's air refueling capacity. That, combined with guidance from the 2001 QDR, leads to the conclusions and recommendations of this analysis.

The 2001 QDR expresses four key, guiding goals for development of U.S. forces and capabilities:

1 - Assuring allies and friends of the United States' steadiness of purpose and its capability to fulfill its security commitments;

2 - Dissuading adversaries from undertaking programs or operations that could threaten U.S. interests or those of our allies and friends;

3 - Deterring aggression and coercion by deploying forward the capacity to swiftly defeat attacks and impose severe penalties for aggression on an adversary's military capability and supporting infrastructure; and

4 - Decisively defeating any adversary if deterrence fails.[211]

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[210] AFDD 1, 7.
[211] QDR Report, 2001, iii-iv.

The Global Strike Task Force concept, combined with the Air Expeditionary Force construct, clearly supports each of the four key goals above. But, the potential Achilles' heel of GSTF is tanker support.

One of the GSTF's principle architects, Major General David A. Deptula, Director of Plans and Program, Headquarters Air Combat Command, stated that the distinction between long and short-range aircraft is artificial and essentially irrelevant to today's Air Force.[212] Deptula offers as support for his position a pamphlet that discusses how, with tanker support, the concept of range-limited aircraft blurs. The pamphlet boldly states, "Fighters + Tankers Equals Any Range We Need."[213] The pamphlet is right, as long as both components of the equation are available in sufficient measure. The reality is that all aircraft are range limited; differences are simply matters of degree. Current USAF conops, GSTF in particular, are based squarely on the assumption that ample tanker support will be available. This brings to light the first conclusion of this study. Without recapitalization, the USAF tanker capability will continue to erode to the point that it becomes a limiting factor rather than a key enabler.

The feasibility, acceptability, adequacy model provides a means through which air refueling recapitalization options can be assessed. Based solely on the results in Chapter five, the USAF should look to modify a commercial derivative as a manned tanker and develop an unmanned, stealthy version as an alternative. The model is, by design, static. It provides insights to the recapitalization issue based on a moment in time. As mentioned, should key parts of the inputs change, the results would be different. The limitation of the static model is that it cannot account for the dynamic analysis possible through an examination of the history of the subject nor the future trends inherent in emerging concepts of operations. Therefore, in order to account for historical trends, the preeminence of effectiveness over efficiency in military operations, future conops, as well as the contextual analysis from Chapter five, a holistic analysis is necessary. The observations and recommendations that follow are based on a synthesis of previous chapters.

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[212] "Major General David A. Deptula, USAF biography, on-line, Internet, 4 June 2002, available from http://www.af.mil/news/biographies/deptula_da.html.

[213] Deptula, interview with author 7 February 2002; Air Combat Command pamphlet, "In Range: Long Range Strike Operations," undated.

The history of air refueling development reveals three trends. First, since 1947, tanker development has been driven primarily by the needs of the receiver aircraft. Second, tanker employment was heavily influenced by the military environment of the day, starting out as support for nuclear-armed bombers and shifting slowly toward conventional conflict employment. Third, and most importantly, the capabilities of the aircraft have been migrating away from the pure tanker role.

When air refueling existed as a stunt, then as a means of gaining the public's attention over another service, it served no vital military need and was, therefore, discontinued. The 1947 Heavy Bombardment Committee recommendations identified the problem and air refueling development matured quickly thereafter. In the subsequent two decades, tanker aircraft designs regularly adapted to meet the needs of their receivers. These decades also witnessed the beginning of the second trend, away from air refueling's original raison d'etre to supporting conventional armed conflict.

In the 1950's and 60's U.S. national leaders were primarily concerned with the specter of all out nuclear warfare. Hence, the design of aircraft, military organizations, and war plans focused on deterring and, if necessary, winning such a conflict. However, we also adopted a policy of containing the spread of communism, which compelled U.S. involvement in multiple lower-intensity operations. The benefits of air refueling were obvious to commanders in these conventional conflicts, and TAC aggressively sought out, developed, and employed tankers for its own aircraft. Hence, tankers became a normal part of U.S. war fighting as early as the Korean conflict. It was during these conventional conflicts the third trend emerged. Tankers began performing roles other than simply air refueling.

In 1962, SAC modified three KC-135s for duty as communications relays under the Post Attack Command and Control System program. Piggybacking on the idea, not long after, TAC modified seven KC-135s into tactical communication relays known as Combat Lightning and employed them for that purpose in Southeast Asia.[214] This trend away from an air-refueling-only aircraft reached its zenith to date with the purchase of the dual-role KC-10. Likewise today, the USAF is working toward fielding the "Smart tanker," which incorporates sensors and communications equipment onto tankers

[214] Hopkins, *Boeing KC-135,* 132.

allowing them to be employed much as the Combat Lightning aircraft were in Southeast Asia, as key nodes of tactical communications networks.[215]

In the development of air refueling, from birth through maturity, extant factors have been more influential than expressed desires. Thus LeMay finally succeeded in "convincing" the USAF of the wisdom of the boom, and Boeing sold more than 900 C-135 variants to the Air Force despite losing the all jet tanker competition. The principal finding of this thesis is likewise based on empirical evidence. There has been a de facto paradigm shift away from specialized tankers toward multi-role platforms. The USAF needs to recognize and accept the shift in order to capitalize on its potential.

Armed with the multi-role tanker mindset, recommendations for future capabilities follow easily. The way ahead for recapitalization efforts should not be based on tanker-only platforms. Future tankers should be primarily designed for other mission needs and serve a secondary role as air refueling platforms. This, in turn, leads to the idea that, while in the past tanker characteristics were driven by receiver needs, future tanker development should flow out of the needs of the air component commander. For example, the air component commander burdened with moving entire squadrons to a combat theater requires a deployment phase tanker that is an airlifter first and a tanker second. The future theater commander, burdened with constraints imposed by airspace and high density air operations needs an employment phase tanker that serves as a key node in the his reconnaissance and communications networks and offloads fuel as a secondary mission. The dual role tanker will also pay benefits in the theater bed down plan, as less ramp space will be required. Dual use tankers will meet all the needs of the theater air commander using fewer aircraft. The role of penetrating tanker is already effectively filled, thus it need not be addressed further. In small ways, the USAF is already working toward this conceptual shift.

The KC-10 can accurately be described as an airlifter that can also offload fuel, and under the smart tanker concept, KC-135s will be configured as communications nodes that can also offload fuel. USAF Special Operations tankers have fully adopted the

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[215] Jonathan M. Block, "Leaf: Smart Tankers Could Spur More Capabilities-Centered Thinking," *Inside the Air Force,* 29 March 2002, 2. Significantly, the USAF is proceeding with the acquisition of 20 Roll-on Beyond-Line-of-Sight Enhancement units in fiscal year 2003. These units are palletized arrays of equipment which will be employed by positioning them in the cargo area of current tankers rather than wait for the KC-X deployment.

idea of air refueling as a secondary mission area. The paradigm shift is already underway de facto, whether or not admitted de jure in doctrine and planning. Accordingly, the USAF must avoid adopting another "Superman" program that results in a platform that can only perform air refueling. There are several options available, from which specific recommendation can be made.

First, based on the significant regenerative capabilities of depot maintenance, the USAF must continue to revitalize its current fleet of KC-135s, KC-10s, and C-130-based tankers in order to maintain these assets for use in the deployment phase, employment phase, and penetrating tanker roles. To enhance near-term effectiveness, the KC-135 Multi-Point Refueling System should be matured and acquired in sufficient quantity to field a substantial capability. A civilian derivative tanker must be selected as a mid-term capability. The aircraft must include its own receptacle to allow it to be refueled, and multi-point drogues in addition to a boom, insuring compatibility with all potential receivers.

Ultimately, the USAF should begin the acquisition process of its next generation tanker. This KC-X should be optimized for flight in the lower altitude regime in which air refueling is conducted rather than the higher altitudes in which civilian aircraft normally operate.

Finally, the USAF should not pursue an unmanned tanker to fulfill the role of a penetrating tanker at this time. Like the U.S. Navy, the USAF should continue to look to C-130 variants to meet this critical need.[216] Current UAVs are incapable of carrying a sufficient payload to make deploying an unmanned tanker platform realistic in the near future. As UAV development continues there will, no doubt, come a point at which using an unmanned tanker to penetrate hostile skies will be worthwhile, but that is a long-term issue.

Since 1947, air refueling development has been consistently reactionary, and appropriately so. However, the predicament presented the USAF by the unexpected maintenance needs of the KC-135 has generated an opportunity to "lead turn" the next developmental step. The embedded argument throughout this thesis is that the first step

[216] Beginning in FY01 the Navy is purchasing KC-130J model aircraft. Source: *Department of Defense Budget for Fiscal Year 2003: Program Acquisition Costs by Weapon System*, February 2002, 22.

toward doing so is a paradigm shift in understanding the potential roles of future tanker aircraft. The USAF does not need any more specialized tankers. "Superman" modifications marked the beginning of a capability that has matured, and become more relevant with time, but has for the most part maximized its operations utility. These mission-specific tankers will continue to be useful, and utilized, but future operations will be maximized by multi-role tanker platforms. It is time to admit the paradigm shift, reexamine the possibilities available at this cross roads, and wisely invest in the future of American war fighting.

The decision will have long-lasting consequences. Before his retirement, Colonel Robert Owen was the Chief of Long-Range Plans for Air Mobility Command. He points out that aircraft acquisition decisions today may well affect the next 100 years:

> Historically, we know that heavy aircraft (C-130s, C-5s, B-52s, KC-135s, P-3s, etc.) have, can, and often will stay in the inventory for 50-80 years. A next-generation tanker likely also will have the capacity to stay in operation for 60+ years. Thus, tankers bought in the 2040s, the planned tail-end years of the tanker recapitalization effort, may well remain in the inventory through 2100 and beyond. Whatever the ultimate configuration of the next-generation tanker fleet, the numbers and design characteristics of the aircraft we buy in those tail-end years will be constrained in part by the aircraft we buy at the beginning of the program. It follows then that the aircraft we buy in, say, 2010, will shape the aircraft we buy in 2040, which will be the aircraft we quite possibly be operating in 2100 and beyond. Of course, future conditions may mitigate against operating next-generation tankers for so long. But, that possibility only reinforces the need to do a careful job of futures and futures planning as we go into this major program.[217]

The opportunity to have such a lasting impact on the shape of America's future air refueling capability is formidable and, most likely, fleeting. The USAF should not squander this chance to take up some of the intellectual slack present in our current way of thinking about tankers. "Superman" is indeed dead. May he rest in peace.

[217] Robert C. Owen, e-mail correspondence with the author, 1 May 2002.

Bibliography

1997 United States Air Force Issues Book, Appendix B, Air Force Background Papers. On-line. Internet, 13 February 2002. Available from http://www.af.mil/lib/afissues/1997/app_b_16.html.

"Advanced Mobility Aircraft: Tanker/Transport," Lockheed-Martin, on-line, Internet, 3 May 2002, available from http://www.Imasc.com/ama/tanker.htm.

"Airbus Multirole Tanker-Transport (MRTT)." Jane's All the World's Aircraft 2002-2003. Jane's Information Group, 2002. On-line. Internet, 16 April 2002. Available from http://www.janes.com.

Air Combat Command pamphlet, "In Range: Long Range Strike Operations."

Air Force Bulletin No. 1. Washington, D.C.: Department of the Air Force, 21 May 1948.

Air Force Doctrine Document (AFDD) 1. *Air Force Basic Doctrine*, 1 September 1997.

AFDD 2. *Organization and Employment of Aerospace Power,* 28 September 1998.

AFDD 2-6. *Air Mobility Operations,* 25 June 1999.

AFDD 2-6.2. *Air Refueling,* 19 July 1999.

Air Force Instruction 65-503. *US Air Force Cost and Planning Factors.* 4 February 1994.

Air Force Pamphlet 10-1403. *Air Mobility Planning Factors,* 1 March 1998.

Air Force Regulation 20-10. *USAF Aircraft and Weapons Board*. 29 September 1947.

Air Force Technical Order (T.O.) 1C-135(K)R-1. "Flight Manual – USAF Series KC-135R/T Aircraft." Change 46. 15 August 1998.

Air Transport Capability Falls Short of Requirements. United States General Accounting Office Report to the Chairman, Subcommittee on Military Readiness, Committee on Armed Services House of Representatives. GAO/NSIAD-00-135. Washington, D.C.: Government Accounting Office, June 2000.

Anderson, Major Clayton M. "Three Degrees of Freedom Compliant Motion Control for Robotic Aircraft Refueling." Master's thesis, Air Force Institute of Technology, 13 December 1990.

"National Resources – Omega Air." Annex 10U to ATP 56(A) NATO Air to Air Refueling Document, June 2001.

Arnold, Henry H. *Global Mission.* New York: Harper & Brothers, 1949.

Arnold, H. H. "Practical Value of Refueling Airplanes in Flight." *Aviation* 17, no. 2 (1924): 750-751.

"Atlantic-Fokker C-2A." USAF Museum, Wright-Patterson Air Force Base (WPAFB). On-line. Internet, 6 June 2002. Available from http://www.wpaft.af.mil/museum/research/cargo /c1/c2a.htm.

"Atlantic-Fokker C-2A 'Question Mark'." USAF Museum, WPAFB. On-line. Internet, 6 June 2002. Available from http://www.wpafb.af.mil/museum/research/cargo/c1/c2aqm.htm.

Baker, Bud, and Dennis Casey. *Fuel Aloft: A Brief History of Aerial Refueling.* US Army Military History Institute, n.p., n.d.

Barlow, Jeffrey G. *The Revolt of the Admirals: The Fight for Naval Aviation, 1945-1950*. Washington, D.C.: Navy Historical Center, Department of the Navy, 1994.

Bennett, Major Richard A. "Brightness Invariant Port Recognition for Robotic Aircraft Refueling." Master's thesis, Air Force Institute of Technology, December 1990.

"Bleriot Monoplane." USAF Museum, WPAFB. On-line. Internet, 6 June 2002. Available from http://www.wpafb.af.mil/museum/early_years/ey1a.htm.

Block, Jonathan M. "Leaf: Smart Tankers Could Spur More Capabilities-Centered Thinking." *Inside the Air Force* (29 March 2002): 2.

"Boeing 767 Tanker/Transport." On-line. Internet, 3 May 2002. Available from http://www.boeing.com/defense-space/military/767t-t/flash.html.

"Border to Border Refueling Flight," *Aviation* 15, no. 25 (1923): 752-753.

Boyne, Walter J. "NICKLE GRASS." Air Force Association: December 1998 81, no. 12. On-line. Internet. 5 December 2001. Available from http://www.afa.org/magazine/Dec1998/1298nickel.html.

Bradley, James. *Flags of Our Fathers*. New York: Bantam Books, 2000.

"The *Bremen* Episode Inspires Notion of Air Refueling." On-line. Internet, 16 May 2002. Available from http://www.bolling.af.mil/organizations/wing/welcome/bolling_history/history/BREMEN.HTM

Byrd, Vernon B. *Passing Gas: The History of Inflight Refueling.* Chico, CA: Byrd Publishing Company, 1994.

Camerer, Major Mark D., "Civilian Contract Air Refueling: Innovative or Insane?" Research Report no. 2001-04. Maxwell AFB, Ala: Air Command and Staff College, 2001.

"Civil Reserve Air Fleet." USAF Fact Sheet. On-line. Internet, 17 May 2002. Available from http://www.af.mil/news/factsheets/craf.html.

Clausewitz, Carl von. *On War.* Edited and translated by Michael Howard and Peter Paret. Princeton, NJ: Princeton University Press, 1976.

Cobham, Sir Alan J., K.B.E., A.F.C. "Flight Refueling." *Shell Aviation News* no. 95 (May, 1939): 14 – 16.

Cohen, Dr. Eliot A. *Gulf War Air Power Survey*, Volume 3, *Logistics and Support*. Washington, D.C.: Government Printing Office, 1993.

Cohen, William S., Secretary of Defense. *Report of the Quadrennial Defense Review.* Washington, D.C.: Government Printing Office, May 1997.

Colburn, Major Tracy W. "Running On Empty: The Development of Helicopter Aerial Refueling and Implications for Future USAF Combat Rescue Capabilities." Research Paper, Maxwell AFB, AL: Air Command and Staff College, March 1997.

Combatant Commanders in Chief. To the Honorable Trent Lott, Senate Majority Leader. Letter. Subject: F-22 Budget Cuts, 28 July 1999.

"Conduct of the Persian Gulf War." Washington, D.C.: Department of Defense, 1992.

Cormier, Antonio. "First East-West Non-Stop Atlantic Flight: The `Bremen'." On-line. Internet, 17 April 2002. Available from http://www.celtic-connection.com/ lit/aviation-04-00.html.

Covey, Stephen R. *The 7 Habits of Highly Effective People.* New York: Simon & Schuster, 1989.

"Curtiss JN-4D 'Jenny'." USAF Museum, WPAFB. On-line. Internet, 6 June 2002. Available from http://www.wpafb.af.mil/museum/ early_years/ey2b.htm.

"De Havilland DH-4: Air Service Workhorse." USAF Museum, WPAFB. On-line. Internet, 6 June 2002. Available from http://www.wpafb.af.mil/ museum/early_years/ey8a.htm.

Douhet, Giulio. *The Command of the Air*. Reprint. Originally published: New York: Coward-McCann, 1942.

"Douglas C-1." USAF Museum, WPAFB. On-line. Internet, Available from http://www.wpafb.af.mil/museum/research/cargo/c1/c1.htm.

Drew, Dennis M. "The Essence of Aerospace Power." *Aerospace Power Journal* 15, no. 2 (Summer 2001): 23-31.

Epilogue," on-line, Internet, 5 December 2001, available from http://www.iwojima.com/battle/battled.htm.

"Expeditionary Aerospace Force." On-line. Internet, 14 March 2002. Available from http://www.af.mil/eaf/.

F-22 Raptor Aircraft Program. Congressional Research Service (CRS) Issue Brief for Congress. Washington, D.C.: CRS, 5 November 2001.

Fessler, Major George R., Jr. *Aerial Refueling in Southeast Asia, 1964 – 1970.* Project Contemporary Historical Evaluation of Current Operations (CHECO) Report. Headquarters Pacific Air Force, 17 June 1971.

Finney, Robert T. *History of the Air Corps Tactical School, 1920 – 1940.* USAF Historical Study 100. Maxwell AFB, Ala.: USAF Historical Division, Air University, 1955.

"First East-West Non-Stop Atlantic Flight: The 'Bremen'." On-line. Internet, 16 May 2002, available from http://www.celtic-connection.com/lit/aviation-04-00.html

Forrestal, James, Secretary of Defense. Memorandum. To General Spaatz and Admiral Towers. Subject: Fundamental Concept of Strategic Warfare, 9 August 1948.

"Foundation of the International Civil Aviation Organization." Available from http://www.icao.org/cgi/goto.pl?icao/en/history/htm.

Freedman, Lawrence. "The First Two Generations of Nuclear Strategists." In *Makers of Modern Strategy from Machiavelli to the Nuclear Age.* Edited by Peter Paret. Princeton, N.J.: Princeton University Press, 1986.

Futrell, Robert F. *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force, 1907-1960, Volume I.* Maxwell AFB, AL: Air University Press, 1989.

Futrell, Robert F. *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force, 1961-1984, Volume II.* Maxwell AFB, AL: Air University Press, 1989.

Gardner, Brian. "Skytanker – The Story of Air-to-Air Refueling." *Air Extra* no. 49 (August-September 1985): 16-36.

Gardner, Brian. "When You Need A Buddy: The Development of Air Refueling in the United States Navy." *The Hook* (Bonita, CA: Tailhook Association, Fall 1983): 11 - 24.

"Global Air Traffic Operations." On-line. Internet, 17 April 2002. Available from http://www.hanscom/af.mil/esc-gat/.

"Global Hawk." USAF Fact Sheet. On-line. Internet, 3 May 2002. Available from http://www.af.mil/news/factsheets/global.html.

Graham, Bradley and Eric Pianin, "Military Readiness, Morale Show Strain; Budgets Contract; Deployments Expand," *Washington Post*, 13 August 1998, final ed., A1, on-line, Lexis-Nexis, 10 June 2002.

Haanpaa, Major Douglas and Major Mark Drajeske. "Force Feedback, Virtual Fixtures, and Reality Registration for Mid-Air Refueling." Master's thesis, Air Force Institute of Technology, January 1997.

Halvorsen, Colonel Gail S. *The Berlin Candy Bomber.* Bountiful, UT: Horizon Publishers & Distributors, Inc., 1997.

"HC-130P/N." USAF Fact Sheet. On-line. Internet, 3 May 2002. Available from http://www.af.mil/news/factsheets/HC_130P_N.html.

Herod, Heather. "Aviation History Underway at NAWCAD." Naval Air Warfare Center Aircraft Division News release. On-line. Internet, 24 April 2002. Available from http://www.nawcad.navy.mil/view_release.cfm?article_id=8.

History of Aerial Refueling, USAF Audio Visual Presentation, Aerospace Audiovisual Service, Military Airlift Command, AVR 467, n.d.

Hopkins, Robert S. III. *Boeing KC-135 Stratotanker: More Than Just a Tanker.* Leicester, England: Midland Publishing Limited, 1997.

Hoyt, Ross G. "Reflections of an Early Refueler." *Air Force Magazine*, (January 1974): 55 – 59.

Hutcheson, Keith. *Air Mobility: The Evolution of Global Reach.* Vienna, VA: Point^{One}VII, Inc., 1999.

Jackson, Paul, ed. *Jane's All the World's Air Forces.* Alexandria, VA: Jane's Information Group, Limited, 2000.

Jane's All the World's Aircraft. Alexandria, VA: Jane's Information Group, Limited, 2000.

Munson, Kenneth, ed. *Jane's Unmanned Aerial Vehicles and Targets*, Alexandria, VA: Jane's Information Group, Limited, 1996.

Joint Chiefs of Staff. To the Honorable Trent Lott, Senate Majority Leader. Letter. Subject: F-22 Budget Cuts, 28 July 1999.

Joint Pubublication (JP) 1. *Joint Warfare of the Armed Forces of the United States*, 10 January 1995.

JP 1-02. *Department of Defense Dictionary of Military and Associated Terms.* 12 April 2001.

Jones, Bradley. "The Questions Are Answered." *U.S. Air Services* 14, no. 2 (February 1929): 17 – 27.

Julian, Thomas A., "The Origins of Air Refueling in the United States Air Force," in *Technology and the Air Force: A Retrospective Assessment,* ed. Jacob Neufeld, George M. Watson, Jr., and David Chenoweth. Washington, D.C.: Air Force History and Museums Program, 1997.

Jumper, General John P. "Global Strike Task Force: A Transforming Concept, Forged by Experience." *Aerospace Power Journal.* Spring 2001. On-line. Internet, 19 November 2001. Available from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj01/spr01/jumper.htm.

"KC-10A Extender." USAF Fact Sheet. On-line. Internet, 19 November 2001. Available from http://www.af.mil/news/factsheets/KC_10A_Extender.html.

"KC-135 Multi-point Refueling System Qualification Operational Test & Evaluation Test Plan." Fort Dix, NJ: Air Mobility Warfare Center, June 1997.

"KC-135 Stratotanker." USAF Fact Sheet. On-line. Internet, 19 November 2001. Available from http://www.af.mil/news/factsheets/KC_135_Stratotanker.html.

Lambeth, Benjamin S. *NATO's Air War for Kosovo: A Strategic and Operational Assessment.* RAND Report MR-1365. Santa Monica, CA: RAND, 2001.

Lane, Spencer. *First World Flight: The Odyssey of Billy Mitchell*. Daytona Beach, FL: U.S. Press, November, 2001.

Laurenzo, Ron. "Private Aerial Tanker Earns Navy's Praise." *Defense Week* 23, no. 17. (2002): 1, 15.

Lawson, Douglas. "Historical Summary of U.S. War Plans." NationalWarPlans AndPolicies.xls. CD-ROM. 15 January 2001.

Lindbergh, Charles A. *Autobiography of Values.* New York: Harcourt Brace Jovanovich, Inc., 1977.

"Master Sergeant Roy W. Hooe: 2001 Airlift/Tanker Hall of Fame Inductee." *Airlift/Tanker Quarterly* 9, no. 4 (Fall 2001): 10-13.

Maurer, Maurer. *Aviation in the U.S. Army, 1919 – 1939.* Washington, D.C.: US Government Printing Office, 1987.

"MC-130E/H Combat Talon I/II." USAF Fact Sheet. On-line. Internet, 3 May 2002. Available from http://www.af.mil/news/factsheets/MC_130E_H_Combat_Talon_I_II.html.

"MC-130P Combat Shadow." USAF Fact Sheet. On-line. Internet, 3 May 2002. Available from http://www.af.mil/news/factsheets/MC_130P_Combat_Shadow.html.

McReynolds, Charles F. "The Refueling Flight of the 'Question Mark'." *Aviation* 26, no. 3 (19 January 1929): 158 - 162.

Mets, David R. *Master of Airpower: General Carl A. Spaatz.* Novato, CA: Presidio Press, 1988.

Milholen, Major Wade. "Experimental Evaluation of Impedance Control for Robotic Aircraft Refueling." Master's thesis, Air Force Institute of Technology, 14 December 1989.

Miller, Edward S. *War Plan Orange: The U.S. Strategy to Defeat Japan, 1897-1945*. Annapolis, MD: Naval Institute Press, 1991.

Multipoint Aerial Refueling Boom Feasibility Study. Technical Report ASD/XR-71-30. Wichita, KS: The Boeing Company, January 1972.

Murray, Senator Patty. "Floor Remarks by Senator Murray Supporting the Lease of Boeing Refueling Tankers by the Air Force." On-line. Internet, 6 June 2002. Available from http://www.senate.gov/~murray/releases/01/12/2001C07A51.html.

Nalty, Bernard C., ed. *Winged Shield, Winged Sword: A History of the United States Air Force, Volume 1, 1907 – 1950.* Washington, D.C.: Air Force History and Museums Program, 1997.

"The New World's Duration Record," *Aviation* 15, no. 23 (1923): 716.

"New World's Records," *Aviation* 15, no. 18 (1923): 580.

New York Times, 25 July 1909.

New York Times, 1 June 1919.

New York Times, 2-8 January 1929.

New York Times, 3 March 1949.

Odeen, Phillip A. *Transforming Defense: National Security in the 21st Century.* Report of the National Defense Panel, December 1997.

Oklahoma City Air Logistics Center, Tinker Air Force Base, OK. In *Air Transport Capability Falls Short of Requirements.* United States General Accounting Office Report to the Chairman, Subcommittee on Military Readiness, Committee on Armed Services House of Representatives. GAO/NSIAD-00-135. Washington, D.C.: General Accounting Office, 2000.

Parr, Andrew. "The History of Fuelling in Flight." *Aeronautics* 16 no. 2 (March 1947): 48 - 51.

Parton, James. *"Air Force Spoken Here": General Ira Eaker and the Command of the Air*. Bethesda, MD: Adler & Adler, Publishers, Inc., 1986. Reprint, Maxwell AFB, AL, 2000.

Penner, Rudolph G. *Improving Strategic Mobility: The C-17 Program and Alternatives.* Congressional Budget Office (CBO) Report. Washington, D.C.: Congressional Budget Office, September 1986.

Penner, Rudolph G. *Modernizing the Aerial Tanker Fleet: Prospects for Capacity, Timing, and Cost*. CBO Report. Washington, D.C.: Congressional Budget Office, September 1985.

"Plane Refueled in Flight." *Aviation* 15, no. 2 (July 9, 1923): 51.

Poulsen, C.M. "Fuelling in the Air: Sir Alan Cobham's System Explained." *Flight and the Aircraft Engineer* 25, no. 6 (1939): a – d.

Poulsen, C.M. "Payload and Long Range: How Refuelling in the Air Can Help." *Flight* (23 August 1945): 200 – 204.

Program Acquisition Cost By Weapon System, Department of Defense Budget for Fiscal Year 2003, Government Printing Office, February 2002.

Polmar, Norman and Timothy M. Laur, ed. *Strategic Air Command: People, Aircraft, and Missiles*. Baltimore, MD: The Nautical & Aviation Publishing Company of America, Inc., 2nd ed, 1990.

"The Quadrennial Defense Review: A Sense of *Déjà vu."* Washington, D.C.: Center for Defense Information 25, no. 2 March 1997. On-line. Internet, 17 June 2002. Available from http://www.cdi.org/ dm/1997/issue2/index.html.

Quesada, Lieutenant General Elwood R. Transcript of oral history interview by Dr. Edgar F. Puryear, Jr., June 22, 1977. United States Air Force Historical Research Agency (AFHRA), Maxwell AFB, AL.

"Range and Payload by Refuelling in the Air." *The Aeroplane* (28 September 1945): 362 – 364.

Rearden, Bob. "The War on Cost." *Mission Brief* 5, no.2 (March-April 2001): 3.

"Refuelling in Air not without Danger," *Aviation* 15, no. 25 (1923): 753.

Report on Heavy Bombardment by Heavy Bombardment Committee. Convened to Report to the USAF Aircraft and Weapons Board, 7 November 1947.

Robertson, General Charles T. Commander in Chief, US Transportation Command. Speech to the Air Force Association Air Warfare Symposium 2000. 24 February 2000. On-line. Internet, 17 June 2002. Available from http://www.aef.org/pub/rob200.asp.

"Roche, DOD Would Need Legislative Changes To Lease Boeing 767s." *Aerospace Daily,* 22 January 2002.

Rumsfeld, Donald, Secretary of Defense. *Report of the Quadrennial Defense Review*, Washington, D.C.: Government Printing Office, September 2001.

RQ-3A DarkStar Tier III Minus. On-line. Internet, 17 April 2002. Available from http://www.fas.org/irp/program/collect/darkstar.htm.

SEA Impact on the SAC SIOP Forces," Project CORONA HARVEST, 5 December 1968 and subsequent report by the same title, 10 March 1969. AFHRA, Call numbers K416.03-5 and K416.03-4.

Shuler, William T. "Some Effects of Tanker Performance Characteristics on Range of B-47E and B-52 Aircraft." Operations Analysis Working Paper 63, Washington, D.C.: Department of the Air Force, May 1956.

"Smith and Richter Up 37 hr. 15 min." *Aviation* 15, no. 11 (1923): 316.

Smith, Richard K. *75 Years of Inflight Refueling: Highlights, 1923-1998.* Washington, D.C.: Air Force History and Museums Program, 1998.

Spaatz, General, Chief of Staff of the Air Force and Admiral Towers, Chief of Naval Operations. Memorandum for Secretary Forrestal. Subject: Your Memorandum of 9 August 1948.

Spatz, Major Carl A. "Report of the Flight of the Question Mark, January 1-7, 1929." Carl A. Spaatz Papers, Library of Congress, Manuscript Division, Box 110.

"Standard J-1," National Air and Space Museum. Available from http://www.nasm.si.edu/nasm/aero/aircraft/standard.htm.

Steiner, John E. "Jet Aviation Development: A Company Perspective." In *The Jet Age: Forty Years of Jet Aviation*. Edited by Walter J. Boyne and Donald S. Lopez. Washington, D.C.: National Air and Space Museum, Smithsonian Institution Press, 1979.

"Summary Minutes of Second Meeting of the USAF Aircraft and Weapons Board," convened on 27 January 1948. Washington, D.C.: Headquarters USAF, 2-4. National Archive, College Park, MD. Box 183.

"Tanker Requirements and the Advanced Tanker/Cargo Aircraft." 1976 Carter Presidential Transition briefing. N.p., n.d.

Tate, James P. *The Army and Its Air Corps: Army Policy toward Aviation, 1919-1941.* Maxwell AFB, AL: Air University Press, July 1998.

Unmanned Aerial Vehicles Roadmap: 2000 – 2025, Office of the Secretary of Defense, April 2001.

X. "The Sources of Soviet Conduct." *Foreign Affairs* 25, no. 4 (1947): 581.