

Seventy-Five Years of Inflight Refueling

Highlights, 1923–1998

Richard K. Smith

Air Force History and Museums Program
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The First Refueling

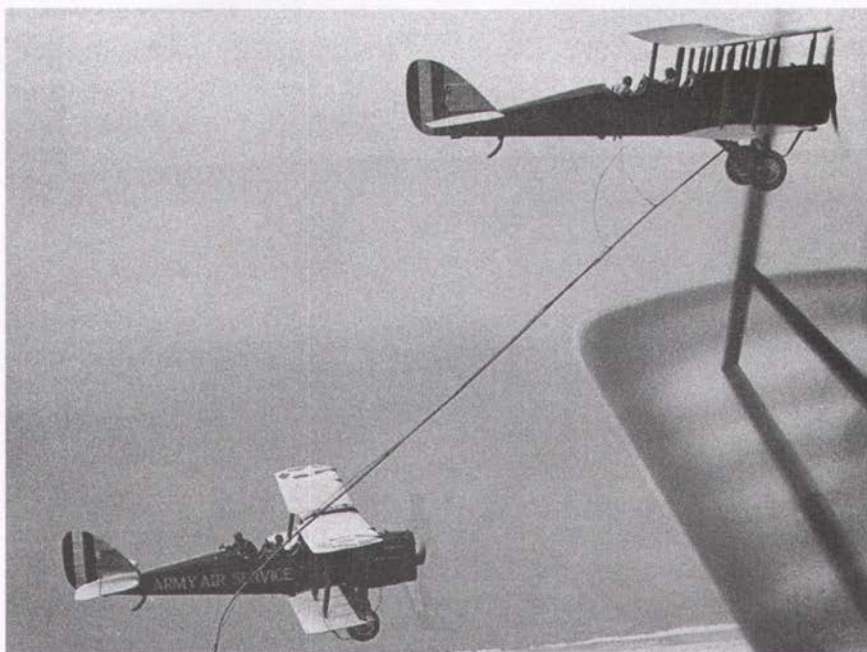
On June 27, 1923, at an altitude of about 500 feet above Rockwell Field on San Diego's North Island, two U.S. Army Air Service airplanes became linked by hose, and one airplane refueled the other. While only seventy-five gallons of gasoline were transferred, the event is memorable because it was a first. The summer of 1998 marks the seventy-fifth anniversary of the use of this elementary technique of range extension.¹

The airplanes were de Havilland DH-4Bs, single-engine biplanes of 4,600 pounds. First Lt. Virgil Hine piloted the tanker; 1st Lt. Frank W. Seifert occupied the rear cockpit and handled the fueling hose. Capt. Lowell H. Smith flew the receiver while 1st Lt. John Paul Richter handled the refueling from the rear cockpit. The refueling system consisted of a fifty-foot length of rubber hose, trailed from the tanker, with a manually operated quick-closing valve at each end. The process is best described in terms of "you dangle it; I'll grab it."

After six hours and thirty-eight minutes, and only one refueling, engine trouble in the receiver terminated the flight. Recognizing that a second refueling plane would provide more safety and flexibility, the next attempt included a third DH-4 as the second refueler. Its crew members were Capt. Robert G. Erwin and 1st Lt. Oliver R. McNeel, who became the world's second refuelers. On August 27 and 28, with fourteen midair contacts, tankers operated by Hine and Seifert and Erwin and McNeel kept Smith and Richter in the air over a prescribed track for thirty-seven hours and twenty-five minutes (see Appendix 1 for a schedule of refuelings and deliveries), and set a world record for endurance. The track flown was 3,293 miles, about the same distance as that from Goose Bay, Labrador, to what was Leningrad in the Soviet Union.

On October 25, 1923, to demonstrate a practical application for in-flight refueling, Smith and Richter took off from Suma, Washington, near the border between the United States and Canada and headed south. In the vicinity of Eugene, Oregon, they were refueled in two contacts by Seifert and Hine, and a few hours later over Sacramento, California, they were refueled in two contacts by Erwin and McNeel. Little more than twelve hours after leaving Suma, Smith and Richter circled the customs house at Tijuana, Mexico, and then landed at Rockwell Field in San Diego.² This border-to-border nonstop flight of 1,280 miles demonstrated how an airplane with a normal range of 275 miles could have its range quadrupled.

It's possible to confuse "firsts" with "beginnings," and these earliest efforts at in-flight refueling proved to be firsts in quest of a beginning. In 1923, Army aviation had not yet recovered from the chaotic demobilization of 1919 and from its straitened budgets. As a result, the Rockwell experiments were dismissed as stunts—especially after November 18, 1923, when an airplane was wrecked and a pilot killed while trying to demon-



The de Havilland DH-4B tanker dangles a hose for the DH-4B receiver to grab over Rockwell Field (top). In the tanker, 1st Lt. Frank W. Seifert holds the hose in the rear cockpit while the pilot, 1st Lt. Virgil Hine, is in the front (left). Capt. Lowell H. Smith flew the receiver, and 1st Lt. John P. Richter handled the hose (bottom).

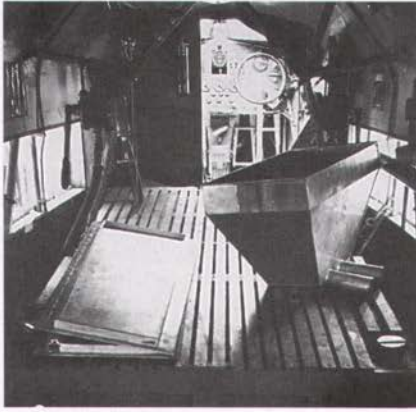
strate aerial refueling during an airshow at Kelly Field, Texas. This was aerial refueling's first fatal accident and, in the absence of a practical application for such refueling, for more than a quarter-century thereafter it was also its only fatality. Shortly after the Rockwell Field demonstrations, the British and French air forces conducted some brief inflight experiments, but they, too, could find no practical use for the technique. Aerial refueling was a solution in search of a problem.

The *Question Mark* and Its Answer

In June 1928, the Belgian air force modified a pair of de Havilland biplanes into a tanker and a receiver and engaged in a refueling operation that stayed aloft for sixty hours and seven minutes. Given the minuscule size of Belgium (11,781 square miles—little larger than the state of Maryland), the purpose of this operation is unclear. But some 3,600 miles westward, at Washington, D.C.'s Bolling Field, it inspired 1st Lt. Elwood "Pete" Quesada to plan a similar venture. His plan had nothing to do with the Army Air Corps; rather, he developed it with a U.S. Marine Corps aviator at the nearby Anacostia Naval Air Station.³ When told of Quesada's plan, Capt. Ira Eaker, then working in the office of the Assistant Secretary of War for Air, appropriated it for the Air Corps alone, and obtained the support of Maj. Gen. James E. Fechet, Chief of the Air Corps. F. Trubee Davison, Assistant Secretary of War for Air, however, wanted more than a publicity stunt and would agree to the operation only if it led to a military application.

What became the much-publicized *Question Mark* operation went forward with a Fokker C-2A trimotor, a high-wing monoplane of 10,935 pounds, modified into the receiver. Its two 96-gallon wing tanks were supplemented by two 150-gallon tanks installed in its cabin. After fuel was received into the cabin tanks it had to be pumped by hand to the wing tanks, from where it gravitated to the engines. In addition, there was a 45-gallon reserve tank for engine oil. A hatch was cut in the plane's roof to receive the refueling hose and other materials. On each side of its fuselage, the Fokker was painted with a large question mark intended to provoke wonder at how long the airplane could remain airborne. Its crew consisted of Maj. Carl Spatz (who had not yet changed the spelling of his surname to Spaatz), Capt. Eaker, 1st Lts. Harry A. Halverson and Elwood Quesada, and S/Sgt. Roy W. Hooe.

Two Douglas C-1 single-engine transports, 6,445-pound biplanes, were transformed into tankers by installing two 150-gallon tanks for off-loading and a refueling hose that passed through a hatch cut in the floor. Tanker No. 1 was flown by Capt. Ross G. Hoyt, 1st Lt. Aubrey C. Strickland, and 2nd Lt. Irwin A. Woodring. Tanker No. 2 was flown by 1st Lt. Odas Moon and 2nd Lts. Joseph G. Hopkins and Andrew F. Salter. By the



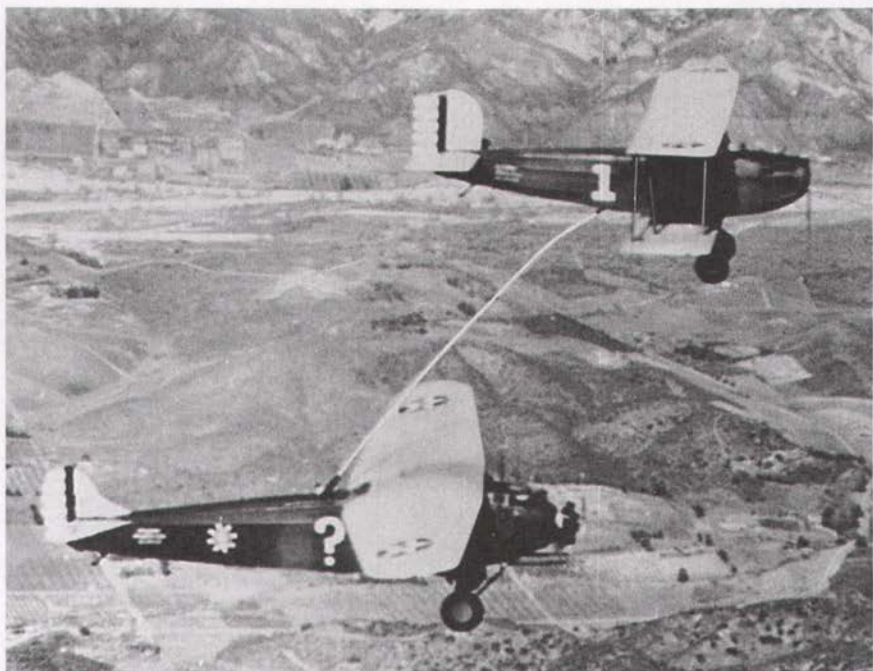
The cabins of the receiver (left) and the tanker. In the receiver, the fueling hose was placed in the funnel, which fed the cabin tanks under the duck boards at center. The tanker's refueling system has three gate valves, a levered quick closing valve, and a strainer in front of the hose.

end of 1928, this small force was concentrated at the Metropolitan Airport in Van Nuys.

On the face of it, using the Los Angeles municipal airport at Mines Field, El Segundo, made more sense for lifting the heavy loads the tankers carried: it was only 150 feet above sea level. By comparison, the newer Metropolitan Airport had an elevation of 799 feet. Metropolitan's manager, veteran aviator Waldo Waterman, wanted to put his new airport "on the map" and he argued hard for his facility. Neither airport had hard, all-weather runways, but the weather at Metropolitan was better and more reliable. Then, as now, Los Angeles was susceptible to temperature inversions that created what even in 1929 was being called "smog." Waterman made the better climate at Metropolitan one of his selling points and did everything he could to accommodate the Air Corps.

The almost anonymous "master of ceremonies" of the *Question Mark* endeavor was Capt. Hugh M. Elmendorf, who was in charge of ground operations and logistics. Radio communications were not used between the *Question Mark* and the ground because aircraft radios in 1929 were big, heavy, delicate, and unreliable, and a system for shielding the radio from the interference created by radiations from an engine's ignition system was not yet available. Instead, communications were accomplished with flags, flares, and flashlights; spreading cloth panels on the ground; dropping weighted message bags; and sending fighters aloft with messages whitewashed on their fuselages.

The operation got under way on New Year's Day in 1929. The Fokker receiver flew a "racetrack" pattern over the 110 miles between Metropolitan Airport in Van Nuys and Rockwell Field at San Diego. Hoyt's tanker was based at Rockwell, Moon's at Metropolitan. However, on occasions



The *Question Mark* and tanker (top); the crew, after 150 hours in the air (left to right): two flight surgeons, Maj. Carl Spatz, Capt. Ira Eaker, Lt. Harry Halverson, 1st Lt. Elwood Quesada, and SSgt. Roy Hooe.



Aviation's invisible men of 1929 and one of their invisible tankers: on the landing gear, Capt. Ross G. Hoyt; on the wing, 1st Lt. Odas Moon; on the ground, *left to right*, Lts. Auby C. Strickland, Joseph G. Hopkins, Andrew F. Salter, and Irwin A. Woodring. The men in the cockpit are anonymous mechanics.

when weather along the coast deteriorated, Hoyt moved his operation to a civilian airport at Imperial Valley, but the dust there was almost as bad as the coastal fog.

In the course of the operation, the tankers made forty-three takeoffs and landings. Hoyt flew twenty-seven sorties, ten of them at night; Moon flew sixteen sorties, two at night. Altogether, they delivered 5,660 gallons of fuel (33,960 pounds), 245 gallons of engine oil (1,838 pounds delivered in forty-nine five-gallon cans), and storage batteries, spare parts, tools, food, clothing, mail, and congratulatory telegrams. Although the success of the operation clearly depended on the tankers, no one sent any telegrams to Hoyt, Moon, or their crews. With two of the *Question Mark's* three engines almost reduced to junk, the operation ended on January 7, 1929, after 150 hours and 40 minutes. The ultimate unreliability of the engines resulted from having no adequate means for lubricating their rocker arms, the linkage that operated the engines' valves.⁴

In a ceremony at Bolling Field on January 26, 1929, the Air Corps decorated each member of the *Question Mark's* crew with the Distinguished Flying Cross. Those who flew the tankers had to console themselves with the Biblical assurance that it is more blessed to give than to receive. At some later date letters of commendation were slipped quietly into their 201 files.*

The flight of the *Question Mark* inadvertently established a precedent. Thereafter, in any operation involving inflight refueling, all accolades would be heaped on the crews of the receivers; only anonymity awaited

*Forty-seven years after the event, in a small ceremony in the Pentagon on May 26, 1976, Hoyt and Hopkins finally were awarded the Distinguished Flying Cross for their refueling labors of 1929; the four other refuelers of 1929 were deceased. See *Air Force Magazine*, Vol 59 (Jul 1976), 22.

the refueler crews who made the operation possible—and successful. Those crews became “invisible men,” and for a half-century before stealth technology was invented they operated more than a thousand “invisible” airplanes.

The *Question Mark* operation was predicated on its potential military utility. Five months later, in the spring of 1929, the Army Air Corps prepared a more formal demonstration of aerial refueling’s military usefulness at the Fairfield Air Depot near Dayton, Ohio, in conjunction with an annual Army war game being played in maneuvers in eastern Ohio and western Pennsylvania. A Keystone B-3A bomber serving as a receiver was to take off from Dayton (accompanied by a Douglas tanker), be refueled over Washington, D.C., at the end of the workday for maximum publicity, and then continue to New York City, where it would drop a flash bomb over the harbor. Returning, the bomber would again be refueled over Washington, D.C., and then proceed to its base in Ohio.⁵

For this operation the Air Corps should have reflected on a bit of pre-1914 Prussian Army humor regarding peacetime maneuvers: “In the event of rain, the war will be held indoors!” A network of thunderstorms stood between Ohio and Washington. The bomber and tanker soon became separated and, although the bomber managed to get through, icing conditions forced the tanker down at Uniontown, Pennsylvania, where it got stuck in the mud of soft field conditions. The bomber had enough fuel to push on to New York City and then back to Washington, but the tanker was still grounded at Uniontown. There were no aerial refuelings.

This operation was supposed to demonstrate the “answer” to the *Question Mark*. Afterward, as far as the U.S. War Department and Air Corps were concerned, the answer was “Forget it!” For the next twelve years, they did exactly that.⁶

Aeronautical Flagpole Sitting

The *Question Mark* operation was too late to be a first, and to the extent that it was a beginning, it provoked an epidemic in aerial refueling among American aviators, each determined to set a new record for flying in circles. This phenomenon approximated the American craze of flagpole sitting that reigned for a few years in the 1920s. Within five months, a team at Fort Worth, Texas, exceeded the *Question Mark*’s time by staying up for 172 hours. This recordbreaking went on and on through 1929, 1930, and beyond 1931, ultimately extending the record to hundreds of hours.

The only significant flight among these ongoing circuses occurred August 15–20, 1929, when N. B. Mamer and Art Walker, with the logistics support of the Texas Oil Company, used a Buhl Sesquiplane named *Spokane Sun God* to fly nonstop from Spokane, Washington, to New York City with five refuelings en route. Without landing at New York, they

turned around and flew back to Spokane, refueled in flight all the way—a nonstop flight of 115 hours and 45 minutes over a distance of 7,220 miles.

The difficulties experienced by the tankers that served Mamer and Walker went unnoticed. The first refueling over San Francisco was routine, but the next took place at Elko, Nevada. Elko's altitude is 5,135 feet above sea level, and the tanker had to struggle to get into the air with a marginal load. The next two refuelings took place in Wyoming, at Rock Springs (6,760 feet) and at Cheyenne (6,156 feet). In August these airports were not only high, but hot, which further reduced air density. After Cheyenne, however, it was "down-hill" to New York. Once past the continental divide, the Alleghenies were hardly noticed. Mamer and Walker provided the first demonstration of inflight refueling as a means of range extension—as distinct from endurance—since the Army Air Service's border-to-border flight of 1923. Unfortunately, their demonstration was lost in the hoopla of circular flight "records."⁷

Later in 1929, emulating Mamer and Walker, Ira Eaker and the Boeing Airplane Company put together a transcontinental refueling operation known as the "Boeing-Hornet Shuttle." The purpose, it seems, was to advertise the reliability of the new Pratt & Whitney R-1690 Hornet engine. A Boeing Model 95 mailplane, a 5,840-pound, single-engine, open-cockpit biplane powered by the new Hornet engine, served as the receiver. Eaker's copilot and hose handler was 1st Lt. Bernard Thompson.

The operation started from Oakland, California, on August 27, a few days after Mamer and Walker's flight. At Elko, Nevada, and Cheyenne, Wyoming, Eaker and Thompson's plane was refueled by Boeing 40B mailplanes modified into tankers. Over Cleveland, Ohio, and Mitchel Field, Long Island, New York, they were served by the two Douglas tankers of the *Question Mark* operation. Their flight from the west coast took twenty-eight hours and fifteen minutes. After refueling over Mitchel Field, Eaker and Thompson turned west for Oakland. In the return refueling over Cleveland, however, the tanker operator accidentally dropped a five-gallon can of oil on the receiving airplane. This thirty-eight-pound missile inflicted serious damage on the receiver's upper wing and the flight had to be terminated at Cleveland.

A second attempt was made, starting from Mitchel Field on September 2. The transcontinental flight to Oakland went well, but while returning eastward, between Salt Lake City, Utah, and Cheyenne, Wyoming, a fuel stoppage caused the engine to quit. Fortunately, it was daylight and a successful crash landing was made in a canyon; the airplane, however, was reduced to salvage. That was the end of Ira Eaker's career in aerial refueling and of the Boeing-Hornet Shuttle—without a totally successful round-trip.⁸

The U.S. aerial refueling record-setting craze ended June 4–July 1, 1935, when James Keeton and William Ward kept brothers Alan and Fred Key and their Curtiss Robin receiver, named *Ole Miss*, in the air for

653 hours and 34 minutes—twenty-seven days. Keeton and Ward flew their Curtiss Robin tanker in 113 takeoffs and landings and, in 484 midair contacts, delivered approximately 6,000 gallons of fuel, 300 gallons of oil, food, spare parts, and even medical advice. Both the tanker and receiver were single-engine, cabin planes of a nominal 2,500 pounds. The record of the Key brothers and *Ole Miss* has remained unbroken to this day. Since 1955 the *Ole Miss* has been on exhibit at the National Air and Space Museum in Washington, D.C.⁹

Refueling at Farnborough

Meanwhile, the widely publicized *Question Mark* operation had revived British interest in inflight refueling, and in 1930 the Royal Aircraft Establishment at Farnborough initiated a series of experiments that continued until 1937—albeit with quiet speculation about the technique's utility continuing for some years thereafter. Those efforts had less to do with range extension than with permitting an airplane to take off with a light fuel load and then filling it up, or overloading it, in flight.

Initially, Royal Air Force (RAF) officials expected that inflight refueling would provide relief for flying boats, which typically had long, hard, hull-punching takeoff runs on the water. Later they expected it would permit bombers to maximize their payloads in the face of treaty restrictions on the size of bombers the League of Nations was then considering. Although it now seems quaint, it was also hoped that it would save wear and tear on the grass airfields that were common in RAF service.¹⁰ The most unusual aspect of this work was contributed by L.H.B. Larrard, a Farnborough engineer, who published the first analysis of the possible benefits of inflight refueling; Larrard gave the world its primer on the subject.¹¹

The Farnborough experiments used a variety of airplanes, all of them biplanes. None had a speed exceeding 110 mph, and the RAF flew most refueling experiments at 80 to 90 mph. The hardest problem was developing a technique for the fueling hookup that did not demand unusual flying skill, but no alternative had yet been found for the elementary dangle-and-grab system of 1923.

In September 1934, Flt. Lt. Richard L. R. Atcherly was assigned to Farnborough. A member of the RAF's racing and aerobatic team, Atcherly had visited the United States for the National Air Races at Cleveland in 1929 and Chicago in 1930. Witnessing some of the U.S. barnstorming efforts at aerial refueling, he thought the prevailing technique was primitive, clumsy, and dangerous. While on duty in the Middle East, Atcherly worked out his own system, which he subsequently patented.¹²

During inflight refueling there is a cruising airplane and a maneuvering airplane. Ordinarily, the tanker cruised while the receiver maneuvered to grab the hose. Atcherly reversed that order of work and put almost the



After watching primitive U.S. efforts at refueling, Flt. Lt. Richard Atcherly invented and patented his own system for aerial refueling.

whole burden of the operation on the tanker, whose crew would inevitably have more experience with refueling than would the crews of occasional receivers. The Atcherly System had both the tanker and the receiver trailing cables with grapnels at their ends. While trailing its cable, the receiver flew a straight course, and the tanker crossed its track from behind, trailing its cable across the receiver's cable until the two grapnels connected. With the two airplanes now joined by their cables and flying side-by-side, a winch aboard the receiver pulled in its cable and along with it the tanker's cable. The refueling hose was attached to the other end of the tanker's cable and winched into the receiver, where it was made fast to a fueling connection. With the two aircraft joined by a huge bight of hose some 300 feet long, the tanker climbed to a position slightly higher than the receiver to put a gravity head on the offload, valves were opened, and refueling began.

When refueling was finished, the receiver disconnected the hose and the tanker reeled it in, but the two airplanes remained joined by the cables of the original connection. The tanker then turned away, breaking a weak link in the cable connection.

It was 1937 before air trials had worked out all of the wrinkles in this refueling system: By that time, as far as the RAF was concerned, a need for aerial refueling had been overtaken by events elsewhere. The modern airplane had come upon the scene and it changed everything.

The Modern Airplane Defers Refueling

At the beginning of the 1930s, inflight refueling promised to compensate for the airplane's many inadequacies. Prior to 1933, the airplane was essentially a relatively crude vegetable product manufactured from wood and linen fabric painted with acetate or cellulose "dope" to obtain a tight, smooth flying surface. Usually a biplane with a fixed landing gear, its structure had many ninety-degree angles. A few all-metal airplanes exist-

ed, but their performance was about the same as that of the vegetable products as both types bristled with objects creating aerodynamic drag. Had aeronautical engineering remained frozen in terms of the technology of 1932, aerial refueling would have been the only means of improving an airplane's range and payload. Inflight refueling likely would have become a global phenomenon before World War II. That did not happen because, in 1933, practically overnight, everything changed.

It is not an oversimplification to say that this change was initially manifested in two airplanes: the Douglas DC-1, which prototyped the epochal DC-2 airliner, and the Martin B-10 bomber. All-metal, low-wing monoplanes of about 17,000 pounds, they had carefully cowled engines, retractable landing gear, and high-lift devices to reduce takeoff distances and landing speeds. They proved to be prototypes for an entire generation of airplanes—and did so across the board, internationally. The key was the concurrent and equally sudden availability of the controllable pitch propeller, a device that finally permitted the aero engine to perform with maximum efficiency. Underlying it all was a “best” weight control in the aerostructure.¹³ Although improvements in payloads were initially marginal, airplane speeds and operating ranges suddenly doubled.

The Europeans were justifiably skeptical of the United States' extraordinary claims being made for the new airplanes. In 1933, Roy Fedden, chief engineer of Bristol Aero Engines and one of the world's foremost engine designers, visited the United States. In California, he was introduced to the Douglas DC-1 and sent a photograph of the craft to an official in the British Air Ministry. Aware that Douglas was located in Santa Monica, not far from Hollywood, that official was certain that the DC-1 was an empty mockup that Douglas had built for a futuristic motion picture; he refused to believe it was a real airplane.

Within a year, such misperceptions disappeared. During October 1934, the MacRobertson International Air Race took place over a track of 14,000 miles, from England to Australia. A two-seat de Havilland DH-88 Comet, a sleek twin-engine racer and one of three Comets built expressly for this contest, won the race. A Douglas DC-2 airliner came in second, despite carrying three revenue passengers and 900 pounds of mail in addition to its crew and losing time at eighteen fuel stops, compared to only five stops for the winning Comet. A Boeing 247, another “ordinary” American airliner, took third place. The MacRobertson Race was the modern airplane's world debut and it was an electrifying *coup de théâtre*. Things were one way before October 1934; they could not be the same thereafter.

The DC-2 and the Martin B-10 bomber were about the same size, weight, and power. Obtaining reliable published data on the DC-2, British and European engineers had no difficulties in running the numbers to determine that claims for the B-10's performance were not exaggerated. In the United States, the Martin B-10 was only the beginning of a “long

reach" by the U.S. Army Air Corps. Developments subsequently pursued on long-range bombers proved to be extraordinary. In 1935, the Air Corps contracted with Boeing, which produced its Model 299 prototype for the B-17 series. In 1939, on another contract, Consolidated produced the XB-24. These airplanes, of some 60,000 pounds and with a range of 2,500 miles, became the great workhorse bombers of World War II. Also in 1939, the Air Corps prepared the specification for a bomber of approximately 100,000 pounds with a hoped-for range of 4,000 miles; put on contract in 1940, it became the Boeing B-29.

Simultaneous improvements in power plants made possible all of these developments. Radial engines included the Wright R-1820 of 1934, with 675 hp; the Pratt & Whitney R-2600 of 1938, with 1,500 hp; and the Wright R-3350 of 1941, initially with 2,000 hp, but eventually growing to 2,300 hp. Finally, there was the mighty Pratt & Whitney R-4360, producing 3,500 hp; although too late for World War II, it became an important engine in the postwar era and for a decade thereafter. The R-4360 made practical the Consolidated B-36, a 328,000-pound intercontinental bomber that went on contract in November 1941. In sum, within ten years, aero engine power quadrupled.¹⁴

With the elements of the modern airplane making it possible to build increasing range *into* an airplane, the Army Air Corps felt no need for the complication of inflight refueling. Although the United States, on its continental island, had to think in terms of transoceanic distances and ranges of thousands of miles, in Great Britain and Europe prospective enemies lay within a radius no greater than 600 miles. A bomber with a 1,500-mile range (figuratively a radius of 750 miles) was more than adequate for U.S. wartime requirements. Even closer to the enemy, the leaders of Europe's air forces also saw no need of aerial refueling.

The 1920s paradox of a solution in search of a problem came to a resolution in England during the mid-1930s—but in the service of British civil aviation, which found itself suddenly faced with an embarrassing range deficit.

A British Dilemma and the American Solution

Shortly after World War I, the British government placed a multimillion dollar wager on the Zeppelin-type airship, expecting it to provide a high-speed communications system for the far-flung British Empire. When this decision was made, the airship represented the only aircraft in the world that could carry tens of passengers and tons of cargo across intercontinental distances. Indeed, until the dawn of the 1930s, the airplane was often unreliable and its commercial payload was hopelessly uneconomical. Although an airship's best speed approached just sixty-five miles per hour, a typical cruising speed for multiengine airplanes of the 1920s



A Martin B-10 in flight over Washington, D.C.

was only a trifle better than ninety miles per hour, and over a distance of 1,000 miles, most of this speed was lost at fuel stops. The dramatic changes that occurred in airplane performance in 1933 could not be foreseen as late as the beginning of 1932.

Unfortunately, the British airship effort was a muddled affair. An initial plan for six airships was reduced to two, and this complex effort in aeronautical engineering and industrial logistics was divided between two rival builders that produced airships of distinctly different designs. One, the R.100, was built by a subsidiary of Vickers, Ltd.; the other, R.101, by the Air Ministry itself. Neither airship flew until 1929. Two years before, when Charles Lindbergh flew 3,610 miles nonstop from New York City to Paris, his only payload was three chicken sandwiches. In contrast to such "lean cuisine," each of the British airships was expected to carry about fifty passengers in stateroom accommodations; they would be served *haute cuisine* in a dining room that had a dance floor. The dirigibles also would feature a cocktail lounge and carry a ton or two of mail over distances of some 3,500 miles within sixty hours. These airships would be the *Mauretianas* of aeronautics.

In the summer of 1930, the Vickers R.100 made a successful flight to Canada. In October, the government-built R.101 took off for Egypt and India, but a few hours later, crashed and burned in France. Of the fifty-four people on board, only six survived. Among those killed were Britain's air minister, the director of civil aviation, and the key people involved in the airship program. The R.101 disaster inflicted on Great Britain a national trauma equal to the sinking of the liner *Titanic* eighteen



Early models of the B-17 (top) and the B-24. With ranges of over 2,500 miles, these bombers had no need for aerial refueling in World War II.

years earlier; at the same time, the paralysis of the Great Depression settled on the world. The whole airship program was called into question and canceled, with the relatively successful R.100 cut up for scrap. Plans for linking up the Empire by airship were abandoned.¹⁵

At that moment, the only airplane under British development that would have become a long-range payload carrier was the Vickers-Supermarine Type 179, a six-engine monoplane flying boat of 75,000 pounds. Although half finished, government support was withdrawn in January 1932, and the airplane was canceled. But at that same moment Pan American Airways contracted with Sikorsky for the S-42 and with Martin for the M-130, both four-engine flying boats (38,000 and 52,000 pounds, respectively) with transoceanic ranges. Although planned as an Atlantic clipper, the M-130 is best recalled as the legendary transpacific *China Clipper*.

It was little known, and Pan American Airways was at pains not to have it mentioned, that both the S-42 and the M-130 originally were plumbed as receivers for inflight refueling as a hedge against shortfalls in range. Both had hatchways on the upper surfaces of their after fuselages, with the hatch opening inward. These hatchways served as entries for passengers, but they were also equipped as refueling stations. As far as can be determined, these flying boats would have used a dangle-and-grab system, but after they demonstrated satisfactory range and payload performances, the plumbing was removed to save weight. The Sikorsky S-42 and Martin M-130 flew in 1934, entering commercial service in 1935. At that time the British had no comparable airplane even under development.

Hastening to catch up, Imperial Airways had Short Brothers produce its S.23, a four-engine flying boat weighing 40,500 pounds; it flew in July 1936 and entered service in 1937. Affectionately known as the "Empire boat," the S.23 had a badly overweight structure that reduced its useful load and payload. A transoceanic airplane demanded a minimum range of 2,000 miles, the distance between Ireland and Newfoundland, but the normal range of an S.23 was less than 900 miles. Two S.23s had their structures reinforced and their fuel capacities substantially increased from a standard 4,680 pounds to 16,704 pounds to conduct with Pan American Airways a joint series of transatlantic survey flights in 1937. These S.23s did well to lift their own fuel loads; they were incapable of carrying any commercial payload.¹⁶

In 1938, Boeing produced its Model 314 Clipper for Pan American, an 82,500-pound flying boat with a range of 3,000 miles. A Boeing 314 was capable of lifting twenty-five passengers and a few hundred pounds of mail between Newfoundland and Ireland. Pan American planned to inaugurate transatlantic services in the spring of 1939. Without an airplane remotely similar to the Boeing 314, Imperial Airways sought some kind of transatlantic aerial service in 1939 that might be comparable with Pan American's service. To that end, it turned to Sir Alan Cobham and Flight Refuelling Limited (FRL).

Sir Alan Cobham and FRL, the British Solution

If British aviation of the interwar years had a counterpart to Charles Lindbergh, it was Sir Alan Cobham (1894-1973). In the 1920s, he became conspicuously identified with long-distance flying. In 1925, he flew Sir Sefton Brancker, Great Britain's director of civil aviation, to the Middle East, India, and Burma over a track of 18,000 miles to investigate possible air terminal sites. That year he also flew a similar survey between London and Capetown. In 1926, he flew a survey of the 14,000 miles between England and Melbourne, Australia, and then returned. The airplane used in all of these operations was a de Havilland DH.50, a single-engine

biplane of 4,200 pounds. King George V knighted Cobham shortly after his return from Australia. He was the last British aviator to be knighted for services to civil aviation.

In the early 1930s, Sir Alan became interested in inflight refueling as a means of range extension, and in 1934, he attempted a nonstop flight from England to Karachi in what was then British India. After topping off his tanks over the English Channel, he would be refueled again over Malta; at Aboukir near Alexandria, Egypt; and finally over Basra, Iraq. Cobham provided the tankers in England and at Malta—Handley Page W.10s, superannuated twin-engine biplane airliners converted to the role. The RAF agreed to provide the tankers at Aboukir and Basra; they were Vickers twin-engine biplanes, obsolete by 1934.

Cobham's receiver was an Airspeed AS.5 Courier, a single-engine, low-wing monoplane that was unusual on two counts: it was the first British airplane with a retractable landing gear, and it was the first airplane in the world certified as a receiver of aerial refueling. Cobham's Courier was placarded for a maximum takeoff weight of 3,500 pounds, but for 5,050 pounds once in the air. The 1,550-pound difference was 209 Imperial gallons of gasoline provided by aerial refueling.¹⁷

On September 22, 1934, with William Helmore as his copilot and hose handler, Sir Alan took off for India from Portsmouth, England. Over the English Channel, a W.10 tanker filled their tanks to the certified overload. The fueling arrangement was the usual dangle-and-grab system. About ten hours and 1,130 miles later, they were over Halfar, Malta, where the other W.10 spiraled up to meet them. The refueling went well, but shortly thereafter, a failure in the Courier's throttle linkage caused a loss of power. Fortunately, Malta was still nearby, and Cobham was able to stretch a glide into a wheels-up deadstick landing at Halfar.¹⁸

In spite of the failure of this operation, Cobham was convinced that inflight refueling had a practical future. On October 29, 1934, he created Flight Refuelling Limited. Well aware that the dangle-and-grab fueling system had no future, he made an arrangement with the British Air Ministry for access to Farnborough's experience and the loan of a series of obsolescent RAF multiengine airplanes for development work. He also had to come to terms with the Atcherly patents. Concurrently, he convinced Imperial Airways of the versatility of inflight refueling.

By mid-1938 Cobham and FRL had a workable system, which came to be known as the "looped hose." Superficially, it was the same as what Atcherly and others at Farnborough had worked out in the early 1930s. FRL's distinct contribution was the invention and development of the small but vital fittings and hose connections that transformed inflight refueling from stunts and ad hoc experiments to rational flight operations that could be performed routinely.

Between August 5 and September 30, 1939, Imperial Airways provided an experimental airmail service between its seaplane base at South-

ampton, England, and New York City, via Foynes on the Shannon estuary in Ireland, Botwood on the north coast of Newfoundland, and Montreal, Canada. The airplanes used were the Short S.30 flying boats named *Cabot* and *Caribou*—S.23s reinforced to operate at 53,000 pounds. Their cabins were stripped to save weight, their payloads were limited to a few hundred pounds of mail, and they were served by inflight refueling. FRL provided two Handley Page HP.54 Harrow tankers stationed on either side of the Atlantic Ocean. One was based at the new airport at Gander, Newfoundland, and the other operated from the new airport at Rineana, Ireland (later known as Shannon Airport). The Harrow was an obsolescent bomber; a twin-engine, high-wing monoplane with a fixed landing gear; weighing 23,000 pounds, it carried 6,840 pounds of offload fuel.

These inflight refuelings were not used to facilitate a nonstop flight from Southampton to Montreal (other factors dictated stops in Ireland and Newfoundland), but simply to fill up the receivers after takeoff. Operations were terminated because of the imminent October freeze-up at Botwood that made seaplane operations impossible. Imperial Airways expected its airmail service to North America would be resumed in the spring of 1940, after the ice broke up at Botwood. FRL also had a new customer in Air France, which looked forward to an aerial refueling service based at Santa Maria in the Azores for the transatlantic operations to New York City it had scheduled for its four-engine Farman F-2234 transports in the summer of 1940. But World War II changed everything.

Wartime Might-Have-Beens

On September 1, 1939, Europe went to war for a second time within a generation. The RAF had solicited proposals for the inflight refueling of its new four-engine heavy bombers, specifically the Short Stirling as a receiver, but all of this went aglimmering among the disasters of 1940. In April, when Germany invaded Norway, the RAF seized the *Cabot* and the *Caribou* to transport matériel to Norway, where both flying boats were destroyed by the Luftwaffe. With them went two of Imperial Airways' three air-refuelable transports.¹⁹

On May 10, 1940, Germany launched a blitzkrieg of dazzling power, focus, and speed. Belgium, the Netherlands, and Luxembourg were quickly overrun, and France collapsed within forty days. The Battle of Britain ensued (July 10–October 31), and Flight Refuelling Limited, with its base at Ford in Sussex on England's south coast, suddenly found itself on the front line. On August 18, a swarm of Ju.87 dive bombers fell on Ford. Among the extensive damage, they destroyed FRL's small tanker fleet—a devastating blow because, without tankers, there could be no further refueling demonstrations.

Among the projects in which Sir Alan Cobham tried to interest the

British Air Ministry was inflight refueling for the Short S.25 Sunderland, a 50,000-pound, four-engine flying boat designed for maritime reconnaissance. A Sunderland had the radius to patrol the area between Great Britain and Spain, a distance of 450 miles, and the range to fly a patrol from Northern Ireland to Iceland, 850 miles, but it did not have the radius to carry a warload 1,000 miles to the mid-Atlantic (site of the bitter convoy battles against German submarines), orbit the convoy for an hour or two, and return to base in Cornwall, Donegal, Iceland, or at Argentina. Inflight refueling from bases on the North Atlantic's rimland would have taken a Sunderland to midocean and given it the endurance to orbit a convoy for some hours.

Britain was wholly dependent on shipping for its survival, quite aside from materials to carry on a war. From 1939 through 1942, however, an average of more than 3.4 million tons of shipping were lost to German U-boats annually; ships were sunk faster than they could be replaced. Strangely, the authorities were unwilling to accept Sir Alan's case that, at minimal cost, inflight refueling could provide midocean air cover with equipment already available in Britain.

The British eventually built 2,381 Short Stirling bombers, and by mid-1942, that aircraft was being displaced in frontline service by the superior Avro Lancaster. Converted to a tanker, a Stirling easily could have lifted an offload of 7,000 pounds. The twin-engine Armstrong-Whitworth Whitley (more than 2,000 were built) was being withdrawn from frontline service in early 1942. While not a very good bomber (some said it was not even a very good airplane), the Whitley could carry two tons of bombs to Berlin and return, a 1,200-mile flight. It could as easily have given a Sunderland 3,000 pounds of fuel at some point 500 miles from base, and another 3,000 pounds at a rendezvous returning.

Given aerial refueling both outbound and returning, the Short Sunderland would have been a devastating antisubmarine weapon, but that did not happen. It was not until mid-1943 that convoys saw airplanes in the mid-Atlantic, and they were American-built B-24 Liberators. Meanwhile, German U-boats continued to decorate the North Atlantic's bottom with millions of tons of Allied shipping.

After the Japanese attack on Pearl Harbor brought the United States into World War II, many Americans desperately wanted to bomb Japan. The most forward U.S. base for such an action was Wake Island, 1,983 miles from Tokyo, but the Japanese preempted its use on December 22, 1941, when they overwhelmed its small garrison of U.S. Marines. In Washington, Imperial Airways' use of aerial refueling was recalled and British authorities in the United States were contacted in hopes of establishing a connection with FRL. Stranded in Newfoundland by the war, the FRL employees had scattered, but Hugh Johnson, who had been in charge of the Harrow tankers at Gander, was available. An officer in the RAF Reserve, he had gone on active duty with the Royal Canadian Air Force (RCAF).



Two huge, underpowered aircraft with tremendous range: the XB-15 (top), with a range of 5,000 miles, was accepted in 1937, and the XB-19, with a range of 6,000 miles, was accepted in 1941. They reflected the effort to build maximum range into the unitary airplane.

Johnson was located and seconded to an American effort in aerial fueling. Alas, the FRL equipment left at Gander was suitable only for the tankers; there was none for a receiver. Johnson was packed into a Liberator and flown to England where he assembled material for a U.S. effort with FRL's equipment. He returned to the U.S. with the equipment, drawings, and a few FRL technicians.

Meanwhile, on April 18, 1942, Col. James E. Doolittle and his small force of B-25s had taken off from the carrier *USS Hornet* and bombed Japan. Nevertheless, the U.S. effort to develop an inflight refueling capa-



The Boeing B-29 Superfortress.

bility went forward, albeit slowly. It was the summer of 1943 before tests began at Eglin Field, Florida, with a B-24D tanker and a B-17E receiver. Every aspect of these operations was successful (see Appendix 2). With three tons of bombs, the B-17's radius was extended from 1,000 to 1,500 miles. But there arose the question of how to manufacture equipment for *squadrons* of B-24 tankers and *squadrons* of B-17 receivers, do the modifications, and train the crews.²⁰

By the summer of 1943, B-29s were rolling out of the Boeing factory at Wichita, Kansas (Boeing-Seattle was still building B-17s) and production was being organized at Bell-Marietta and Martin-Omaha. B-29 squadrons were already in training, and this bomber carried more than twice the bombload of a B-17, with a combat radius of about 1,500 miles. It was expected to enter combat by early 1944, and in fact, on June 15, 1944, B-29s based in China made their first attack on the Japanese homeland. An expensive effort to create squadrons of B-24s for the inflight refueling of B-17s no longer made sense. This is a rare example of a valid requirement for inflight refueling being *directly* transcended by improvements in the performance of the unitary airplane.

In Great Britain, Sir Alan Cobham was summoned to the Air Ministry in February 1944 and informed of plans for the RAF to bomb Japan by means of aerial refueling. At that moment, the D-Day invasion of Hitler's Europe was almost four months away. The war in Europe was expected to be finished by mid-1945, and the war against Japan was expected to drag on into mid-1946. The British plan to bomb Japan called for 600 Lancaster bombers to be converted into tankers to serve 600 Lincoln bombers. The Lancaster was a 50,000-pound airplane, and although there was a su-

perfidial resemblance between it and the Lincoln, the latter had a gross weight of 82,000 pounds and represented a wholly different airplane. This operation was to be known as TIGER FORCE.

The Lincoln prototype had not yet flown, however, and would not fly until June 9, 1944, after which it could be expected to have its share of developmental problems. Exactly where TIGER FORCE would have been based is uncertain, but in the summer of 1944, U.S. amphibious forces captured the islands of Saipan, Tinian, and Guam, all within 1,560 miles of Tokyo, and those islands supported subsequent B-29 operations.

Previously a prophet without honor, suddenly Sir Alan could do no wrong in the eyes of the British Air Ministry's mandarins, and FRL enjoyed all kinds of industrial priorities in obtaining scarce materials for refueling systems. Three airfields were put at FRL's disposal and a school was created for training hundreds of aircrews. Then, in the spring of 1945, everything stopped. After a bitter battle at sea and on land, in April U.S. amphibious forces seized the island of Okinawa, less than 360 miles from southernmost Japan and 950 miles from Tokyo. Lincoln bombers and in-flight refueling were no longer necessary; from Okinawa, even Lancasters could hit Tokyo with ease. Within four months Japan surrendered.²¹

Refueling Frustrations and the Onset of the Cold War

With World War II ended, Cobham sought to pick up the threads where they were snatched away in 1940, selling FRL's services to the commercial airlines. Six surplus Lancaster bombers were obtained and transformed into tankers and receivers. Each Lancaster tanker would deliver 2,830 U.S. gallons (16,980 pounds). During the winter of 1946-47, an intensive series of demonstration flights was flown in Britain between Dover and Land's End, in association with British South American Airways (BSAA). These were all-weather, day-and-night operations, and involved distant interceptions that used radar and transponders, unlike the prewar refuelings that were daylight visual flight rules operations in which tanker and receiver were rarely out of one another's sight. The object was to simulate midocean rendezvous. FRL used its Lancaster tankers; BSAA used Lancaster receivers. Forty-three successful operations were flown, twenty-six by day and seventeen at night. FRL took pains to have BSAA rotate the pilots of the receivers so the greatest number would learn that there was nothing extraordinary about the operation.

In the spring of 1947, these trials were expanded to an ocean track between London-Heathrow and Kindley Field, Bermuda, with the tankers based in the Azores at Santa Maria. Between May 28 and August 11, eleven scheduled weekly return flights were made. The offloads varied from 960 to 2,400 gallons. Westbound, flying against the prevailing wind, the average refueling was 2,230 gallons, eastbound it was 1,365. As a

rule, the receivers' tracks passed within 200 miles of Santa Maria, but on one flight the refueling rendezvous was made 500 miles out. These flights went off without a hitch, except on one occasion when a receiver developed engine problems and diverted to the Azores.

Finally, there were winter trials on the North Atlantic in association with the British Overseas Airways Corporation (BOAC). For these operations, FRL bought four "Lancastrians" from Trans-Canada Airlines and converted them to tankers. During the war, some Lancaster bombers built in Canada were converted into airliners, called "Lancastrians," for wartime transport of Canadian forces in Great Britain. Avro in England also built some Lancastrians, but those built in Canada were especially prized because they were fully winterized for operations above North America's 49th parallel.

Two Lancastrian tankers were based at Shannon, Ireland; the other two in North America, at Goose Bay, Labrador, and Gander, Newfoundland. The receiver was a B-24 Liberator that BOAC had converted to carrying mail and freight. Between February 4 and May 30, 1948, fifteen return flights were served by inflight refueling, permitting the Liberator to fly London to Montreal nonstop—3,240 miles. Westbound there were two refuelings, one 200 miles west of Shannon, the second in the vicinity of Gander or Goose Bay, depending on the weather. Eastbound, only one refueling was necessary, usually 200 miles east of Gander or Goose Bay.

Of the forty-five refuelings scheduled, three miscarried: one because of radar failure and cabin heating in the tanker; another because fuel would not flow; and the third because a nervous BOAC captain refused to have anything to do with it. In any case, BOAC officials did not want to buy British airline equipment; they chose to spend Britain's precious dollar exchange on Lockheed Constellations and Boeing Stratocruisers. They were also willing to pay for lost time and high-priced fuel at Gander and at Prestwick or Shannon. Those decisions precluded all aspects of aerial refueling.

The London-Bermuda test operations in 1947, nonetheless, were encouraging enough that FRL prepared studies for modifying the new four-engine Avro Tudor IIs that BSAA was then putting into service for inflight refueling. A postwar design and not a converted bomber, the Tudor II was a troubled airplane. On the night of January 29/30, 1948, one disappeared between the Azores and Bermuda. A year later, on January 17, 1949, another Tudor disappeared between Bermuda and Jamaica. Along with providing grist for legends about the so-called "Bermuda Triangle," these accidents caused the Tudor II to be withdrawn from passenger service and forced BSAA to suspend operations; its assets were taken over by BOAC.²² Given the hostility that BOAC had developed toward inflight refueling, it seemed in 1948 that Sir Alan Cobham's dream of a global inflight refueling service would come to nothing. But suddenly an extraordinary customer turned up from the United States.

As relations between the United States and the Soviet Union deteriorated after World War II, U.S. Army Air Forces' leaders started measuring distances between North America and such points in the USSR as Magnitogorsk, Novosibirsk, Omsk, and Sverdlosk. They found them to be more than a few nautical miles (nm) too far to fly.* A means of range extension became urgent.

On March 18, 1948, a B-29 from Wright-Patterson AFB, Ohio, landed at London Airport, Heathrow. Six passengers climbed out for a visit to Ford aerodrome and the FRL offices in nearby Littlehampton. They knew what they wanted, they had the money to pay for it, and after brief negotiations Sir Alan Cobham was pleased to accept their money. When they left a few days later, the Air Force had two sets of FRL's inflight refueling hardware, manufacturing rights to FRL's system, and a contract for FRL to produce an additional forty refueling sets and provide a year of technical support.

The U.S. Air Force had bought a system proof-tested by Imperial Airways in 1939, again by the U.S. Army Air Forces in 1943, and repeatedly by FRL, BSAA, and BOAC during 1946-48. Because no one else in the world had a system remotely similar, much less available as "shelf" technology, it would have been reasonable enough at twice the price. That contract put the Air Force directly into aerial refueling.

The Aircraft and Weapons Board

The Air Force's journey to Heathrow, Ford, and Littlehampton had its origins in the first meeting of the Air Force Aircraft and Weapons Board some months earlier, in August 1947. That board's members recognized that only two airplanes could reach targets in the USSR: the Convair B-36 and the Boeing B-52. The B-36 had a range of 6,950 nm, but on all other counts it was at that moment a great disappointment; and the Boeing B-52, while nominally a six-engine turboprop, was still a paper airplane and one that could not fly before the mid-1950s. The fate of the B-52 was especially thorny, so the board turned the problem over to a special subcommittee on heavy bombardment.²³

Members of the bombardment committee did not like the B-36; in 1947, no one did. Indeed, in committee meetings, General George C. Ken-

*On Jun 26, 1946, the War Department's Army-Navy Aeronautical Bd agreed unanimously that the nm and the knot be adopted as standard units of distance and speed. With aviation then "going global" this made sense; it brought aviation into correspondence with geodesic measurements firmly in place since the eighteenth century. A nm is the length of one minute of the arc of a meridian at the Equator, that is, a nominal 6,080 feet. A knot is simply a rate of speed: one nm per hour. The distance from Goose Bay, Labrador, the northeasternmost air base in North America, to Moscow is 3,106 nm; the distance from New York City to Moscow is 4,037 nm; and the distance from Chicago to Moscow is 4,303 nm.



The B-36 was designed to have the range to bomb Germany during World War II from bases in the United States. It was the ultimate development of the piston-engine bomber, and production models could reach the Soviet Union without aerial refueling from bases in North America.

ney, the first commander of the Strategic Air Command (SAC), made sarcastic remarks about the B-36 that often provoked laughter. Everyone wondered what was to be done with the 100 B-36s on contract. The only thing the 328,000-pound B-36 had to recommend it was its great range. Committee members liked the B-52 design even less because it weighed in at 490,000 pounds (a sneaky way of saying "500,000"). With only a 10 percent weight increase, a nominal measure, the airplane could become 550,000 pounds on rollout day. The committee was convinced that a 500,000-pound turboprop would be, like the B-36, too big, too slow, too vulnerable, and quite obsolete when it debuted in 1955 or 1956.

Even on paper the B-52 was caught up in a fuel-weight spiral, driven by the requirement for a range of 10,860 nm. This is a trifle less than half the globe's circumference at the equator, 21,636 nm. And the paper B-52 grew ever bigger to carry the fuel necessary to achieve that range, its size dictated by the need for "carrying fuel to consume fuel."

The committee recommended replacing turboprops with turbojets. When the B-52 specification had been prepared in 1944, the fuel consumption of turbojets was extravagant and turboprops seemed a better bet. The fuel efficiency of turbojets was improving annually and clearly promised speeds superior to turboprops. An all-around defensive armament, i.e., a dozen 20-mm guns in a half-dozen heavy turrets with a complicated and weighty fire control system and the weight of the crew required to operate them, should be eliminated. With the speed promised by turbojets, defensive armament should be reduced to a tail gun.

Finally, the requirement for a range of 10,860 nm should be reduced by 36 percent, to 6,950 nm, eliminating the weight of fuel used to carry fuel. As one engineer made clear, for every pound put on board an airplane as payload, eight pounds of structure and fuel had to be built into the airplane to carry it.²⁴ With range reduction accepted, everything else started to fall into place. The airplane was reduced to something around 300,000 pounds. The deficit in range would be met by aerial refueling.

The bombardment committee emphatically concluded that the development of aerial refueling should be the Air Force's top priority, not only for the B-52 of the distant future, but also for existing B-29s and the new B-50s then entering the inventory. As a receiver for aerial refueling, the prospects of the B-47 were perceived as problematic. When the committee prepared its report in November 1947, the Boeing XB-47 had not yet flown.²⁵

In January 1948, the second Air Force Aircraft and Weapons Board accepted the bombardment committee's recommendations on those points, and its report was passed on to Chief of Staff General Carl A. Spaatz, who had been in charge of the *Question Mark* operation.²⁶ When he read the board's consensus on inflight refueling, Spaatz may have had more than a few moments of reflection. He gave aerial refueling top priority; Lt. Gen. Curtis E. LeMay, who succeeded General Kenney as commander of SAC on October 19, 1948, would discharge that commitment.

Back in the autumn of 1947, the Air Force had asked Boeing to investigate aerial refueling. That request resulted in a few studies and some experiments with B-29s flying in close proximity to one another. But in January 1948, when General Spaatz identified air refueling as the service's primary priority, retired Lt. Gen. James Doolittle paid another visit to England and Flight Refuelling Limited. This, his second visit to FRL (he had been there in 1946), was on the eve of FRL's beginning its North Atlantic trials.

Prior to World War II, Doolittle had been aviation manager in the United States for Shell Oil, which owned 60 percent of FRL. That was a natural association in those prewar years when it was imagined that FRL would create a worldwide refueling service that a half-dozen or more airlines would be inclined to buy; FRL's tankers would be offloading Shell gasoline. It was Walter Hill, general manager of Shell's aviation section, who brought Doolittle to Ford aerodrome for a look at FRL's operation.

Doolittle came away from Ford with a wealth of data on aerial refueling and a motion picture of FRL's operations. Those data were subsequently circulated in Air Force Headquarters and the film had many viewings there. Among those who saw the FRL movie was Secretary of the Air Force Stuart Symington. The Air Force wanted to make copies of the film for internal distribution but Doolittle regarded it as an FRL proprietary item, to be treated as confidential. Sir Alan Cobham, however, was delighted to grant permission; he could not have asked for better advertising.

The KB-29 and B-50

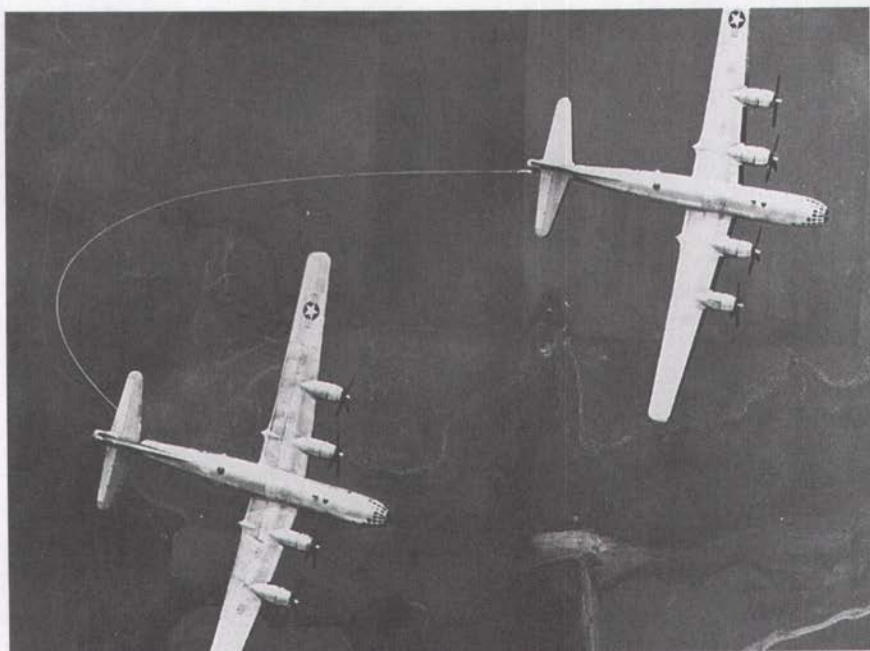
Shortly after arriving in the United States in March 1948, the two FRL fueling units from England were flown to the Boeing factor in Wichita, Kansas, where they were installed in B-29s; one airplane was retained at Boeing and the other went to the Air Matériel Command at Wright-Patterson AFB, Ohio. Flight testing started in May. At that time, Air Force leaders decided to modify eighty B-29s into tanker-receiver pairs; the tankers were known as KB-29Ms, the receivers as B-29MRs. In June the service directed that all B-50 bombers be equipped as receivers; those in the inventory would be retrofitted and others would be modified on the production line. Concurrently, B-50s would be retrofitted or modified while in production for "single-point refueling," a change made necessary by inflight refueling.

Prior to this time, airplanes were refueled much like automobiles, except that big airplanes had more than one fuel tank. At an airfield, a fuel truck's hose was moved from gas tank to gas tank, the filler caps usually located on a wing's upper surface and the fuel flowed by gravity. It was slow and awkward, but that was the way it had always been done. Flying boats were the only exceptions. Because they floated on the water, it was impossible to drive around them with a fuel truck, running out fuel hoses for a transfer. Hereafter, Air Force fueling would be at a single point on the airplane into an integrated and well-vented fuel system, and accomplished under pressure.

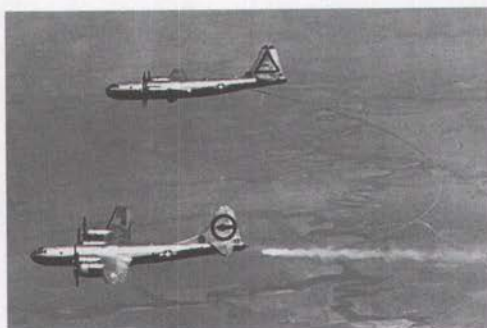
Meanwhile, FRL's orders multiplied, and Boeing-Wichita started rolling out the first KB-29Ms and B-29MRs. On June 30, 1948, twenty-five years after the world's first aerial refueling, the world's first aerial refueling units were created—the 43d Air Refueling Squadron at Davis-Monthan AFB, Arizona, and the 509th at Walker AFB, Roswell, New Mexico.

With the sudden flood of orders and the Air Force's reluctance to become dependent on an overseas supplier, FRL created an American subsidiary—Flight Refueling, Incorporated, known as FRInc. With manufacturing facilities in Danbury, Connecticut, and later at Friendship Airport in Baltimore, Maryland, FRInc remained on the scene until purchased by Aeronautical Corporation of America (Aeronca) in the 1960s.

The cumbersome looped-hose system clearly had its limitations, and the Air Force had asked Boeing to investigate alternatives. The result was the "Boeing boom," a telescopic pipe with small aerodynamic surfaces called "ruddervators" near the nozzle end. An operator, sitting in what had been the B-29's tail gun turret, manipulated the ruddervators to "fly" the boom to a receptacle in the receiver. FRL's looped-hose system had an inside diameter of only 2.5 inches and did well to deliver 110 gallons per minute (gpm). As most mathematicians and *all* plumbers know, if the diameter of pipe is doubled, its capacity is quadrupled. With an inside diameter of four inches and a powerful pumping system, the early-model Boe-

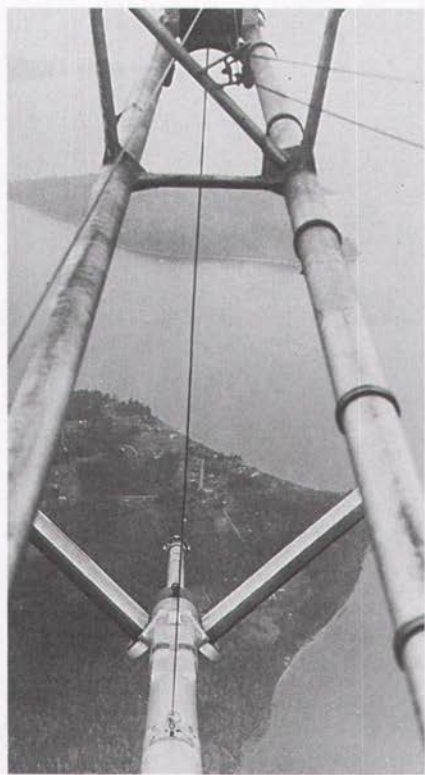


Looped hose refueling using KB-29M tankers and B-29MR receivers. The tanker (top left and bottom right) is above and ahead of the receiver. The huge bight of hose made connection awkward, and this system could not be used above 190 knots.



ing boom delivered 700 gpm. Boeing tested its new boom in the autumn of 1948. More than 100 B-29s were ordered to be modified into boom tankers; they became KB-29Ps. All of the new B-50Ds were to be boom receivers.

In June 1948 the work took on new urgency when, in an attempt to squeeze the Allies out of Berlin, the Soviet Union declared a blockade of the city. The U.S. response was the Berlin Airlift. Overnight, the military requirement to be able to reach Moscow became urgent, but if by a B-29, a B-50, or at some future date with a B-47, they would have to be air-refuelable. The fate of the B-36 was salvaged by hanging a pair of J47 jet engines on each wing, beginning with the B-36D; they helped get this 360,000-pound behemoth off the ground and gave it speed in the combat zone. Ultimately, nearly 400 B-36 variants were procured. The only at-



The earliest model of the Boeing boom was temporary, with exposed girders, cables, and pulleys. The boom operator in the KB-29P sat in what had been the tailgunner's space.

tractive aspects of the B-36 were its phenomenal payload in excess of forty tons and its intercontinental range (along with the Kremlin's certainty that Moscow's Red Square was within B-36 range).

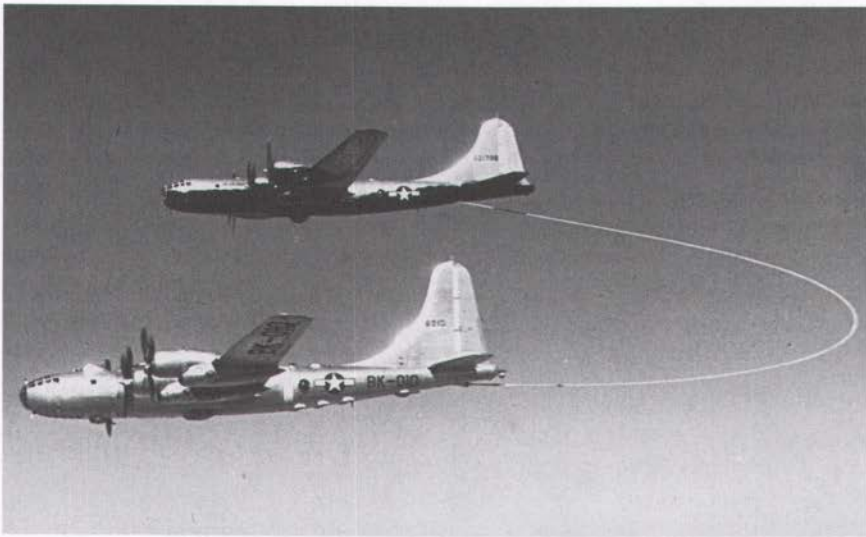
During December 7-9, 1948, the Air Force conducted an operational testing of the looped-hose system. A B-50A was flown from Carswell AFB in Fort Worth, Texas, to Hawaii, where it dropped a dummy bomb load. It returned to Carswell nonstop via a roundabout route over Montgomery, Alabama, flying a track of some 6,720 nm. KB-29M tankers refueled the B-50 once outbound, and twice on the return trip. Unpredicted headwinds ran up the B-50's fuel consumption between Hawaii and the west coast. As it approached California, the plane was almost running on tank vapors. On its first pass, the KB-29M tanker's contact line failed to catch the receiver's. It circled for a second try, which also missed. Time was running out. While they still had power, the B-50 crew planned for an emergency landing on a small airstrip for Navy fighter planes built on one of California's offshore islands. The tanker's third pass made a connection and fueling began. Because of problems with that fueling, a second one had to be accomplished over eastern California. Once that fueling was completed, the B-50 possessed B-36 range.

Lucky Lady II: Air Refueling Ascendant

On January 26, 1949, the Air Force ordered a more dramatic demonstration—an around-the-world flight. To avoid possible embarrassment in the event of failure, the Air Force made its preparations in great secrecy. KB-29Ms, accompanied by C-54s and one C-97 with logistics support, were positioned at Lajes in the Azores; at Dhahran, Saudi Arabia; at Clark Air Base in the Philippines; and at Hickam AFB, Hawaii. At least three tankers waited at each site. Work crews prepared five B-50As as receivers. One would be launched to see how far it would go. If it flew around the world, well and good; if not, the second B-50 would be launched. It was assumed that one of the five would succeed. If none succeeded, some useful data would be collected.

On February 25, a B-50 optimistically named *Global Queen* took off from Carswell AFB for the circuit. Sixteen hours later it was down at Lajes with a troubled engine. The next day, a B-50 named *Lucky Lady II* under the command of Capt. James Gallagher and with a crew of thirteen took off for the great go-round. An unremarkable ninety-four hours and one minute later, on March 2, they landed back at Carswell, having made the first nonstop flight around the world—thanks to four inflight refuelings using FRL's looped-hose system.

Capt. Gallagher and his crew were celebrities, feted everywhere, and decorated with Distinguished Flying Crosses. The tanker crews, like their predecessors, received maximum anonymity, but they may have had let-



The B-50 *Lucky Lady II* using the looped-hose system to refuel from a KB-29M during training for the around-the-world nonstop flight.

ters of recommendation slipped into their 201 folders. At Carswell, Lt. Gen. Curtis E. LeMay, SAC commander, explained the significance of this flight for assembled members of the news media by saying that the Air Force could now deliver an atomic bomb to any place in the world that required one.

The global circuit by the *Lucky Lady II* had been a close thing, with the whole operation lashed together within four weeks. The tanker crews had a bare minimum of experience—as of December 20, 1948, the 509th Air Refueling Squadron had flown only a dozen refueling contacts and the 43d only one. Moreover, the experience of the B-50 receivers could not have exceeded that of the tankers. The world flight required eight flawless refuelings—a minimum of two at each refueling point. Additionally, the B-50 had not yet been in squadron service for a year and there was the temperamental nature of its new R-4360 engines—as the crew of the *Global Queen* had discovered.²⁷ All things considered, the *Lucky Lady II* deserves to have her name written mathematically as “*Lucky Lady*².”

Following the flight, LeMay directed the multiplication of SAC's air refueling squadrons. At the end of 1949, SAC had six refueling squadrons, but only the 43d and 509th were fully equipped. By the close of the following year, there were twelve squadrons with 126 KB-29Ms. In the fall of 1950, the first inflight refueling of a jet bomber took place between a KB-29P and a North American RB-45C, both assigned to the 91st Strategic Reconnaissance Wing at Barksdale AFB, Louisiana. Over the next eighteen months, the 91st developed jet bomber refueling equipment, techniques, and procedures, including the first night refueling and instrument

weather refueling. By 1951, SAC had twenty understrength squadrons with a mix of KB-29Ms and KB-29Ps, but also two with new Boeing KC-97s. The next year it had twenty refueling squadrons with 318 tankers. In 1952, SAC planners for the first time incorporated a dependence on aerial refueling into their war plans, and by 1953, SAC had almost thirty squadrons with 502 tankers, most of which were new KC-97s. At the end of 1954, SAC's refueling fleet had grown to thirty-two squadrons with 683 tankers, with an average of twenty-one airplanes per squadron. In July 1956, with SAC operating forty full-strength air refueling squadrons, a concerned Maj. Gen. Frank Armstrong, Jr., commander of the Second Air Force, advised LeMay, "We built, and we are continuing to build, our strategy around refueling. As of today, 'the tail is wagging the dog.'"²⁸

Two efforts to extend the range of fighters without aerial refueling included connecting F-84s to the wingtips of a B-29 (top), and a B-36 carrying a fighter on a trapeze that would lower to release the fighter or to catch it returning from a mission. Both were hazardous and were terminated, the B-29 experiment ending with the fatal loss of aircraft.



The Probe-and-Drogue

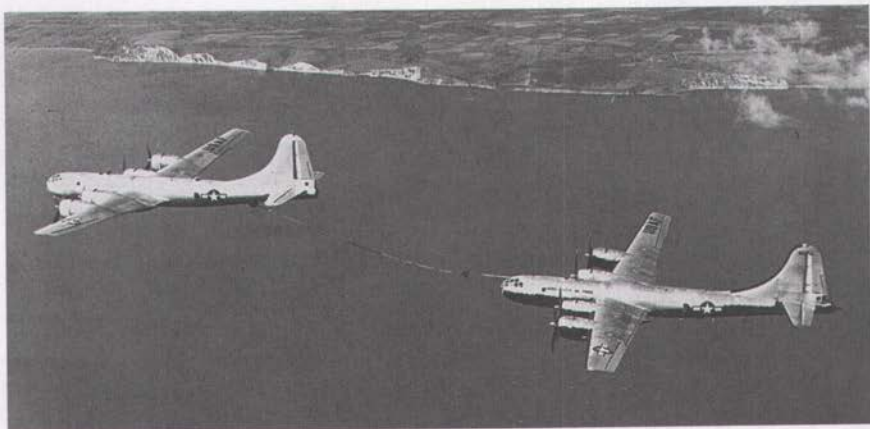
As early as 1939, FRL's looped hose provided a workable inflight refueling system for large, multiengine airplanes, but its adaptation to fighter planes in which there was no crew to connect the hose was clearly impossible. Locked into the idea of doing something with a hose, FRL soon hit upon what became known as the probe-and-drogue system. The tanker trailed a hose with a cone-shaped receptacle at its end; the receiver had a probe it inserted in the cone; valves opened and fuel flowed.

While the *Lucky Lady II* was circling the globe, FRL was developing probe-and-drogue technology, and on April 4, 1949, it was given its first test. A Gloster Meteor III jet fighter connected to a Lancaster tanker. No fuel was passed, but everything worked as expected. A few days later, a U.S. Air Force delegation watched a demonstration. Subsequently, the Air Force flew four B-29s and a pair of F-84Es to England for FRL's modification. Two B-29s were given probes that jutted out conspicuously from the upper curve of the nose of their fuselages, making them receivers; these aircraft became known as "unicorns." A third B-29 was modified with a single hose-reel unit in its fuselage and with hose-reel units in pods, one on each wing tip, enabling it to refuel three fighters in a single contact. It was designated the YKB-29T; its three-hose capability led to its being called the "Triple Nipple." The two F-84Es were fitted with single-point fueling systems, including conspicuous refueling probes on the leading edges of their left wings.

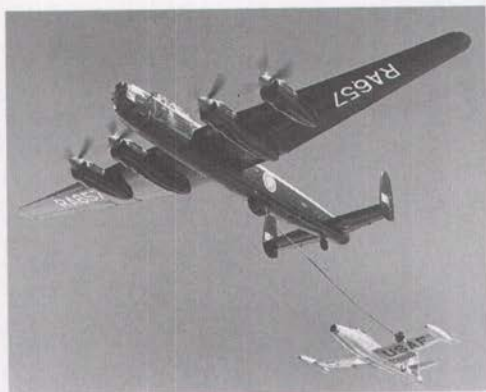
Meanwhile, on August 7, 1949, Thomas Marks flew an FRL Lancaster tanker which, in ten contacts, kept a Gloster Meteor, flown by Patrick Hornidge, in the air for twelve hours and three minutes. This was not simply a first for jet fighters, but at that moment a world record for jet endurance.

FRL finished modifying the U.S. Air Force fighters and, on September 22, 1950, Col. David Schilling and Col. William Ritchie flew the two F-84Es from Great Britain to North America nonstop with three aerial refuelings. After takeoff from the RAF base at Manston, England, near the Strait of Dover, the first refueling was from an FRL Lancaster near Prestwick, Scotland; the second from an FRL Lincoln over Iceland; and the third by a KB-29 offshore of Labrador. Unfortunately, Ritchie damaged his probe while refueling from the Lincoln and could not get fuel from the KB-29. He ran out of fuel over Labrador, ejected safely, and was picked up by a helicopter. Schilling landed at the nominally secret Air Force base in Limestone, in northernmost Maine, after a flight of ten hours and eight minutes, scoring a transatlantic first for jet airplanes.²⁹

Back in July 1948 Schilling had led sixteen Lockheed F-80s from Selfridge AFB, Michigan, to the RAF base at Odiham, England, flying via fuel stops at Bangor, Maine; Goose Bay, Labrador; BW-1 at the southernmost tip of Greenland; Meeks Field, Iceland; and Stornoway in the Heb-



A pair of FRL-modified B-29s practice refueling off the coast of England in 1951 (top). Col. David Schilling's F-84 receives fuel from an Avro Lincoln during his transatlantic flight in September 1950.



rides. This was FOX ABLE ONE (Fighters Atlantic, Operation No. 1). With refueling stops and weather delays, the movement took ten days. A FOX ABLE TWO movement over a similar island-hopping track in May 1949 took sixteen days. The aerial refueling of transatlantic fighter movements clearly promised to make a phenomenal time difference.³⁰

The Cold War Gets Hot, Refueling Becomes Vital

On June 25, 1950, in the midst of these developments, communist North Korea invaded South Korea and the United States soon came to the south's assistance. Within sixty days the North Koreans almost overwhelmed the peninsula, driving the defenders back to an enclave around the port of Pusan. There were momentary fears of a "Korean Dunkirk" with an evacuation by sea to Japan.

The Air Force conducted most defensive air operations for South Korea from Japan. It was some 130 nm from bases in southern Japan to Pusan, and 175 to 300 nm to targets on the North Koreans' line of advance

along the Seoul-Taejon-Taegu axis. It was 540 nm from U.S. Air Force bases near Tokyo to Pusan, and some 600 nm to Seoul and targets along the 38th parallel. Piston-engine airplanes had few difficulties with those distances, but such long trips were often at the limits of a jet fighter's combat radius.

The U.S. mission in South Korea urgently needed a means to extend the range of the F-80 jet fighters already on the scene and the F-84s en route from the United States to Japan aboard Navy aircraft carriers. Aerial refueling, as it was understood at that moment, was out of the question because the available fighter planes were not plumbed for single-point refueling; that is, there was no receptacle on the airplane from which all of its tanks could be filled.

Engineers at Wright-Patterson AFB, Ohio, hit upon the idea of using the new probe-and-drogue system to refuel only the external drop tanks of the fighters. A receiver probe and its valve were welded on the inside forward curvature of an external drop tank. Instead of filling the internal tanks, the receiver pilot simply filled his wing tanks. Development work was turned over to Lockheed, Republic, and North American for their F-80s, F-84s, and F-86s, respectively. There were few problems with the straight-wing F-80s and F-84Es, which had wing-tip tanks, but many difficulties with the F-86. An F-86 carried its drop tanks beneath the wing and close inboard toward the fuselage, and the wing's sweepback placed the tanks well below and far behind a receiver pilot's peripheral vision. Subsequent operations were limited to F-80s and F-84s.

The capacities of the external tanks varied from 160 to 260 gallons (1,040-1,690 lbs), and the movement generated by a half-ton of fuel suddenly placed at the wing tip could make an airplane uncontrollable. To avoid making the airplane unstable in the roll axis, refueling the wing-tip tanks of an F-80 or an F-84E involved three fueling contacts. The receiver pilot filled his left tank half full, disconnected from the drogue, and connected with his right tank. When it overflowed, he disconnected that tank and reconnected his half-full left tank, filling it to an overflow. With both wing tanks full, he flew away to execute his mission.

By June 1951, the U.S. Air Force had stationed one of its two KB-29 hose-and-drogue tankers in Japan. On July 6, 1951, the world's first combat mission using aerial refueling was executed. Three RF-80As took off from Taegu, South Korea, and rendezvoused with a tanker offshore of Wonsan, North Korea. It was 210 nm from Taegu to Wonsan, and the normal radius of an RF-80A was approximately 330 nm. After refueling, the RF-80As' original radius was restored—enough to let them photograph targets in northernmost Korea.

This refueling of tip tanks to achieve range extension grew beyond occasional operations with probe-tanked F-80s and RF-80s into Project HIGH TIDE, in which the three squadrons of the 136th Fighter-Bomber Wing were equipped with probe tanks. SAC released ten KB-29Ms for



An F-84 with a wing tank fitted with a probe for refueling.

this operation. With SAC absolutely committed to the Boeing boom, KB-29Ms were becoming surplus to its needs. These KB-29Ms had their looped-hose mechanisms removed and hose-reel sets installed in their after bomb bays; they were known as “Quickie” tankers. Additionally, the YKB-29T “triple nipple” was sent to the Far East.

HIGH TIDE’s objective was an operational test of large tactical units, using inflight refueling. The project had three phases: training the three squadrons in a series of small exercises, deploying them in combat air patrol missions over northern Japan, and deploying them in combat against targets in North Korea.

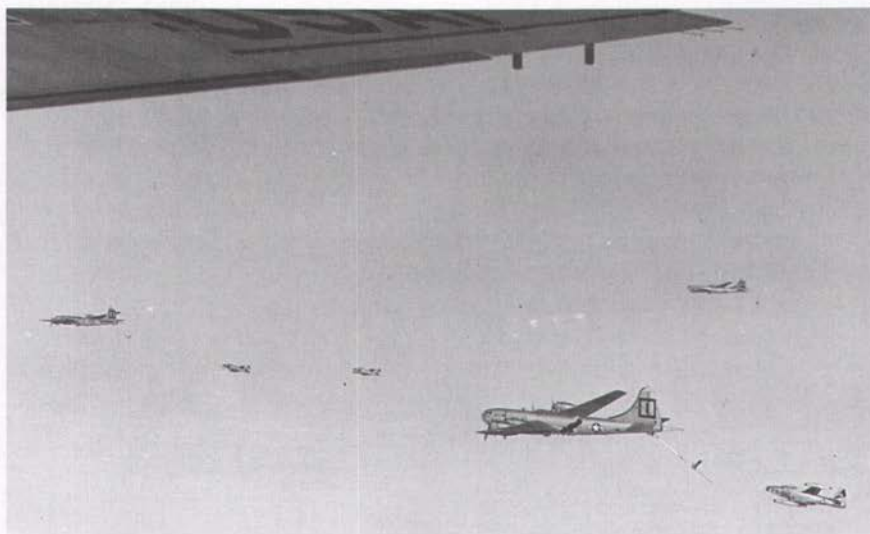
The U.S. Air Force concluded from HIGH TIDE that, although the refueling of tip tanks was a successful ad hoc operation, it was only an emergency substitute for a receiver with a single-point refueling system.³¹ Otherwise, there was no question about inflight refueling being of value to the Tactical Air Command (TAC) and to theater air forces.

Concurrently, Republic Aviation had started to produce the F-84G for SAC; it was essentially an E model with its fuel system plumbed for single-point fueling and it had a receptacle near the leading edge of its left wing to receive the nozzle of a KB-29P’s refueling boom. On July 4, 1952, sixty F-84Gs took off from Turner AFB, Albany, Georgia, and flew to Travis AFB, near San Francisco, California, some 1,800 nm nonstop, being refueled en route by two dozen KB-29Ps over a radio beacon at Wink, Texas (fifty miles west of Odessa). This operation was a dress rehearsal for HIGH TIDE’s follow-on: FOX PETER ONE (Fighters Pacific, Operation No. 1), the movement of a whole wing (three squadrons) of fighters transpacific to Japan with the assistance of aerial refueling.

Col. David Schilling, of the transatlantic FOX ABLE ONE flight of 1948, organized and led FOX PETER ONE, the first air-refueled jet flight across the Pacific. The critical leg was from California to Hawaii, 1,860 nm and the longest nonalternative over-water flight in the world. The movement was made in three increments, one squadron on July 6, the second on July 7, and the last on July 8, all being refueled by KB-29Ps in midocean on a refueling track 18,000 feet above a Coast Guard cutter at Weather Station Alpha. In the event that some of the fighters did not get enough fuel over Alpha, a half-dozen KB-29Ps were orbiting the Coast Guard ship at Weather Station Uncle a few hundred miles east of Hawaii.

West of Hawaii the longest distance was to Midway, 990 nm, and the F-84s island-hopped from Hawaii via Midway, Wake, Eniwetok, Guam, and Iwo Jima to Yokota, Japan, where they landed on July 16—less than two weeks after leaving Georgia. This was substantially faster than what would have been necessary to fly the F-84s to the Naval Air Stations at Alameda or San Diego, California, dress them for shipment as a deckload aboard a Navy aircraft carrier, and then undress them for flight operations. This dramatic demonstration of intercontinental mobility by FOX PETER ONE could only have left the Soviets suitably impressed.³²

FOX PETER ONE was more than a simple demonstration, however. With the assistance of KB-29P boom tankers during October 1952, FOX PETER TWO moved another wing of F-84Gs from California to Hawaii and on to Japan over a similar route. After 1952, FOX PETER movements with inflight refueling across the Pacific Ocean became routine for short-legged fighter planes.



Between Travis AFB, California, and Hickam AFB, Hawaii, F-84s swarm after the booms of their KB-29 tankers during FOX PETER TWO IN 1952.

Similar fighter movements across the Atlantic Ocean quickly followed. On August 20, 1953, eight F-84Gs took off from Turner AFB, Georgia, again led by Col. Schilling; ten hours and twenty minutes, and 38,000 miles later they landed at Nouasseur Air Base, French Morocco, one of four large bases the Air Force developed in French Morocco during the early 1950s. Three inflight refuelings from new KC-97s served the fighter movement: one west of Kindley Field, Bermuda; the second between Kindley and the Azores; and the last one in the vicinity of Lajes in the Azores.

A few minutes after Schilling and his two sections took off, Col. Thayer S. Olds led twenty F-84Gs out of Turner AFB. Within eleven hours and twenty minutes, seventeen of them landed at the RAF base at Lakenheath, England. KC-97s refueled them three times: once over Boston, Massachusetts; the second time near Labrador; and the third time close to Iceland. Three of the fighters had to abort with mechanical problems at Keflavik, Iceland.

This double-barreled transatlantic movement of fighters was named Operation LONGSTRIDE. Less important as an Atlantic first by large numbers of jet fighters, the operation was primarily a test of how quickly fighters could reinforce SAC bases in Europe and North Africa. Three weeks later all the fighters flew back to Turner, again served by KC-97 tankers.

Bombers also rotated to Europe and North Africa. SAC had operated B-29s and B-50s, accompanied by their KB-29M and KB-29P tankers, from bases in England since 1948, but in the early 1950s, the B-47 was something quite different. At the end of the twentieth century, when prac-



A KC-97 refueling a B-50. A comfortable aspect of this piston-engine pair was that both tanker and receiver used the same grade of fuel. The row of bumps on the underside of the KC-97's fuselage are lights that helped the receiver fly into proper position for refueling.



When the XB-47 was rolled out of the Boeing Factory without fanfare on September 12, 1947, it was a breathtaking sight, and no one realized they were looking at a classic form. Although the XB-47 first flew on December 17, 1947, several years were needed to develop it into a weapon.

tically all airline equipment resembles a B-47, it may be hard to imagine, but in 1953 the sight of a B-47 almost overwhelmed the imagination: it was a 200,000-pound bomber that looked like a fighter; even while parked on the tarmac it seemed to be in motion; it was the United States' new *Wundervogel* and it attracted attention anywhere it touched down.

As feared, however, the aircraft was not wholly compatible with SAC's slower and altitude-limited piston-engine tankers. Fully loaded at its 175,000-pound takeoff weight, a KC-97G was hard put to reach an altitude of 20,000 feet. But a B-47's cruising altitude was 35,000 feet. For its refueling, a B-47 had to descend to the KC-97's altitude and start refueling around 18,000 feet. While the tanker got lighter, the B-47 became heavier, requiring more speed to stay in the air than a KC-97's engine could match. The result was the "toboggan" maneuver in which both airplanes entered a shallow dive, a risky descent for two very large airplanes joined by a refueling boom.

These refueling descents also were not always "blue-sky" operations. There were cloud formations, and within them unpredictable, often great turbulence. Two airplanes each weighing more than 150,000 pounds joined by forty-plus feet of ostensibly rigid duraluminum tubing do not constitute a flying machine; the Wright brothers never imagined anything like this. To be sure, no one cared for the toboggan. Refueling could end as low as 12,000 feet, after which the B-47 had to climb back to its cruising altitude—and consume as much as 50 percent of the fuel it had just taken on board.

These climb-backs cost SAC millions of gallons of fuel and millions

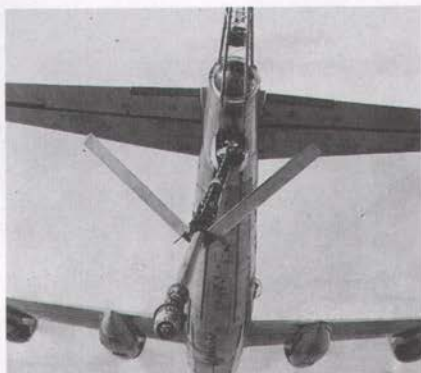
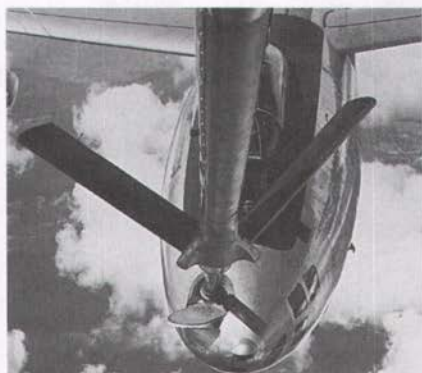


A B-47 had to fly nose up to stay with a slower KC-97, but the negative angle of this KC-97 may indicate that the tanker-bomber pair is in a shallow dive to permit the bomber to stay on the boom. With 75 percent of a B-47's fuel load distributed along the fuselage axis, fuel management was critical.

of dollars annually. More to the point, they degraded the bomber's mission. Clearly, the only remedy was a turbojet tanker that could deliver its offloads at altitudes that turbojet receivers found congenial.

During June 3-4, 1953, a squadron of B-47s led by Col. Michael N. W. McCoy flew from MacDill AFB, Tampa, Florida, to the RAF base at Fairford, Gloucester, about thirty-five miles from the west coast port of Bristol. The squadron staged through Limestone AFB, Maine. The next day a second squadron flew the same track from MacDill, and the day after that a third squadron made the trip. By June 6, the whole 306th Bomb Wing was at Fairford. Simultaneously, a squadron of KC-97s staged across the Atlantic Ocean, via Harmon AFB, at Stephenville, Newfoundland, en route to its base at Mildenhall, 100 miles northeast of Fairford. For obvious reasons, tankers were always based at some point ahead of the bombers' path to their targets. En route to Great Britain, the KC-97s served as transports, carrying extra air crew, support personnel, and spare parts.

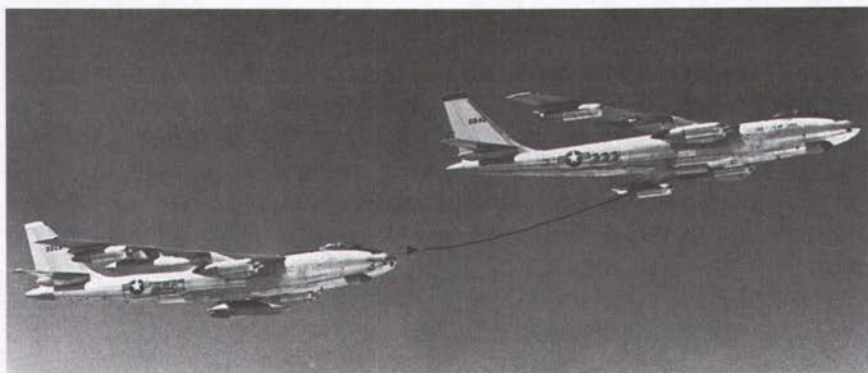
After completing a ninety-day deployment, the 306th was relieved by the B-47s and tankers of the 305th Bomb Wing, and the B-47s of the 306th flew back to Florida in spurts of squadrons. The 3,800 nm from Fairford to MacDill were flown nonstop with KC-97s providing one in-flight refueling over the Irish Sea. This was the first deployment of B-47s outside the United States, and the first of many occurring over the next five years. Until 1958, SAC kept at least one B-47 wing and its tankers in England.



The B-47's receptacle for boom refueling was in the nose (left). Struggling against the downwash of the tanker with the refueling boom swinging directly in front of the canopy made aerial refueling difficult in a B-47.

Boom Versus Probe-and-Drogue Refueling

Many hailed probe-and-drogue refueling as the system of the future. It was simpler, cheaper, and it weighed less than a Boeing boom. It imposed less aerodynamic drag on the tanker and did not require a skilled operator. The probe-and-drogue became the darling of engineers at Wright-Patterson AFB. In 1951, in an effort to demonstrate a "cheap," off-the-shelf jet tanker, Wright-Patterson engineers modified a pair of B-47Bs into an ad hoc tanker and receiver. The tanker (YB-47F) had an FRL hose-reel set; the receiver (YB-47G) was equipped with a probe. The B-47 was a good tanker. As a bomber it carried 18,000 gallons of fuel (117,000 lbs) and could carry almost 2,000 gallons more (13,000 lbs) with its bomb bay modified. SAC, however, needed *more* than just a tanker; it required a workhorse like the KC-97 that could also move personnel and spare parts to its bases overseas.



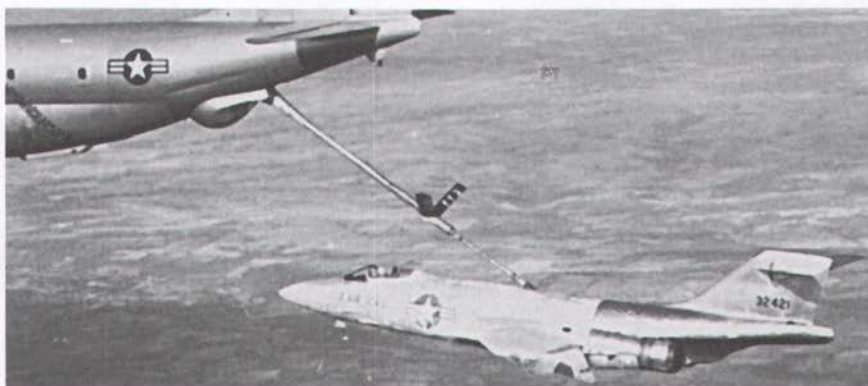
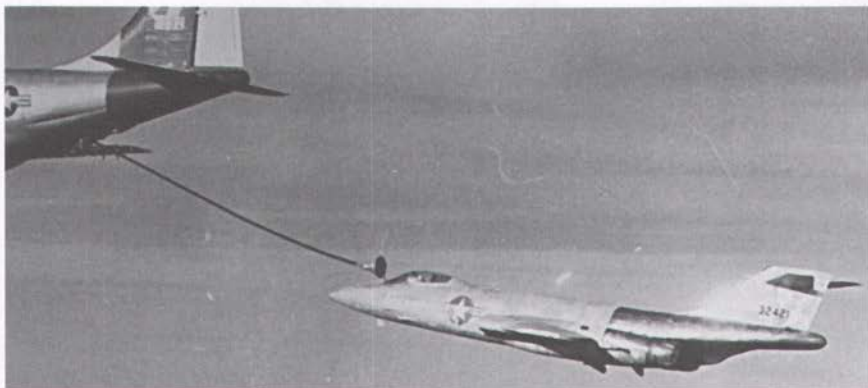
The B-47 drogue tanker refueling the B-47 probe receiver.



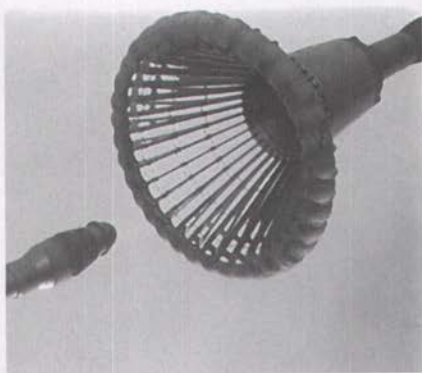
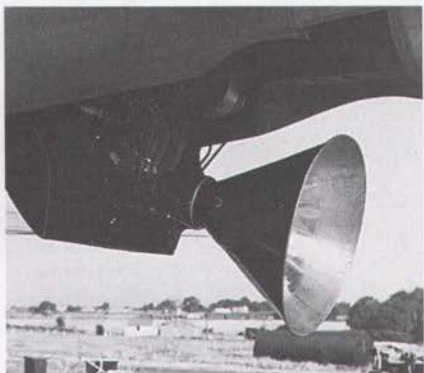
The receptacle for boom refueling could be placed anywhere on the upper surface of the receiver. It was on the fuselage behind the canopy on the RB-45 (top), and on the leading edge of the left wing on the F-84. The best position was eventually determined to be outside the pilot's vision, allowing the pilot to concentrate on the receiver's position relative to the tanker.

In any case, probe-and-drogue refueling was not beloved by SAC commander General LeMay. Probe-and-drogue involved a lot of rubber, a material that could become unreliable in the -60°F temperatures above 30,000 feet. Furthermore it seemed a bit too much to expect a tired pilot of the sluggish mass of a 200,000-pound airplane to chase through 180 degrees of his vision ahead to put a probe into the small, dancing target of a drogue's refueling basket. Further, the B-52, twice as massive at 400,000 pounds, loomed on the production horizon. Finally, the optimum transfer capacity of a probe-and-drogue system was only 250 gallons per minute, compared with the Boeing boom's 700 gpm.

During February 4-7, 1951, a fly-off between the probe-and-drogue and the Boeing boom conducted at Offutt AFB, Nebraska, produced predictable results. Pilots of small maneuverable airplanes liked probe-and-



The F-101, one of the few airplanes designed with both systems, receives fuel from KC-97s through a drogue (top) and a boom (middle). Because of the F-86's internal structure, it was not fitted for inflight refueling. This F-86 (bottom) had to have its gun radar removed to create space for a refueling receptacle. No production F-86 models were refuelable.



The early receptacle of probe-and-drogue systems was simply a funnel (left), but it was soon discovered that it flew better when holes or longitudinal slits were cut in it. The final evolution was a collapsible drogue (right), which often has small lights around it to aid night operations.

drogue; those who flew big airplanes preferred the boom. There was no decision. SAC went its own way with the boom; TAC adopted probe-and-drogue,* as did the Navy, the Marines, and some years later the RAF and the North Atlantic Treaty Organization (NATO), all of which operated smaller airplanes.

Headquarters United States Air Force finally settled this issue on July 14, 1958, when it announced that boom refueling would be standard for its airplanes. (It may not be a coincidence that this decision was made 378 days after General LeMay became Air Force Vice Chief of Staff.) The boom's incompatibility with probe-equipped airplanes was resolved in 1959 with a boom-drogue-adapter—a flexible “tassel” fitted to the end of the boom with a basket at its end to receive a probe. However, when a boom tanker had an adapter attached, it could not serve receivers fitted with a boom receptacle.

The B-52 and KC-135

The U.S. Air Force finally put the turbojet B-52 on contract in 1949 and its prototype flew in 1952, with B-52B production models delivered to squadrons four years later. The B-52 created problems for aerial refueling. A KC-97 could serve two B-47s, giving each a minimum of 26,500 pounds of fuel (22.6 percent of a B-47's full load), but a B-52B's tankage required 243,000 pounds to fill it, and a KC-97's total offload (53,000

*The McDonnell F-101A and the F-105 each had both a retractable probe *and* a boom receptacle, representing rare exceptions to “either/or.”



Creating drag to reduce speed and match that of the slower KC-97, the pilot has lowered the landing gear of this B-52. This was not a recommended procedure as the temperature at altitude could prevent retraction of the gear, which would abort the mission.

lbs), was only 21 percent of this. In other words, to achieve approximately the same delivery given to two B-47s, a minimum of one KC-97 was required for each B-52B. However, a B-52's fuel consumption was greater than a B-47's, and two KC-97s were necessary to serve one of the eight-engine giants. Additionally, there remained the incompatibility between turbojet and piston-engine equipment. This not only required basing the slow tankers about 1,000 nm ahead of their receivers and establishing a rendezvous system, but also meant the B-52 had to descend for its fuel and then expend fuel climbing back to cruising altitude.

In 1957, SAC sent three B-52Bs nonstop around the world in Operation POWER FLITE. Seventy-eight KC-97s, plus a number on alert in case of adverse wind conditions, were needed to support that operation (see Appendix 3). Data from that operation show that it took two KC-97s to guarantee one B-52B a minimum 26 percent refueling. SAC clearly needed a tanker larger than a KC-97, one with turbine engines that could cruise at the receiver's speed and altitude, but no funds existed to develop a new dedicated tanker. Boeing proposed putting turboprops or turbojets on the KC-97; the Air Force was not interested. Boeing proposed a redesign of the KC-97 with a swept wing and turbojets; again there was no interest. Some interest arose around the Douglas XC-132, a turboprop cargo plane of a nominal 389,000 pounds; but it was stillborn and, in any case, unacceptable to SAC.

Seeing the possibilities of a turbojet that would serve as a tanker, a military transport, *and* a commercial airliner, Boeing had invested its own funds to produce a prototype known as Model 367-80 in May 1952. It flew two years later on July 15, 1954. At least three other aircraft manufacturers—Convair, Douglas, and Lockheed—were capable of making a similar

speculative investment in their future, but only Boeing took the initiative.

When the 367-80 took to the air in the summer of 1954, the Air Force announced a requirement for a jet tanker and convened a design competition. Of the three companies responding, Douglas and Lockheed submitted only paper designs; Lockheed won the competition and the Douglas design was rated second best. Boeing submitted two design variants of its existing 367-80 but they came in a poor third and fourth. The Air Force, however, faced a wait of at least two years before Lockheed's marvelous paper tanker could fly in three dimensions, and four years before production models appeared in squadron numbers.

Because Boeing was far along with its prototype, Air Force leaders decided as an interim measure to procure twenty-nine of them as tankers (to be known as KC-135s). A few months later, SAC requirements demanded another eighty-eight of those interim tankers; then 118 more, and then another 157. Ultimately, Boeing delivered to the Air Force 830 KC-135 variants, 732 of them identified as interim tankers. Along the way, the service canceled Lockheed's winning paper proposal for a turbojet-powered aerial tanker.³³

It is commonly, but incorrectly, assumed that Boeing's 367-80 prototype, the KC-135, and the 707 airliner are essentially the same airplane. Aside from weights, wing areas, engines, and the host of other vital aspects of the modern aircraft, one has only to measure the width of the fuselage diameter (the "tube") to establish that the differences among the three airplanes are absolute. The 367-80 is 132 inches in diameter, the KC-135 is 144 inches, and the 707 is 148 inches. A few inches may not seem significant, but when the tube of any airplane design is altered, the change ripples through the whole configuration with explosive effects and is tantamount to building a new airplane. As a result of those and many other differences, there was less than 22 percent commonality of tooling for manufacturing KC-135s and 707 airliners.³⁴

A KC-135A could lift 31,200 gallons of JP4 (202,800 pounds of aviation jet fuel)—16,848 gallons in wing tanks, 12,178 gallons in fuselage tanks below the cargo deck, and 2,174 gallons in a tank on the tail cone's upper deck (see Appendix 4). In practice, weight limitations dictated about 5 percent less than that. Additionally, the KC-135 provided 882 square feet on its main cargo deck for transporting personnel and spare parts to SAC's overseas bases. The fuel in its below-deck tanks alone was enough to refuel two B-47Es to 33 percent and one B-52B to 32.5 percent.

A KC-135's below-deck fuel tanks, upper-deck and tail cone tanks, plus its center-wing tank, allowed it to replenish 57 percent of one B-52B's fuel, or 29 percent of two B-52Bs' fuel. The tanker did that at the bomber's operating altitude and comfortably within its speed envelope. A new refueling boom and pumping system delivered JP4 to receivers at a rate of 900 gpm.

The Air Force ultimately procured 744 B-52s and 732 KC-135s,

seemingly to have one tanker for each bomber. In the SAC alert system, that is exactly how it worked. Although KC-135s could be and often were based ahead of their B-52 receivers to refuel them at a given rendezvous, they could also take off with, fly alongside, and refuel the bomber in “buddy” fashion. Forward basing, however, continued to have distinct advantages, and at the rendezvous, the tanker had more fuel to give to the receiver than it would otherwise have had. For almost twenty years, the B-52 and KC-135 were the Castor and Pollux (twin sons of Zeus) of SAC’s nuclear deterrent system—until their exclusive mission was overshadowed by intercontinental ballistic missiles.

To ensure that its bombers could execute war plans, SAC started packing most of its tankers into the northeastern United States during the mid-1950s. Two tanker wings were created: the 4050th headquartered at Westover AFB, Springfield, Massachusetts; and the 4060th at Dow AFB, Bangor, Maine.³⁵ This was the territory of the Northeast Air Command, which reached from bases in New York State to Labrador and Newfoundland. It became known as the “Northeast Corridor.” Moreover, U.S. negotiations with Canada yielded secret air bases for SAC’s KC-97 tankers at Cold Lake and Namao in Alberta; Churchill, in Manitoba; and at Frobisher Bay on Baffin Island.³⁶



The KC-135’s original J57 engines were “smokers,” especially when water was injected to increase thrust (left). A B-52 maneuvers to connect with a KC-136 over Washington state in 1957.



In 1958 and 1959, SAC created ground and airborne alert forces of B-52s armed and ready to retaliate. The airborne alert force flew three routes: Chrome Dome, Southern Route, and Thule Monitor. In Chrome Dome, B-52s from bases in the United States flew over the Northeast Corridor to be refueled off Labrador by tankers at a rendezvous known as "Black Goat," circled across the Arctic to Alaska, where tankers out of Eilson AFB met them at a rendezvous known as "Cold Coffee," and then returned to base. The Southern Route went from the United States to a refueling over northern Spain, after which the bombers wove a path through international air space over the Mediterranean to a turnaround over the Aegean, and then returned for a refueling over southern Spain while en route to their home base. The Thule Monitor was an operation out of Thule in northernmost Greenland, where bombers seem to have circled the Polar regions, being refueled as necessary. SAC's airborne alert operated for nine years; it stood down in 1968.

At the end of 1961, the number of SAC tankers peaked at 1,095: 651 KC-97s and 444 KC-135s. This was an "air force" unto itself. In addition, the Tactical Air Command operated about 130 Boeing KB-50 tankers. The grand total was approximately 1,225 large, multiengine airplanes, all devoted to aerial refueling. The following year, at the time of the Cuban Missile Crisis, SAC's tankers included 503 KC-97s and 515 KC-135s, 1,018 airplanes—fewer total aircraft, but more jet KC-135s.

Tankers Aweigh

After 1945, the U.S. Navy wanted desperately to get into the long-range "atomic attack" business, and it seemed to have the law on its side: the Atomic Energy Act of 1946 did not permit atomic weapons to be based on foreign soil. In the early 1950s, this was changed to permit the weapon's external high-explosive encasement to be based overseas, but in the event of war the cores of fissile material would have to be flown from the United States to overseas bases where the bombs would be assembled. A Navy aircraft carrier, however, had a flag at its stern identifying it as sovereign U.S. territory.

U.S. naval leaders still recalled Britain's Royal Navy pleading with the RAF's Bomber Command in 1941 and 1942 to attack targets in France where the Germans were building huge, concrete shelters to protect their submarines at Saint-Nazaire, Nantes, and in the vicinity of Bordeaux. While under construction, these projects were vulnerable, but Bomber Command was too busy striking targets in Germany's industrial Ruhr Valley. When Bomber Command got around to attacking the U-boat shelters the cement encasing them had hardened and 2,000-pound bombs simply bounced off their roofs. The inability to destroy German U-boats in their dockyards resulted in a bitter and costly Battle of the Atlantic.

Acting as was customary for weak naval powers, the Soviets had an unusually large submarine fleet and the Navy did not look forward to engaging them in oceanic conflict. The Navy's primary targets were Soviet naval installations in the Black Sea, the Kola Peninsula near Murmansk, and ports in the Baltic Sea, as well as Vladivostok and the maritime provinces in easternmost Siberia. However, an aircraft carrier cruising the easternmost Aegean Sea could be within 1,500 nm of Moscow, and a carrier in the Barents Sea north of Murmansk could be within 1,200 nm of Moscow.

After 1949, the Navy gained the 52,800-pound North American AJ-1, its primary atomic-attack airplane through the mid-1950s. An AJ-1 was powered by two R-2800 piston engines and a single J33 jet engine in its tail. The jet engine was used only for heavy takeoffs from a carrier, evasive action in combat, and for speed over the target. An AJ-1's range was a nominal 1,500 nm; its combat radius about 700 nm. It could easily carry a Mark 5 atomic weapon (yield: 60,000 kilotons), which became available after 1952.

An AJ-1 might reach Moscow, but it would never achieve a postattack landing in friendly territory, much less return to its carrier, a consideration that promoted Navy interest in aerial refueling. More important was extending the distance of the aircraft carrier's launch point. Although interested from the time of the first Air Force experiments in 1948, the Navy did not equip its carrier airplanes for aerial refueling until 1953. As AJ-1s were displaced by improved AJ-2s, the AJ-1s became the Navy's first aerial tankers.³⁷

After 1956, the AJ-2s were displaced by the Douglas A3D, an all-turbojet airplane weighing 82,000 pounds and with a combat radius of 900 nm. With aerial refueling from an AJ-1 tanker, that radius could be extended beyond 1,400 nm. Both the AJ-1s and the A3D were large airplanes, and space on an aircraft carrier's flight deck is finite. In 1953, to relieve the Navy's carrier space problem, Douglas developed the D-704 self-contained "buddy" refueling unit—an external store that held 300 gallons of fuel, a hose-reel unit, its own pumping system, and was self-powered by a generator turned by ram air. At first glance, the unit could be mistaken for an external fuel tank, but was distinguished by the propeller in its nose that turned its generator. The D-704 became the "granddaddy" of all buddy stores.

Initially developed for the Douglas AD series single-engine attack plane, the D-704 refueler had no fuel incompatibility problems because the ADs and AJs both had piston engines that used aviation gasoline. When the A3D and A4D jets came on the scene after 1955, D-704 refueling units were assigned to the diminutive 16,000-pound A4D. (However versatile and lethal, the A4D was so small it was often called the "scooter," the "roller skate," or the "bantam bomber.")

For a long-range atomic attack mission (for example, from a launch

point in the Aegean Sea against targets in the Black Sea), two A4Ds carried a 300-gallon buddy pack on their centerline, two 260-gallon drop tanks on their wings, and 770 gallons of internal fuel, a total of 1,590 gallons for each A4D. They accompanied a third A4D carrying two 260-gallon wing tanks and an atomic bomb on its centerline. One A4D refueled the bomb carrier through the first stage of its flight, the second through the next stage, after which the bombed-up A4D flew on to its target. Using this buddy technique doubled the range of the little A4D, ordinarily 950 nm.³⁸

The best aerial tanker the Navy ever had was a modification of the Douglas A3D (after 1962, A-3)* attack plane that could lift an offload of 3,350 gallons, or 21,775 pounds. Its heyday was 1959 to 1969, including service in the war in Southeast Asia, but after retirement of the A3Ds, the offload capabilities of Navy tankers declined. In spite of Navy KA-6 and KS-3 tankers flying more than 1,000 refueling sorties during the Persian Gulf War, Navy airplanes depended on Air Force KC-135s for refueling. Somewhat more than 30 percent of the KC-135 aerial refueling in that war was performed on behalf of the U.S. Navy.

Tactical Air Command Adopts Aerial Refueling

Operation HIGH TIDE in Korea proved the overture to the Tactical Air Command's adoption of aerial refueling. With only about a dozen cast-off KB-29Ms from SAC modified with FRL and FRInc hose-reel sets, those first efforts were inevitably modest. As B-47 squadrons started to multiply in the mid-1950s, however, SAC began retiring B-50s. TAC snapped up a number of B-50Ds and TB-50Hs and modified 136 of them as tankers. The B-50D bombers, stripped of equipment irrelevant to the tanker mission, became KB-50Js. The TB-50Hs, used for training aircrews, had few military features, so their stripping was simple and less costly. They became KB-50Ks.

Both the KB-50Js and the KB-50Ks could carry 7,978 gallons in five wing tanks devoted to the tanker's own supply of aviation gas; a 2,262-gallon tank in the forward bomb bay and another 2,040-gallon tank in the rear were reserved for JP4 for offloading. This brought the total to 4,302 gallons (27,963 pounds). However, a KB-50's center wing tank could be brought into the JP4 system, a total of 5,444 gallons of jet fuel. This was enough to give a 50-percent fill-up to six combat-loaded F-100C fighter-bombers. An F-100C had space for only 1,195 gallons of internal fuel (7,767 pounds; 23 percent of its takeoff weight) and usually carried two 275-gallon drop tanks (3,575 pounds).

*In 1962, all U.S. military services began to use a common system of aircraft designation, and the Navy's existing aircraft received new designations.



A Navy F-14 with a probe refuels from a drogue at the end of a KC-135's boom.

The KB-50s had a pod with a J47-23 turbojet engine under each wing, outboard of its R-4360 piston engines. Used to boost the tanker off the ground at its 173,000-pound maximum takeoff weight, they also were useful in holding a fully loaded KB-50 at a refueling altitude of 25,000 feet. A KB-50 usually cruised on its piston engines at 230 knots, but while refueling jet fighters, the turbojets were cut in, accelerating the tanker to more than 300 knots.

The KB-50 modifications took a page from the YKB-29T "triple nipple" that FRL and David Schilling put together in England in 1950 and subsequently employed in Operation HIGH TIDE. In addition to an FRInc A-12B-1 hose-reel unit in the tanker's tail there was one in a pod at each wing tip. Each hose-reel unit deployed seventy-five feet of hose. While pumping to three receivers at the same time, the system delivered about 285 gallons per minute. An F-100C taking a 50-percent load might be on the hose for as long as seven minutes.³⁹

The KB-50s multiplied TAC's mobility. With tankers temporarily based at Kindley Field, Bermuda, and at Lajes, transatlantic fighter deployments to NATO bases in France and West Germany became routine and spared them the many problems involved with hippety-hopping through Labrador, Greenland, and Iceland. The tankers followed their receivers to the destinations in Europe, where they were put on alert or otherwise remained available to serve local exercises. The same became true of transpacific movements to Japan and Okinawa, with tankers operating from Hawaii and Wake Island.

In 1957, TAC received its first McDonnell F-101A, another SAC cast-off. For almost a decade after World War II, the Air Force sought to develop an escort fighter for its long-range bombers. The Bell XP-83, the Convair XP-81, the McDonnell XF-88, and the Lockheed XF-93, so-called "penetration" fighters, were tried; they were all disappointments. None had a combat radius that would take it from West Germany to Moscow and back. With the F-101, SAC gave up, and TAC took over the project. The F-101 was less a fighter than an attack plane, a platform for



A TAC KB-50 trails three drogues for refueling. An RF-101 is connected (left), while a B-66 (center) and a F-100 (right) move up to connect.

delivering a nuclear weapon. In its RF-101 photoreconnaissance version, however, the airplane proved to be a magnificent performer.

TAC worked out a system for F-101Cs to operate in pairs. One airplane carried a “dial-a-yield” nuclear weapon (ten to seventy kilotons), and the other carried a buddy-pack to refuel the bomber, whose normal radius of 690 nm could be extended to 900 nm. From bases in West Germany this radius would include most of western Russia. The idea of “every fighter a tanker; every fighter a bomber” was carrying TAC’s mission of battlefield interdiction a bit too far, treading as it did on SAC’s turf. TAC received only one wing of F-101Cs.

TAC’s KB-50s had relatively short careers. The first were not delivered to the command until early 1958, and by 1964 most had become part of the Far East Air Forces (later Pacific Air Forces), where they showed signs of corrosion and structural fatigue. In 1965, the last KB-50s were taken out of service. Too risky to fly transpacific to the boneyard at Davis-Monthan AFB, Arizona, they were scrapped where they stood on their hardstands at Yokota, Japan.

Tension between TAC and SAC over wartime missions existed throughout the Cold War. Although it went unstated, SAC leaders felt that if deterrence failed and its bombers had to execute their mission, anything TAC might do would be superfluous to the war’s outcome. Inevitably, TAC officials took an interest in the KC-135 to refuel its fighter-bomber aircraft, but the KC-135 was too large for the relatively short runways at TAC bases.

SAC, TAC, SIOP, and Tankers

By the end of the 1950s, SAC’s deterrent force consisted of manned bombers and a small but growing force of intercontinental ballistic mis-

siles (ICBMs). The U.S. Navy, however, was beginning to field Polaris ballistic missiles launched from submarines. In October 1960, the submarine *George Washington* with sixteen Polaris missiles on board sailed on its first war patrol.

A few months earlier, in June 1960, President Dwight D. Eisenhower ordered the services together to create the Single Integrated Operational Plan, known as the SIOP (pronounced "sigh-op"). It eliminated target redundancies and rationalized the targeting of nuclear weapons, specifically strategic missiles. The SIOP was coordinated with SAC's bomber force, tactical theater forces, and forces launched from the Navy's aircraft carriers. Equally important, it called for annual analyses and updating of this targeting system. To prevent its own airplanes from being caught on the ground in a Soviet surprise attack, and to execute the SIOP, SAC forces drilled incessantly to be ready to go to war on ten minutes' notice—not to prepare for war, but to go to war.⁴⁰

Aerial tankers represented a vital component of the country's nuclear deterrent forces, and SAC was not inclined to let other commands impose on aircraft that it needed to execute the SIOP. Nevertheless, TAC had a legitimate need of aerial refueling as well and time was running out for its KB-50s. Some accommodation was necessary. On November 17, 1961, Headquarters USAF designated SAC as the single manager of KC-135 refueling operations, responsible for supporting fighter aircraft assigned to TAC and all other major commands. At that moment, SAC had 1,095 tankers in the refueling force, its peak strength. The KC-135's future strength was established as 640 airplanes (thirty-two squadrons), and their scheduling would be arranged so that 70 KC-135s (about three squadrons; one wing) were always ready to meet TAC's needs.

Throughout the war in Southeast Asia (1961-75), SAC retained control of its tankers. After 1974, the Military Airlift Command developed a frequent need for aerial refueling and it relied on SAC tankers. Almost to the day SAC passed out of existence, May 31, 1992, it retained control of the nation's premier aerial refueling force. A partial exception occurred with Operations DESERT SHIELD/DESERT STORM, but that was in 1990-91, after the Soviet Union had collapsed internally in 1989.

In Europe: NATO and Others

After World War II, Air Force efforts to develop a medium bomber quickly focused on one aircraft, the Boeing B-47. The British developed three bombers of similar weight and performance capabilities, each powered by four turbojets, the so-called "V" bombers—the Vickers Valiant, a 140,000-pound airplane of rather conservative design that first flew on May 18, 1951; the delta-wing Avro Vulcan, weighing 220,000 pounds, which first flew on August 30, 1952; and the Handley Page Victor,



Because of the delta wing's large flat area, the high angle of attack at which it had to be flown at slow speeds, and its high stalling speed at any altitude, a B-58 required maximum pilot skill to bring it to a refueling boom and keep it there.

216,000 pounds, with an unusual, complex, three-step swept wing that decreased in sweep toward the tip, which flew on December 24, 1952. All had performances similar to the B-47. The British tested their first atomic bomb on October 3, 1952, after which they all eventually became "atomic capable."

Great Britain is only 1,550 nm from Moscow—within the range, if not the combat radius, of the V bombers—and there seemed small reason to pursue aerial refueling. In 1959, after Vulcans and Victors had clearly displaced the Valiants as first-line bombers, early-model Valiants were converted to tankers to serve the Vulcan and Victor bombers using FRL's hose-and-drogue system. After Valiants were introduced to low-altitude operations in the 1960s, however, fatigue cracks began to appear in their wingspans and by 1965, they were all retired from service. Their role was quickly taken over by the conversion of early-model Victor bombers into tankers.

The first Victor tankers had two-point refueling, with an FRL hose-and-drogue unit beneath each wing. After 1965, later Victors had an additional unit installed beneath their fuselages, thus making them three-point tankers. Initially created as bombers, the Victor tankers already had probes for receiving; once converted, they could both give and receive. This double-duty outfitting permitted relay refueling in which two or more tankers could accompany a receiver to give it maximum range, with the tankers topping off one another en route. Some years later, the Vul-

cans, too, were converted from bombers to tankers, and they also had that double-ended capability.

After 1964, the RAF acquired a few of the Vickers VC10 series, former airliners of 322,000 pounds. As transports, they were modified to be receivers for inflight refueling. Later yet, they were modified into tankers and had double-ended fueling capability. In the spring of 1982, this feature delivered an unanticipated payoff for the RAF in the Falklands War with Argentina: refueling in relays. The RAF's nearest base of operations was Ascension Island, about 4,000 nm to the northeast. Most of these RAF tankers, plus Lockheed L-1011 Tristar airliners converted to double-ended tankers, flew in the Persian Gulf War of 1990-91. The U.S. Air Force first exploited the versatility of the tanker-receiver by designing that feature into the Douglas KC-10, which began to be delivered in 1981.⁴¹

Elsewhere, on February 13, 1969, near Reggane in the Algerian Sahara, the French tested their first atomic bomb. Concurrent with the bomb's development was a decision that France should have an independent nuclear deterrent—a *force de frappe* (striking force). The delivery vehicle was a Dassault Mirage IV; a force of 50 was to be built. It is 1,325 nm from the Place de la Concorde to Red Square and, although the Mirage's 1,550-nm range would take it to Moscow, it would not get its crew



An RAF Lockheed L-1011 Tristar tanker trails a refueling drogue for Jaguar fighters. The probe over the nose allows the Tristar to be refueled in flight.

back. One refueling, however, transformed the Mirage into a credible threat with a range of 2,975 nm.

The French needed a means of range extension, and they convinced the United States to sell them twelve Boeing KC-135s. Delivered in 1964, those airplanes became known as C-135Fs. Little more than a year later, on March 7, 1966, French President Charles DeGaulle announced France's intention to withdraw from NATO and ordered all elements of NATO removed from French soil by April 1, 1967. The *force de frappe* now became even more independent. Although pathetically small by SAC standards, the French independent *force de dissuasion* (deterrent force) served Gaullist notions of grandeur and gave the Soviets one more thing to worry about.⁴²

In the 1990s, eleven of the original C-135Fs were still operating, albeit modified with CFM56 engines, and some of them participated in the Persian Gulf War.

The War in Southeast Asia

After 1847, when Americans visited the Halls of Montezuma, the foreign wars of the United States have involved great distances. It is more than 2,100 nm from Travis AFB, east of San Francisco, to Hickam AFB, Hawaii; another 5,040 nm to Andersen AFB on Guam; and then 2,241 nm to Tan Son Nhut airport at Saigon, capital of the Republic of South Vietnam—in sum, 9,391 nm. At 500 knots this involves eighteen hours and forty-three minutes of nonstop flying time, assuming no headwinds. For twelve years, however, there were nothing but headwinds of every description.

All fighter-bombers that moved from the United States to Southeast Asia over those 9,400 nm required aerial refueling. Even B-52s needed a precautionary fill-up between the United States and Guam. A final leg to the transpacific journey involved flying 626 nm between Saigon and Hanoi, the capital of North Vietnam, where a Communist regime was dedicated to overthrowing the government of South Vietnam by means of guerrilla warfare and to unifying the country.

U.S. airmen first tasted this warfare on November 1, 1964, shortly after the United States' overt intervention in the conflict. Communist guerrillas attacked Bien Hoa, only twenty miles northeast of Saigon. That night attack destroyed five Martin B-57 bombers and damaged thirteen others; one helicopter was destroyed and a half-dozen others damaged. Four Americans were killed. Clearly, multimillion-dollar airplanes were no match for mortars and satchel charges. The Bien Hoa episode inspired the Air Force to base large, conspicuous, and expensive airplanes elsewhere.

Eventually, the U.S. air war against North Vietnam was conducted from three points: bases in Thailand, Navy aircraft carriers, and Andersen AFB on Guam, becoming the "first tanker war." SAC's refuelers were

based at Kadena on Okinawa, at Clark Air Base in the Philippines, in Thailand, and later at Ching Chuan Kang on Taiwan.

The United States initially conducted the air war against North Vietnam with Republic F-105Ds, sleek twenty-six-ton airplanes capable of limited supersonic cruising. The aircraft was designed to fly at subsonic speed to a target somewhere in eastern Europe and dash in at supersonic speed to deliver a nuclear weapon. To accommodate the nuclear weapon, the F-105 had an internal bomb bay, an odd feature in a fighter. In Southeast Asia, however, an F-105's load of conventional "iron bombs" had to be carried externally—gaggles of 750-pound bombs on multiple ejection racks. These loaded racks increased the aerodynamic drag of the airplane enormously, by at least 50 percent and probably more, and correspondingly decreased its range.

The F-105s were based at Takli and Korat in central Thailand, about 475 nm from Hanoi. The nominal radius of an F-105 was 650 nm, but the F-105s did not fly an "airline" track to their targets, and with all that ordnance hanging under their wings, their operating radius markedly declined. En route to Hanoi and its environs, they had to be refueled simply to return to base; and after taking evasive action in the target area, going to afterburner for too many minutes, fighting enemy MiG interceptors, and getting holes shot in their fuel tanks, poststrike refuelings were also necessary.

By 1968, the U.S. Air Force had lost about 350 F-105s in operations and replaced them with McDonnell F-4 Phantoms. In its time, the F-4 became a fighter *sans pareil*; before the F-4 series went out of production around 1980, more than 5,000 were produced. As an attack plane, the F-4 suffered from all the limitations of the F-105. By rule of thumb since 1915, the internal fuel of any fighter plane at any point in time is something less than 25 percent of its nominal maximum takeoff weight. A requirement for more fuel involves strapping on external fuel tanks. If that is not enough, inflight refueling is necessary. Like the F-105D, the F-4 had to be refueled en route to the target, and poststrike refueling was usually necessary as well. Because it was a Navy airplane, the F-4 was originally equipped for probe-and-drogue refueling; the F-4C variant developed for the Air Force was plumbed with a boom receptacle.

The Navy did its own refueling with Douglas KA-3 tankers and later with Grumman KA-6 tankers. Strike forces launched from aircraft carriers in the Gulf of Tonkin were accompanied by tankers for a final refueling before they went to the target. Tankers were held in standby orbits for attackers returning from the target, and a tanker was always in orbit over the aircraft carrier in the event a returning airplane, almost out of fuel, missed its "trap" and had to circle for a second attempt at landing.

Air Force tankers also operated over the Tonkin Gulf area, and from time to time, KC-135s refueled hard-pressed naval aviators. Because Air Force tankers were not supposed to refuel other airplanes, these acts of



A formation usually refueled from left to right; here the first of four Republic F-105 Thunderchiefs en route to North Vietnam in 1965 takes on fuel from a KC-135 (top) and the second of four McDonnell Douglas F-4 Phantoms, also armed for a mission over North Vietnam in 1965, is connected to a KC-135.

charity often had to be concealed by the KC-135 crew that did it, normally by “cooking the books” about their offloads.

On April 31, 1967, a classic KC-135/Navy refueling occurred over the Gulf of Tonkin, where a KC-135 was stationed to serve F-104s providing cover for an ongoing air strike against the Hanoi-Haiphong area. The F-104 was a probe-equipped aircraft, so the KC-135 trailed a boom-

drogue adapter. In a saga of aerial refueling, this KC-135 replenished two Navy KA-3 tankers, two Navy F-8s, and two F-4s returning from the strike, in addition to its F-104s. While it was pumping fuel to one of the KA-3s, the F-8 fighters came on the scene, desperate for fuel. The KA-3 reeled out its hose for them. For a few minutes a K-135 was refueling a KA-3, which at the same time was refueling F-8s—a trilevel refueling.

Without the service from this obliging KC-135, the Navy airplanes probably would not have reached their carrier. When it was finished, the KC-135 did not have enough fuel to fly back to its base in Thailand and had to put down at Danang on the coast of South Vietnam. There was no way to alter the records, and the small F-104s simply could not have absorbed all that fuel. Moreover, landing a conspicuously large airplane at Danang was forbidden. Danang was surrounded by an amorphous corps of Vietnamese Communist guerrillas, and a parked KC-135 was a magnet for mortars and 57-mm recoilless rifles.

There were Air Force rumblings about a court martial for the KC-135 commander and reprimands for his crew. When word of a possible court martial trickled back to the Pentagon, Navy officials let it be known that the KC-135 crew might be eligible for the Navy Cross, ending talk about disciplinary action. Finally, this KC-135 crew received proper credit: the Mackay Trophy, an award dating back to 1912 and given for the most extraordinary aerial flight of the year; this was the first time a tanker crew had been so honored.⁴³

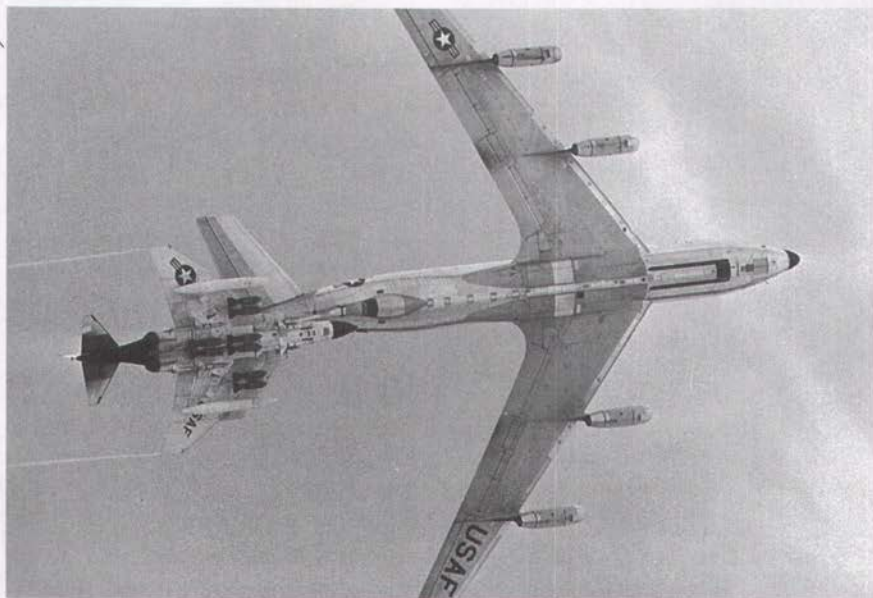


The crew of the KC-135 in the trilevel refueling demonstrate it with models representing the aircraft involved: a KC-135 refueling a KA-3, which was delivering fuel to an F-8. The fourth model is that of an Air Force F-104.

Saving six Navy airplanes was a dramatic but small episode in a long series of similar events that occurred across a decade. KC-135s occasionally flew leaking fighter planes back to their bases attached to their refueling booms, meanwhile pumping enough fuel to keep the fighter's engine barely running. The KA-3s did the same for Navy fighters and attack planes, leading them at the ends of their refueling hoses. This practice soon was called "wet-winging" it.

Those saved were invariably fighters or attack planes returning from North Vietnam's Red River Valley, aircraft that had expended too much fuel in evasive action or on afterburner, or were full of holes and leaking fuel. Hearing their cries on the radio, KC-135s rushed north to their assistance, often into hazardous airspace where the rules said that the big and vulnerable birds were not supposed to go. This generally was done in a moment's silent conspiracy with Ground Control Intercept operators who had both tanker and receiver on their radar scopes and brought the two together in minimum time. Fearful of official reprimands, or worse, many such saves went unrecorded.

Still another operation involved B-52s from Andersen AFB, Guam, which flew about 2,500 nm to drop their bombs on targets along the border between South Vietnam and Laos, where North Vietnam was using a series of primitive jungle roads to support its covert armies in the south. B-52s, in a controversial "secret" operation hit targets in ostensibly neutral Cambodia and flew their loads "on call" during special situations.



The lights that guide a pilot into the proper position for refueling appear as small squares on the fuselage just behind the wing on this KC-135.

Taking off with maximum bomb loads, the B-52s required inflight refueling en route to their targets. This was done at a rendezvous over the South China Sea, the KC-135 tankers usually coming from Kadena on Okinawa. After refueling the B-52s, the tankers flew south to Clark Air Base in the Philippines, a distance of about 750 nm. At Clark, the KC-135s refilled their tanks and took off to meet the returning B-52s, refueling them en route to Guam, approximately 1,400 nm eastward. Later, refuelings from Clark were changed to a new base at Ching Chuan Kang near the port of Kaoshiung on Taiwan. These operations, with some variation in details, went on regularly for nine years.

In the course of the war, KC-135 tankers flew 194,687 sorties, averaging 21,631 sorties per year. They executed 813,378 inflight refuelings, an average of 90,375 per year, 7,531 per month, 251 per day. Total flying time was 911,364 hours, an average of 10,126 hours annually, 8,438 hours each month. In total, they delivered almost 1.4 billion gallons of fuel weighing almost 9 billion pounds.⁴⁴ All of this transpired "invisibly." The news media rarely paid any attention to tanker aircraft; its representatives only saw the big refuelers parked on the ground and, to the extent that they thought of them at all, assumed them to be part of the landscape.



View over the right shoulder of a KC-135 boom operator as a B-52 armed with bombs for a mission over Vietnam approaches for refueling. The B-52's open refueling receptacle can be seen just to the right of the boom.

Refueling Helicopters

From its inception, the helicopter was a severely range-limited aircraft. The Sikorsky R-4, the first operational helicopter of the U.S. military, was a charming little machine of 2,020 pounds that had an operating radius of sixty statute miles. In any vehicle that lifts its own weight directly off the earth, weight is worse than critical—it is *everything*. Fuel is range, but fuel quickly adds up to lots of weight.

The French, from 1954 to 1962, in a futile effort to put down an Arab insurrection in Algeria, demonstrated how the helicopter could give an army mobility in the field and be used offensively against guerillas. However, the U.S. Army's intensive development of the helicopter from 1955 to 1965, accelerated by the war in Southeast Asia, transformed rotary wing aviation into a massive assault vehicle.

Nonetheless, military aviators, from the very beginning of rotary wing aviation, viewed the helicopter as an instrument to rescue people from predicaments with difficult access. From the first covert U.S. intervention in the affairs of South Vietnam and Laos in 1962, downed airmen needed rescue. This meant helicopters, and the effort quickly grew to more than just rescue. It meant dashing in to snatch these airmen out from under the guns of the enemy, being shot at, and shooting back. These circumstances generated requirements for range extension and an expanded loiter time. Helicopter advocates faced the same problem as their Aircraft and Weapons Board counterparts in 1947: either build a ridiculously large and hopelessly conspicuous flying machine, or go to inflight refueling.

In 1964, the Air Rescue Service submitted a requirement for the aerial refueling of helicopters; the Air Force acted on it the next year. Engineers at Wright-Patterson AFB, Ohio, believed that the aerial refueling of helicopters would be extremely hazardous, with all those whirling, delicate blades. Fearing that if the helicopter approached the tanker in the usual mode, the tanker's downwash would wreck the rotor blades, they recommended that the helicopter trail the drogue and the tanker plug into it and then pump its fuel up to the helicopter. A few others, however, thought differently.

Downwash is *down-wash*; it flows off the airplane in great, turbulent waves, but dissipates downward and outward. The Navy's Sikorsky SH-3 helicopter was amphibious and, being designed to alight on water, it had a boat hull—complete with a keel and chines. The dissenters thought an SH-3's hull had the stability to *ride* the waves of a downwash's turbulence. It was a good point of argument.

In U.S. Air Force parlance, an SH-3 was a CH-3. One was obtained and fitted with a long, dummy fuel probe. The KB-50s were gone, the Air Force had no more probe-and-drogue tankers, so an appeal was made to the Marines for use of one of their Lockheed KC-130s. In the 1950s, the Marines had developed a system for helicopters to refuel one another, but



An HC-130, trailing two drogues, refuels an HH-3 over the Gulf of Tonkin.

helicopters were so weight limited that the offload was negligible. However, if this Air Force idea worked, it would be useful to the Marines and they gladly cooperated. The CH-3 was flown to the Marine base at Cherry Point, North Carolina.

On December 17, 1965—the sixty-second anniversary of the Wright brothers' first powered flights at Kitty Hawk—the helicopter flew in behind the KC-130 and, as predicted, rode the tanker's downwash and propeller turbulence as neatly as a California surfer rode the Pacific's waves. The KC-130 reeled out a drogue and the CH-3 plugged in. No fuel could be taken, but the flight and its experiments continued without incident. The date of December 17 was doubtless coincidental, but this flight was the Kitty Hawk of helicopter inflight refueling. In that moment, not only had air rescue operations been revolutionized, but so had the general scope of helicopter operations.

It took six months to convince the doubters, but after that, things moved quickly. Lockheed was ordered to convert eleven C-130s into tankers capable of a 7,461-gallon offload (48,500 pounds). The C-130s became HC-130Ps; six were delivered in late 1966 and the remainder in early 1967. Training began at Eglin AFB in Florida, and on December 14, 1966, the first fuel transfer was made from an HC-130P to an HH-3E helicopter.

Six months later, two HH-3s took off from the Naval Air Station at Floyd Bennet Field, Brooklyn, New York, and flew 4,157 miles nonstop to the Paris Air Show, where they landed on the third day; average speed, 113 knots. En route refueling was provided by five HC-130P tankers. After a few days in Paris, they continued flying eastward halfway around the world to South Vietnam, where they were soon being shot at while rescuing downed airmen. Because of the colors in which it was painted, in Vietnam the nine-ton HH-3 became known as the "Jolly Green Giant."⁴⁵

In the course of the war, the helicopters and crews of the Air Rescue Service picked up 3,383. It is doubtful that score would have been what it was without inflight refueling extending the range and expanding the endurance which was necessary for so many successful executions of the mission.⁴⁶

The U.S. Navy, Marines, and Coast Guard quickly adopted inflight refueling for helicopters built for rescue work and special missions. Although the U.S. Army operates the largest fleet of helicopters in the world, it has little use for aerial refueling because battlefield distances are relatively short. However, the Army Special Forces, which fly unusual distances to do unusual things, invariably have a refueling probe on their helicopters.

Moments of Truth

On October 6, 1973, Egypt and Syria launched a surprise attack on Israel, and within a few days, it became apparent that this was a war Israel might lose. When the Soviets mounted an airlift to resupply the aggressors with key weapons, U.S. President Richard Nixon ordered an American resupply of Israel by sea and by air, but only the airlift would be timely.

Concurrently, the Arab oil-producing nations, acting in support of Egypt and Syria, imposed a petroleum embargo on nations assisting Israel.⁴⁷ Absolutely dependent on Mideast oil, western Europe was alarmed. The United States' NATO allies quickly decided that an Arab-Israeli war had nothing to do with NATO, and the U.S. Air Force was denied use of bases in western Europe if those bases were to be used to support Israel. This was a bitter reminder of a truism that American naïveté dislikes: "Nations cannot have 'friends'; they can only have interests." Petroleum was no longer simply the lifeblood of war; it had become the daily lifeblood of nations, and keeping it flowing was in everyone's interest.

In 1973 only Portugal allowed the United States to use facilities (Lajes field in the mid-Atlantic Azores). Portugal was then fighting a costly and reprehensible colonial war in its African colonies in a clearly futile effort to retain control of Angola and Mozambique. The United States threatened Lisbon with complete diplomatic isolation if it was not agreeable to the use of Lajes. Stories circulated of the Central Intelligence Agency organizing an Azorean Liberation Committee among Portuguese immigrants in Rhode Island, and of a possible independent "Azorean Republic."⁴⁸

For almost twenty years after World War II, the U.S. airlift capability, as institutionalized first in the Military Air Transport Service and then in the Military Airlift Command (MAC), depended on equipment developed for airlines: Douglas DC-4s and DC-6s and Lockheed L-49s and L-749s of the Constellation series. In the mid-1950s, the Air Force started acquiring Lockheed C-130s, but they were not designed to be intercontinental load carriers. An effort to acquire the turboprop Douglas XC-132 as a

heavy airlifter ended in frustration, and the turboprop Douglas C-133 proved a disappointment.

The Air Force tended to frame the range requirement for large transport planes in terms of straight-line distances, and 4,000 nm was a "magic number." It is about 3,390 nm from McGuire AFB, New Jersey, to Rhein-Main, Germany; a nonstop still-air range of 4,000 nm would accommodate headwinds and do nicely. And payloads could be increased by refueling at Newfoundland or at Lajes on the island of Terceira in the Azores. However, it is about 5,000 nm from McGuire to Tel Aviv, Israel, not considering headwinds. Furthermore, some flights would originate from other bases in the United States, making for a maximum distance of 6,450 nm.

The U.S. Air Force had two primary instruments of airlift in 1973, both built by Lockheed: the intercontinental C-141A and the gigantic C-5A. The C-141 weighed 323,100 pounds and was capable of carrying thirty-one tons over a distance of 3,600 nm; the C-5 was nominally a 769,000-pound aircraft, but it had a flawed wing that substantially reduced its loaded weight. The C-141A had been put on contract in 1961; it flew in 1963 and 268 were procured, but it had no provision for inflight refueling. The C-5A was put on contract in 1965, first flew in 1968, and its design included a system to receive inflight refueling. Its wing flaw resulted from a peculiarly ideological approach to contracting that was adopted by U.S. Secretary of Defense Robert S. McNamara. Although more than one hundred C-5As were initially planned, only eighty-four were procured.⁴⁹

In theory, the C-5A had a life of 30,000 flying hours; in fact, its flawed wing reduced this to a dismal 8,000 hours, thus making flying time



In August 1969, in the vicinity of Edwards AFB, the test facility's KC-135 flies the first boom connections to a C-5A. The great mass of a C-5 creates a huge bow wave that tends to push away the tanker, a factor that has to be considered in the refueling of such a large airplane.

precious and requiring that it be rationed. Although a C-5A was supposed to lift sixty-two tons some 6,900 nm, the reality was fifty tons over 5,800 nm. Except in emergency operations, payloads were restricted to twenty-five tons. The C-5A had been plumbed for inflight refueling, but because of the weak wing, it was feared that flying at an abnormal angle of attack in a tanker's downwash would contribute further to loss of wing life, and aerial refueling was not done in Military Airlift Command operations.

A C-5A could fly nonstop from McGuire AFB to Tel Aviv with a reduced payload; for a C-141A, any payload was out of the question. It is 2,180 nm from McGuire to Lajes, and a further 3,070 nm to Tel Aviv. Even this staging involved reduced payloads, compared with what would have been possible with inflight refueling, in which case the material could have been delivered with fewer flights (see Appendix 5). Starting on October 14, 1973, the Israeli airlift went on for thirty-two days. C-141As flew 421 missions and delivered 11,632 tons; C-5As flew 145 missions with 10,763 tons. A resupplied Israel finally turned the war around and fought it to the edge of victory; the war ended in a cease-fire.

U.S. leaders could take heart at this outcome, but the airlift to Israel produced a few sobering moments of truth. The United States could not always depend on its NATO allies; it needed an airlift capability independent of European bases, one it could deploy unilaterally; the Air Force had to replace the C-5A's "McNamara wing"; and the Military Airlift Command had to get on board with respect to inflight refueling. Shortly thereafter, MAC directed SAC to cycle 72 C-5A crews through training to qualify them for inflight refueling. Studies were prepared for adding an aerial refueling capability in C-141As.

From 1976 to 1981, C-141As were retrofitted for inflight refueling and their fuselages were stretched some twenty-three feet to increase their cubic capacity. After completion, they were redesignated C-141Bs. Almost concurrently, eighteen C-5As a year started to be cycled through the Lockheed factory for new wings; they emerged as fully capable 769,000-pound airplanes. Lockheed, between 1986 and 1989, delivered fifty new C-5Bs, 837,000-pound airplanes capable of carrying a 145-ton payload over an unrefueled 2,950 nm. With tanker support, the C-5B could fly this load anywhere. On the eve of the Persian Gulf War in 1990, MAC had, for all practical purposes, a wholly new fleet and all of it air refuelable.

June 1973 also marked the fiftieth anniversary of the first aerial refueling efforts at Rockwell Field; it passed with scant notice. In England on October 21, while the airlift to Israel was under way, Sir Alan Cobham, the progenitor of inflight refueling, died at age 79. Although he always believed aerial refueling had great utility for commercial aviation, that was not to be. His name is still prominent in the realm of aerial refueling. A quarter of a century after his death, the company he founded, Flight Refuelling Limited, has grown into Cobham Plc., an engineering organization of which aerial refueling has a part. In 1948, the U.S. Air Force purchased forty



The nose of the refuelable C-141-B. The large hump on top of the fuselage houses the refueling receptacle, and the spine leading from it carries the plumbing that connects the receptacle to the fuel tanks inside the aircraft.

looped-hose sets from Cobham (some of which helped the *Lucky Lady II* fly around the world in 1949). One must wonder if he could have foreseen that this small start would grow into the vast military aerial operation it has become.

The Aerial Refueling Systems Advisory Group

As a result of its position as the Air Force single manager of KC-135 in-flight refueling operations, SAC, at the end of the 1970s, was doing almost as much refueling for the Navy, Marines, and allied air forces as it was for itself. Concurrently, KC-135s were being transferred to Air Force Reserve units and to the National Guard. All the while, calls for inflight refueling services were increasing.

SAC's mission remained nuclear deterrence, not pumping gas for every pilot who popped out of a cloud, looking for fuel and carrying a DOD credit card to pay for it. Nevertheless, by 1978, almost 40 percent of SAC's refueling was provided to aircraft not operated by SAC. Moreover, these increasing numbers of customers were outfitted with probes rather than boom receptacles. Unwilling to relinquish control over aerial refueling, yet having more and more to do with other services and their refueling problems, in March and June 1978 SAC leaders convened meetings of service representatives and civilian engineers at Offutt AFB, hoping to create regular forums to identify significant problems in aerial refueling and work toward their resolution. This was the beginning of the Aerial Refueling Systems Advisory Group (ARSAG).

ARSAG's first formal meeting convened at Wright-Patterson AFB, Ohio, on June 28–29, 1978. The principal subject was the MA-3 refueling probe nozzle. This topic may not sound very exciting, but over the years, probe nozzles had caused too many undesirable “thrills” for pilots. If the probe could not connect for refueling, the receiver's crew was put at risk, and there were occasional losses of expensive airplanes. Other ARSAG subjects included pumping systems, surge protection, the handling of different fuels, pressure regulation, and standardization wherever it could be achieved. After 1978, ARSAG met on an ad hoc basis one or more times a year until 1991, when the meetings became annual events. Prior to ARSAG's creation, aerial refueling was an arcane topic on which people worked separately in their own discrete corners, almost oblivious to what was going on elsewhere. Within the realms of operations, design, manufacturing, and the integration of systems, ARSAG brought much-needed illumination and focus to the problems of inflight refueling.

Aeronautica Geriatrica

When the KC-10 tankers first entered the Air Force inventory in the early 1980s, the KC-135 fleet was growing older. The life of an airplane is less a matter of years per se than it is hours of flying time and the number of flight cycles measured in landings. Not only is the cabin shell put under stress from being pressurized and depressurized, but landings are hard on an airplane—its wings are deflected downward and the thumping of landing gear on concrete is a jolt to the whole aerostructure. The intensive operations of the war in Southeast Asia put the KC-135 fleet through a lot of flight cycles that were not anticipated prior to 1965.

All SAC operations that served the nuclear deterrent mission were carefully structured. The tankers took off, flew to a rendezvous with their bomber receivers, and performed refuelings, ordinarily at 30,000 feet or more while flying straight and level. With the refueling finished, the tankers returned to base. To be sure, SAC flew lots of training exercises and the airborne alert forces had to be served daily, but tankers spent most of their time parked on ground alert, waiting for the Emergency War Order that everyone hoped would never come. Like carefully groomed aerial racehorses, they waited for the bugle to blow on race day. The war in Southeast Asia changed that; SAC's racehorses became workhorses, having to earn their keep every day.

Refueling an outbound attacking force was a straightforward, orderly operation, but serving a returning force was often chaotic. As drawn on paper, oval refueling tracks are smooth and tidy, but the refueling of a dispersed returning aerial force involves a lot of zigzags—especially when trying to rendezvous with a solitary and crippled craft among the clouds over Laos. Refueling was often done while jinking through cloud canyons

and around thunderstorms, in the dense air at lower altitudes. Additionally, the tankers based in Thailand were exposed for months to tropical heat and humidity that diminished the longevity of their systems. It all added up to accelerated wear and tear on these airplanes. SAC crews were rotated to Southeast Asia on 179-day tours; SAC's KC-135s also rotated, but in an order relative to their flying times and flight cycles so as to carefully distribute attrition of the airplanes.

In 1976, the newest KC-135s were eleven years old and the oldest had twenty years of service. Many had been flown long and hard beyond the planning estimates made in the 1950s, and the refueling fleet was starting to fly into the realm of *aeronautica geriatrica*. Furthermore, after almost twenty years, some aspects of the KC-135 had slipped far behind the times on points of technology. When it was built in the late 1950s, the U.S. Air Force had specified a new, strong, and lightweight aluminum alloy, which now was showing signs of embrittlement and, after many flight cycles, was developing hairline cracks. In 1977, the Air Force began reskinning KC-135 wings with the heavier and more durable alloy that Boeing routinely used on 707 airliners. This was done when an aircraft reached 8,500 flying hours; Air Force officials estimated that the reskinning added some 18,000 flying hours to an airplane's life.

In 1979, SAC began replacing existing KC-135 engines with CFM-56 turbofan engines, a new, top-of-the-line, clean-burning engine with maximum fuel efficiency. The J57, a great engine when introduced in the late 1950s, produced 13,700 pounds of thrust, while the CFM-56 produced approximately 22,000 pounds, an increase of almost 40 percent, along with improved specific fuel consumption. With increased performance, the CFM-56 engines transformed the KC-135 into a new airplane. With the new engines, the KC-135s became KC-135Rs. Whereas a KC-135's maximum takeoff weight was 296,000 pounds, the KC-135R's was 322,000 pounds. This required strengthened landing gear and refurbishment of a host of other less-than-dramatic features of the aircraft. The KC-135's cockpit and communications and navigation systems were updated, bringing them up to the standards of commercial airline aviation.

The Advanced Tanker Cargo Aircraft/KC-10

In December 1964, after a production run of nine years, Boeing rolled out the 732d and last KC-135 tanker. By the time the Berlin Wall was dismantled in 1989, that "newest" airplane was twenty-five years old; and the KC-135 produced in 1957 would be at least thirty-two years old. Meanwhile, buying a tanker to replace the aging KC-135s had become as politically convoluted as procuring a new bomber.

In 1968, SAC prepared a requirement for a tanker more capable than the KC-135. This became the Advanced Tanker Cargo Aircraft—ulti-

mately the KC-10. Eight years passed. The Air Force wanted one hundred of them, but studies showed that sixty-seven might do. In 1976, the procurement of two prototypes was approved. In 1977, the outgoing Ford administration raised this to ninety-one productions, but the new Carter administration reduced that number to forty-one. At that point, no contractor had been selected.

For the Air Force, the choice boiled down to tanker versions of either the Boeing 747 or the McDonnell-Douglas DC-10. Airplanes are like potatoes and nails: you buy them by the pound. The 747-300 had a tare weight of about 395,000 pounds; a DC-10-30's tare weight was only about 265,000 pounds, 32 percent less. A DC-10 variant clearly had to be less expensive than a 747, and more could be bought for the same money. Not surprisingly, on December 19, 1977, the service announced that McDonnell-Douglas had won the contract. The KC-10A first flew on July 12, 1980, and the first was delivered to the Air Force in March 1981—twelve years after SAC formulated its requirement for a new tanker. Ultimately, sixty KC-10s were procured.

The KC-10 is a 590,000-pound aircraft with a total capacity of 365,000 pounds of fuel (56,153 gallons), 61 percent of its takeoff weight, theoretically, all deliverable. A wholly new boom of McDonnell-Douglas design and its pumping system can deliver more than 1,000 gallons per minute. The KC-10A is air refuelable, making possible range extension by relay, refueling by a series of tankers. Additionally, some KC-10s have been equipped with wing-tip refueling pods with FRL hose-reel systems, thereby making the KC-10A the Air Force's first two-system tanker (boom *and* hose), and its first three-point tanker since the KB-50s were retired in 1965.

EL DORADO CANYON: The Longest Fighter Mission

The versatility of the air-refuelable KC-10 tanker was demonstrated in April 1986 during the punitive U.S. strike on Libya known as Operation EL DORADO CANYON. A series of terrorist attacks that killed U.S. citizens in Europe in December 1985 were traced to Libya and its erratic leader Mu'ammur Muhammad al-Gadhafi. At the Pentagon, U.S. military leaders made contingency plans for retaliation against Libya.

It was to be a joint Navy-Air Force operation. Navy planes from two aircraft carriers in the Mediterranean would hit Benghazi; Air Force F-111s based in England would hit Tripoli. Although the Navy was already on the scene, it is some 1,300 nm from bases in East Anglia to Tripoli—and that becomes 2,600 miles on a return flight even if flown directly across France. Clearly, aerial refueling would be needed. In the event that European nations denied overflight privileges, however, a roundabout flight via the Strait of Gibraltar would be necessary to gain entrance to the



The McDonnell Douglas KC-10, here connected to a KC-135, is air refuelable, extending its range and versatility.

Mediterranean and reach targets at Tripoli. This would involve a round-trip flight of nearly 4,400 nm and double the demands for inflight refueling.

To train for operations such as that, F-111s based in England conducted Operation GHOST RIDER, a transatlantic exercise flown to the Canadian Air Force's bombing range near Goose Bay, Labrador, in January 1986; in February to Incirlik, Turkey, overflying France en route; and in March in the central Mediterranean against a ship of the Sixth Fleet meant to simulate a Libyan target—an operation that also overflew France. Meanwhile, the United States recalled all Americans employed in Libya, all of whom were potential hostages. On April 2, 1986, a bomb exploded aboard a TWA airlines flight en route from Rome to Athens. The airplane survived, but the blast tore a hole in the fuselage through which four American passengers were blown out to certain death. A few days later, another bomb destroyed La Belle Disco, a West Berlin nightclub popular among Americans; two people were killed and hundreds wounded.

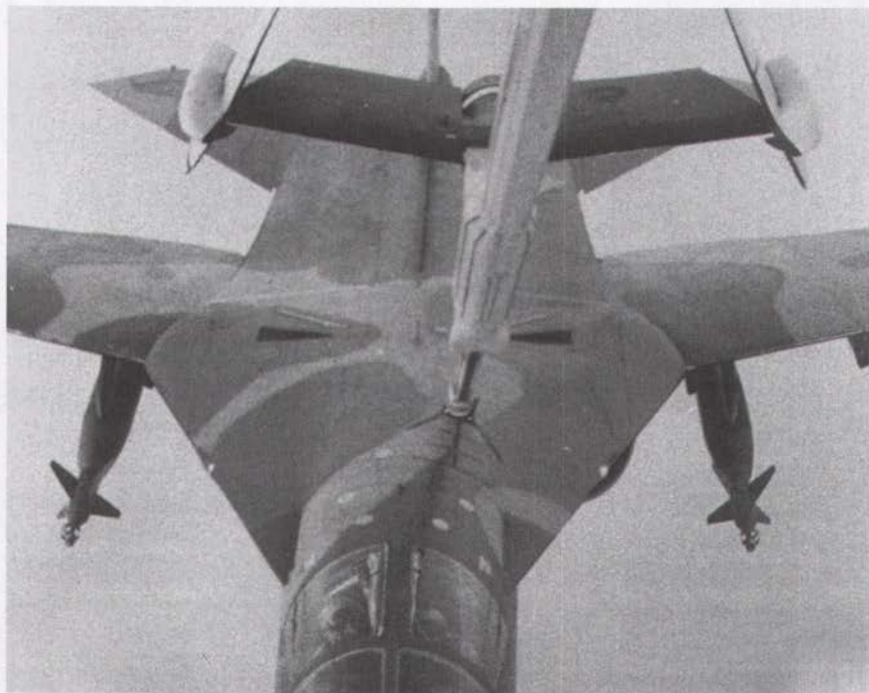
Intelligence sources traced the disco bombing to Libyan agents, and on April 10, U.S. President Ronald Reagan ordered retaliation. The U.S. Air Force strike force included eighteen F-111Fs, assisted by three EF-111A Raven electronic countermeasures aircraft. The French, dependent on oil from Arab countries, denied overflight privileges for the operation, and the aircraft had to be routed around Gibraltar, necessitating an extraordinarily large tanker force. Without an adequate number of KC-135s in Europe to support the mission, SAC made available twenty-three KC-10s, nineteen of which were used, with one also serving as an airborne command post. Until that moment, the KC-10 had been a rare bird in European skies, and the sudden appearance of so many roosting in England made it clear that something unusual was in the works.

Although a fully loaded KC-10 carries about 365,000 pounds of fuel and can deliver 98,500 pounds at a radius of 3,000 nm, it was inadequate

to serve one four-plane section of combat-loaded F-111Fs on a 4,500-mile mission—much less the eighteen F-111Fs and three EF-111A receivers involved in this strike. The solution was to have ten KC-135Rs give inflight refueling to the KC-10s so they would be 100 percent full when the force entered the Mediterranean.

Altogether, a force of fifty-eight airplanes took off from England on the evening of April 14, 1986, to execute Operation EL DORADO CANYON. In addition to the tankers, there were twenty-four F-111Fs and five EF-111As, including spares, which yielded the planned attack force of eighteen and three, respectively. Shortly after the spare aircraft turned back to their bases, the first refueling occurred in twilight off Land's End, England. Thereafter, the KC-135s started refilling the KC-10s and finished in the vicinity of Gibraltar. A KC-135R can deliver 127,700 pounds (19,645 gallons, 35 percent of a KC-10's full load) of fuel within a radius of 1,500 nm, and it is only 1,100 miles from bases in England to Gibraltar. After offloading, the KC-135s also returned to their bases in England.

East of Gibraltar, the F-111s were recycled again and again to the KC-10s' refueling booms to make sure they had maximum fuel before diving away for the low-level strike against Libya. Of the eighteen F-111Fs, a mishap in timing and the strict rules of engagement caused one to abort,



An F-111F with guided bombs under its wings refuels en route to Libya. The distinctive boom identifies the tanker as a KC-10.

but seventeen attacked. Until the actual attack, the operation had been conducted in strict radio silence—an endeavor that removed the aerial refueling in darkness from the realm of routine. Indeed, there was nothing routine about these refuelings. Prior to EL DORADO CANYON, few of these F-111 pilots had refueled from a KC-10 under *any* circumstances, and none had done so at night in radio silence. One pilot had never even seen a KC-10 except in photographs. Nonetheless, the refuelings went without incident, and the results of the combined attack were more than satisfactory. One F-111, however, was lost in the Mediterranean Sea.

With the attack finished, the KC-10s turned on their tactical air navigation systems (TACANs), which provided bearings and distances to interrogators aboard the F-111s, permitting pilots to find their tankers in the darkness somewhere west of Sicily. Then it was back to England the way they had come, a flight of almost 2,200 nm and more than another six hours. On touchdown at their British bases, the F-111s and their KC-10s had been aloft for almost fourteen hours. They had flown nearly 5,000 nm and transferred 1.5 million pounds of fuel (230,769 gallons). It was the longest and most complex fighter mission ever flown. The reach demonstrated by this successful military operation produced the desired effect: an enduring pause in the state-sponsored terrorism originating from Libya.

The Persian Gulf War

Desperate for cash to service a horrendous debt built up during a futile eight-year war with Iran in the 1980s, the government of Iraq sought a radical increase in oil prices. Other petroleum-producing states were content with the status quo or would consent to small, gradual increases, including Iraq's neighbor, Kuwait. Iraq had an ancient, but specious, territorial claim against Kuwait, asserting it was Iraq's nineteenth province. On August 2, 1990, Saddam Hussein, Iraq's brutal dictator, sent his armies into neighboring Kuwait and quickly overwhelmed the small (6,200 square miles), but oil-rich Arab sheikhdom.

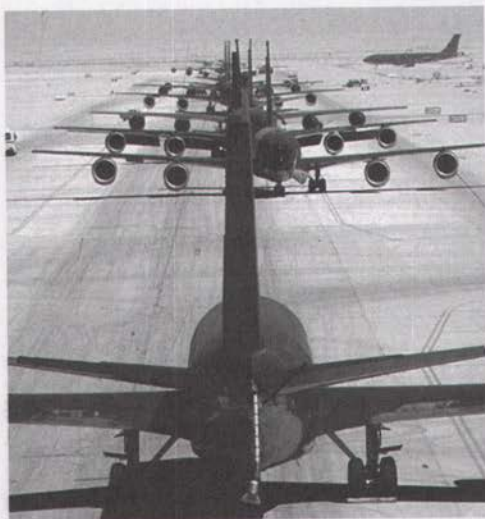
The Persian Gulf area holds about 60 percent of the world's known oil reserves. The United States imports approximately 30 percent of its oil from the Persian Gulf, but Europe and Japan depend on the Gulf for as much as 70 percent of their oil. Iraq held about 10 percent of the Gulf's oil and was one of the world's premier oil-producing nations. Tiny Kuwait held something more than 8 percent. The threat of Iraq gaining control of 18 percent of the Gulf's oil not only upset the region's delicate balance of "petro-power," but also shook the entire industrialized world. Kuwait, furthermore, had served as a buffer between Iraq and Saudi Arabia, and that buffer was wiped out by Saddam's aggression. If the world had ignored Kuwait's annexation, Iraq might have been encouraged to expand the aggression to Saudi Arabia and the oil-rich sheikhdoms in the southern

stretches of the Persian Gulf. Imagery from space satellites showed the Iraqi army massing on the Kuwait–Saudi border.

On August 3, 1990, U.S. President George Bush declared a national emergency. Under United Nations Resolution 661 of August 6, calling for the restoration of Kuwaiti sovereignty, the United States organized the most diverse coalition of countries in the history of warfare. However, the backbone of the coalition was provided by forces deployed directly from the United States. It is 5,850 nm by a great circle route from Washington, D.C., to Riyadh, the capital of Saudi Arabia, and substantially more than that from the many military bases within the continental United States from which these forces were drawn. Most U.S. and coalition forces that focused against Iraq were based within a 460-nm radius of Riyadh. But payloads lifted from the United States to Saudi Arabia at a speed of 450 knots could not be managed without one or more fuel stops or intensive inflight refueling en route.

Within hours of President Bush's declaration, two dozen F-16 fighters took off from Langley AFB at Hampton Roads, Virginia; fifteen hours, some 6,000 nm, and a dozen inflight refuelings later, they landed at Dhahran, Saudi Arabia. They were the first of hundreds of fighters and attack planes flown from the United States to the Middle East, all requiring inflight refuelings. Others arrived from U.S. bases in Germany. At the same time, C-5As, C-5Bs, and C-141Bs began moving troops and cargo from the United States and Europe to the Middle East, this time without having to land at Lajes for refueling. Indeed, Lajes was one of the points from which tankers spiraled up to meet them with JP4. Some 300,000 tons of cargo were moved and 209,000 troops delivered to Saudi Arabia. The airlift provided a stopgap that deterred Iraq until the operation's massive requirements could be met by sea deliveries.

KC-135Rs lined up at a base in the Persian Gulf area. The tanker in the foreground has a drogue attached to its boom.



Coalition countries conducted two major operations. The first, DESERT SHIELD, which lasted from August 7, 1990, to January 16, 1991, was a build-up of forces to protect Saudi Arabia and prepare for war in the event it became necessary to force Iraq out of Kuwait. The second, DESERT STORM (January 17 to February 28, 1991) was a combination of air and ground campaigns that liberated Kuwait. During the 132 days of the DESERT SHIELD build-up, U.S. Air Force tankers flew 4,967 sorties, logging more than 19,700 hours of flying time, offloading 28.2 million gallons of fuel (183 million pounds), and making 14,588 fueling hook-ups. Most of these refueling contacts were with tactical aircraft over Saudi Arabia during intensive combat rehearsals for the assault on Iraq.

After Iraq refused to respond to an ultimatum for its evacuation of Kuwait, the U.S. Air Force and its allies unleashed the DESERT STORM air campaign. The first move occurred on the morning of January 16 when seven B-52Gs took off from Barksdale AFB, Louisiana, and flew to the Gulf region, where they launched cruise missiles against communications targets in the vicinity of Baghdad. This was one of the most sensational operations of the whole surprise attack. It is some 6,300 nm from Barksdale to Baghdad, and the B-52s flew to their targets and returned to Louisiana nonstop—thanks to four inflight refuelings outbound and four returning. Other B-52s operated from England, Spain, and the island of Diego Garcia in mid-Indian Ocean, all assisted by aerial refueling.

Air Force tankers did not serve alone in DESERT STORM. The RAF had its old Handley Page Victors, its newer Vickers VC.10s, and its newest Lockheed Tristar tankers; the French were on the scene with some of their KC-135Fs; the Canadians flew their Boeing CC-137Cs, 707 airliners converted to tankers. The Saudis had their own force of tankers as well—eight Boeing 707-300s (EK-3As) built as three-point tankers. On the day the operation was launched, 160 tankers were in the air and, considering how they attracted combat airplanes in swarms of squadrons, the air traffic control problem was formidable.

The forty-three days of DESERT STORM included 15,434 tanker sorties, an average of 358 every day. The refuelers logged 60,000 flying hours and made 45,995 fueling contacts, an average of three contacts per sortie. Approximately 110.2 million gallons of fuel (716 million pounds) were pumped through tanker booms or hose-reel sets to their receivers.⁵⁰ One of the most interesting—indeed, truly provocative—statistics to emerge from this forty-three-day operation is that on any given day of DESERT STORM, 18 percent of the airplanes in the air—almost one-fifth of the force—were tankers.⁵¹

For thirty-nine days it was an air war; then on February 24, 1991, the ground war began. With Kuwait liberated three days later and the war's limited aim achieved, a cease-fire took effect on February 28th. When the war was over, the tankers gave inflight refueling to coalition aircraft returning home.

The tankers were “first in and last out”: they had to be in place to serve refueling tracks near Labrador, the Azores, Europe, the Mediterranean, and the Middle East before DESERT SHIELD got under way, and they had to support the westward retirement of aircraft after DESERT STORM’s successful conclusion. Their function and reliability taken for granted, they arrived back to the United States in their usual role, “invisible men in invisible airplanes.”⁵²

The Legacy of Curtis LeMay

The U.S. Air Force’s development of aerial refueling cannot be attributed to any one person, but among all of those involved, General Curtis E. LeMay remains an outstanding figure. During his nine years as SAC commander, LeMay built the U.S. aerial refueling capability into what was practically an air force unto itself, an “invisible” foundation for the nation’s original nuclear deterrent. With only a bit of exaggeration, it can be said that the KC-135 was *his* airplane. When LeMay retired as Air Force Chief of Staff on February 1, 1965, Boeing already had delivered its 732d and last KC-135 tanker. At the time, SAC had forty-nine tanker squadrons with 641 KC-135s, with almost 200 other KC-135 variants performing a bewildering number of specialized military missions.

During the quarter-century after General LeMay retired, land- and sea-based ballistic missile forces gradually upstaged manned bombers. LeMay had left “all those tankers” in the wake of his career, and some people had wondered openly what the Air Force would do with them. First, the tactical air forces and B-52 bombers answered that question in Southeast Asia. After the experience of the airlift to Israel, the Military

Gen. Curtis E. LeMay is sworn in as Air Force Chief of Staff, with Secretary of the Air Force Eugene M. Zuckert administering the oath of office.



Airlift Command had its own answer. In no way could tankers be considered surplus to anything, much less a declining asset.

On October 1, 1990, as hundreds of SAC tankers were cruising over the Atlantic Ocean and the Mediterranean Sea, refueling fighters and transports on their way to Operation DESERT SHIELD, and other tankers were offloading fuel to support intensive combat training exercises over Saudi Arabia in anticipation of DESERT STORM, Curtis Emerson LeMay died at March AFB, California, just six weeks short of his eighty-fourth birthday.

Within two years, at midnight on May 31, 1992, the mighty Strategic Air Command passed silently into history. Three new organizations divided its assets: the Strategic Command acquired the intercontinental missiles and some bombers, the Air Combat Command (formerly TAC) got what remained of the big bombers and some of the aerial tankers, and the Air Mobility Command (the old MAC) gained most of the tankers. The Old Order changeth; it was the end of an era.

Tankers do not generate the glamour, controversy, and speculative emotions—much less the inspirations to speech making and romantic nostalgia—that bombers and fighter planes do. When history deals with Curtis LeMay, it will likely be in clichés about bombers, with hardly a word about tankers; but the U.S. Air Force's aerial refueling capability will always be LeMay's most enduring monument. In reaching for Magnitogorsk, Novosibirsk, and Moscow, he left to his country an instrument that can encompass the world.

In June 1990 the U.S. Air Force issued a white paper titled *Global Reach—Global Power*. Without “reach” the “power” becomes problematic. That reach is absolutely dependent on some 2,000 invisible men in about 500 unexciting, unnoticed airplanes, providing for the nation's military services' inflight refueling.

Appendix 1

U.S. Army Air Service, Inflight Refueled Endurance Flight, August 27-28, 1923

Capt. Lowell H. Smith and 1st Lt. John Paul Richter took off at 0504 on August 27, flying the receiver, a de Havilland DH-4B single-engine bi-plane. Their flight was terminated at 1830 on the twenty-eighth. The No. 1 tanker was flown by Capt. Robert G. Erwin and 1st Lt. Oliver R. McNeel; the No. 2 tanker by 1st Lt. Frank W. Seifert and 1st Lt. Virgil Hine. Both tankers were DH-4Bs.

Refueling Time	Tanker	Delivered
1. 0925	No. 1	90 gal fuel
2. 1210	No. 2	lunch
3. 1348	No. 1	90 gal fuel
4. 1553	No. 2	94 gal fuel
5. 1653	No. 1	15 gal oil
6. 1713	No. 2	38 gal fuel
7. 1815	No. 1	48 gal fuel
8. 0502	No. 2	82 gal fuel
9. 0543	No. 1	15 gal oil
10. 0625	No. 2	90 gal fuel; breakfast
11. 1110	No. 2	88 gal fuel
12. 1326	No. 2	lunch
13. 1351	No. 1	8 gal oil
14. 1545	No. 2	67 gal fuel

Appendix 2

Inflight Refueling Experiments Using a B-24D Tanker and a B-17E Receiver, Eglin Field, Florida, June 1943

Wing Commander Hugh C. Johnson, Royal Canadian Air Force, was in charge; Percy R. Allison, British Air Commission, was technical adviser; Capt. Fred C. Bretcher and 1st Lt. M. K. Norton were pilot and copilot, respectively, of the B-24D tanker; and Capt. Ralph C. Hoewing and 1st Lt. John A. Kelting were pilot and copilot, respectively, of the B-17E receiver. Refueling was accomplished at a speed of 150 mph. During the seventh flight, the receiver's tanks were filled to 101 percent and fuel was seen to be flowing out of its tank vents.

Flight No.	Available Offload (gal)	Offloaded (gal)	Transfer Time (min)	Flow (gal/min)
1	1,500	1,112	01.0	112.0
2	1,500	1,325	03.0	108.0
3	1,000	1,835	06.0	137.5
4	1,200	1,935	08.0	117.0
5	1,200	1,150	12.0	195.8
6	1,500	1,380	12.0	115.0
7	1,550	1,450	13.5	107.5

Appendix 3

Tanker Support to Operation Power Flite Sending B-52s Nonstop Around the World, January 16-18, 1957

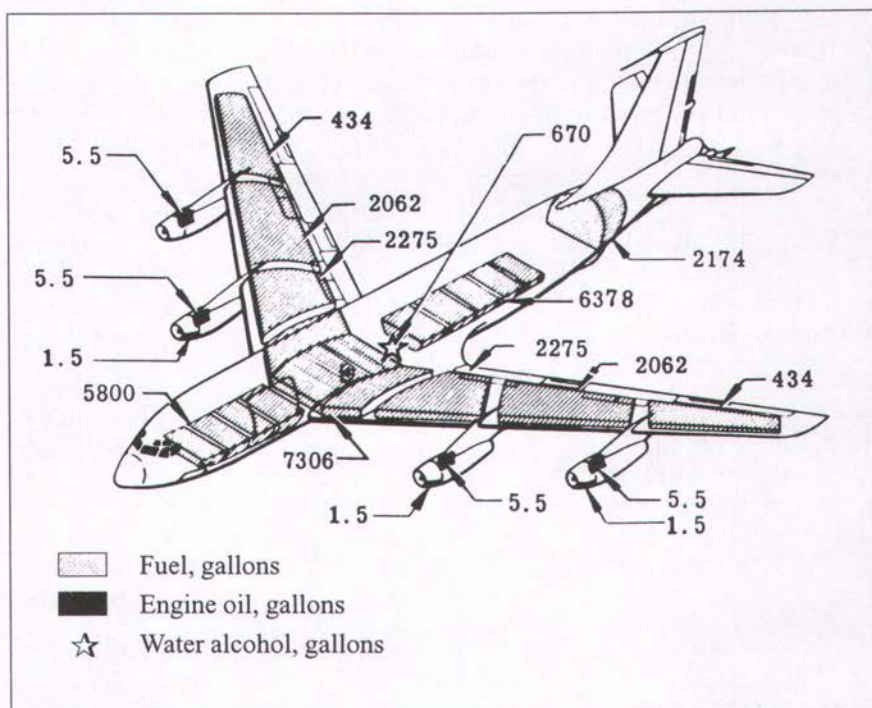
Five B-52Bs took off from Castle AFB. Three were to fly around the world, and after refueling over Morocco, two were to divert to Great Britain. Their takeoff weight was 401,000 pounds with 100 percent fuel (243,000 pounds). However, at the first refueling, one B-52 was unable to receive because of an iced-up receptacle, and it landed at Goose Bay, Labrador. Only one bomber went on to Britain. In addition to the minimum number of tankers in the ratio, there were two spare KC-97s, one airborne (+1) and one on the ground on strip alert at the refueling point (+1). A KC-97's maximum offload of jet fuel was 46,350 pounds, but if necessary, a 10-percent contamination by aviation gasoline was acceptable. Altogether, seventy-eight KC-97 tankers were required to fly three B-52s around the world nonstop, a distance of 21,135 nm. That figure does not include KC-97s on alert in England, at Hickam AFB, Hawaii, nor at Elmendorf AFB, Alaska, in the event the bombers met unexpected headwinds transpacific.

Refueling Point	Required Ratio of Tankers to Each B-52	Number of KC-97s	Minimum Onload of Fuel per B-52 (lbs)	Percent of B-52's Full Fuel Load
Goose Bay	2:1+1+1	12	103,800	12.7
Morocco	5:1+1+1	27	138,000	56.7
Dharahn	4:1+1+1	14	164,300	67.6
Philippines	2:1+1+1	08	063,800	26.0
Guam	5:1+1+1	17	180,800	74.4

Appendix 4

KC-135 Fuel Tanks

A KC-135 can carry 16,848 gallons (109,512 lbs) of fuel in its wing tanks, 12,178 gallons (79,157 lbs) in its below-decks cabin tanks, and 2,174 gallons (14,131 lbs) in its "tail cone" tank. The total is 31,200 gallons (202,800 lbs/101.4 tons).



Appendix 5

Airlift Flight Profiles, United States to Israel

If aerial refueling had been available in October 1973, allowing Air Force C-5As and C-141As to fly nonstop between the United States and Israel, 44 fewer C-5A missions and 57 fewer C-141A missions would have been needed to move the same amount of cargo that was actually carried on flights that had to stop at Lajes for refueling.

Flight Profile	Payload (tons)		Number of Missions Required	
	C-5A	C-141A	C-5A	C-141A
Refueling on ground at Lajes and Tel Aviv*	074.3	27.6	145	421
Nonstop without Lajes	033.5	00.0	659	000
Nonstop with aerial refueling	107.4	32.0	101	364

*Actual mission in October 1973.

NOTES

1. An EO of Oct 26, 1935, terminated Army Air Corps operations on North Island; sole tenancy transferred to the Navy, and Rockwell Field passed into history.
2. Maj. Henry H. "Hap" Arnold, Rockwell Field's commanding officer, was an interested observer and supporter of these operations. Less than twenty years later Arnold was Chief of the U.S. Army Air Forces during World War II. Maurer Maurer, *Aviation in the U.S. Army, 1919-1939* (Washington, D.C.: Office of Air Force History, 1987), 183-84, 188; "The Latest Endurance Flight," *Aviation*, Vol 15 (Sep 10, 1923), 716; and "Border-to-Border Refueling Flight," *Aviation*, Vol 15 (Dec 17, 1923), 752-53.
3. Oral History, Lt Gen Elwood Quesada, USAF (Ret) (Maxwell AFB, Ala.: Air Force Historical Research Agency, May 12, 1975), 2-4, 24-36, 63.
4. Maurer, *Aviation in the U.S. Army*, 260-65; Ross G. Hoyt, "Recollections of an Early Refueler," *Air Force Magazine*, Vol 57 (Jan 1974), 55-59.
5. The Keystone bombers, B-3 through B-6, formed the backbone of the Air Corps bomber forces from 1927 through 1934. They were twin-engine biplanes of approximately 12,000 pounds and bore more physical relationship to the German Gothas that bombed London in 1917 than to any bomber acquired after 1933. Without a headwind, a Keystone might reach a speed of 120 mph.
6. A. M. Jacobs, "Preparation of Bomber for Refueling," *Air Corps News Letter*, Vol 13 (Jun 7, 1929), 209-10; *New York Times* (May 22, 1929), Sect. 1, 1, (May 23, 1929), Sect. 1, 8, (May 24, 1929), Sect. 17, 2; and Maurer, *Aviation in the U.S. Army*, 244-45.
7. N. B. "Nick" Mamer, "Texaco Across the Sky," *The Texaco Star* (1929), 3-6, 32; and "Sun God Flight a Distance Mark," *Aviation*, Vol 27 (Aug 31, 1929), 483.
8. Boeing Shuttle File (Seattle: Boeing Company Archives).
9. Stephen Owen, *The Flying Key Brothers and Their Flight to Remember* (Meridian, Miss.: Southeastern Printing Co., 1985).
10. John A. Bagley, "RAE Tanker Trials," *Aerospace*, Vol 2 (Dec 1975), 26-27.
11. J.H.B. Larrard, "The Refuelling of Aircraft in Flight," *Journal of the Royal Aeronautical Society* (Dec 1931), 1137-45.
12. R.L.R. Atcherly, "Transferring Articles, and Fuel Between Aircraft in Flight," patent no. 460,843 (Jun 4, 1935), *Airplane Patent Digest: British Supplement*, Vol 8, No. 6 (Jun 30, 1937), 67-68.
13. Richard K. Smith, "The Weight Envelope: The Airplane's Fourth Dimension—Aviation's Bottom Line," *The Aerospace Historian*, Vol 33 (Spring 1986), 30-44; reprinted in *Weight Engineering*, Vol 47 (Summer 1987), 32-47.
14. The "R" prefix identifies a radial engine; the numerals thereafter describe the engine's total cylinder volume in cubic inches.
15. There are at least a half-dozen books on the British airship effort. The best book, written by Peter G. Masefield, is *To Ride the Storm: The Story of the Airship R.101* (London: William Kimber, 1982); the aborted Type 179 flying boat is described in C. F. Andrews and E. B. Morgan, *Supermarine Aircraft Since 1914* (London: Putnam, 1981), 315-19.
16. Richard K. Smith, "Sikorsky S-42 vs Short S.23: A Tale of the Tares of Two Airplanes and the Superiority of the American Transoceanic Airliner," *American Aviation Historical Society Journal*, Vol 29 (Summer 1984), 82-94. The focus is on weight control.
17. H. A. Taylor, *Airspeed Aircraft Since 1931* (London: Putnam, 1970), 41-54. An Imperial gal (277.4 cu in) of gasoline weighs 7.4 lbs; a U.S. gal (231 cu in) of gasoline weighs 6.0 lbs, and a U.S. gal of aviation fuel, slightly denser than gasoline, weighs 6.5 lbs.
18. Sir Alan Cobham's own detailed account of the abortive flight to India is "Refuelling in the Air," *The Aeroplane* (Oct 10, 1934), 425-26.
19. In addition to *Cabot* and *Caribou*, there were *Connemara* and *Clyde*, all modified to fly at 53,000 lbs after inflight refueling. But in Jun 1939, *Connemara* was destroyed by

fire while moored alongside a fueling barge; *Clyde* was subsequently lost in an accident at Lisbon in Feb 1941.

20. Rpt, Army Air Forces Bd, "Tactical Application and Test of Refueling in Flight of Heavy Bombardment Aircraft," Project No 2455/MX-204 (Wright-Patterson AFB, Ohio: Material Command Archive, Area B, Mar 10, 1944), AD-B191 077, microfiche.

21. Colin Cruddas, *In Cobham's Company: Sixty Years of Flight Refuelling Limited* (Wimborne, Eng: Cobham PLC), 63–80.

22. *Ibid.*, 81–96.

23. "Verbatim Minutes of the First Meeting of the Aircraft and Weapons Board" (College Park, Md.: National Archives, HQ-USAF, Aug 19–22, 1947), record group 341, entry 190, *passim*, boxes 181–182. These minutes run to 783 typewritten pages.

24. This 1:8 ratio was probably based on past experience with the aerostructures of relatively low density that prevailed prior to 1945. Seven years later, in 1952, Edward H. Heinemann, one of the world's great artists in aerostructure weight control, gave the estimate of 1:10. Edward H. Heinemann, "Airplane Weight and Cost Can Be Reduced," (Santa Monica, Calif.: Douglas Aircraft Co., Rpt No ES 16162, Jul 3, 1952); and E. H. Heinemann, personal papers (San Diego, Calif.: San Diego Aerospace Museum Library), box 13.

25. "Report on Heavy Bombardment," Agenda for the Second Meeting of the USAF Aircraft and Weapons Board, Air Force Plans: central decimal files 1942–1954 (College Park, Md.: National Archives, Jan 27–30, 1948), record group 341, entry 336. The XB-47 made its first flight on Dec 17, 1947, after which it required five years of intensive development before it became a weapon.

26. "Verbatim Minutes of the Second Meeting of the USAF Aircraft and Weapons Board" (College Park, Md.: National Archives, HQ-USAF, Jan 27, 1948), record group 341, entry 190, box 183. These minutes run to 699 typewritten pages.

27. "History of the Strategic Air Command, 1948," and hist of 43d Bombardment Wing and the 43d and 509th Air Refueling Sqdns (Maxwell AFB, Ala.: Air Force Historical Research Agency)

28. Ltr, Maj Gen Frank A. Armstrong, Jr, Comm 2d AF, to Gen Curtis E. LeMay, CINCSAC, July 18, 1956.

29. Although operating by mid-1950, Limestone was not "officially" admitted to be operational until eighteen months later; in 1954 it was named Loring AFB; see Robert Mueller, *Air Force Bases*, Vol I (Washington, D.C.: GPO, 1982), 327.

30. John and Charlotte McClure, *Follow Me: The Life and Times of David C. Schilling* (Dallas, Tex.: Taylor Publishing Co., 1995), 87–101; and Frank W. Klibbe, "Fox Able One: The First Transatlantic Jet Deployment," *Air Force Magazine* (Oct 1980), 72–80; Cruddas, *In Cobham's Company*, offers further information. A World War II ace (P-47s/22.5 kills), and the pioneer of inflight refueling for fighter planes, Schilling was killed in an automobile accident in England on Aug 16, 1954. On Mar 16, 1957, the Smoky Hill AFB, Salina, Kans., was named in his honor. It was a B-47 base and, with B-47s phased out, Schilling AFB was closed on Jun 30, 1965. Today it is the site of Salina's municipal airport and industrial park.

31. "Final Analysis of Project High Tide" (Maxwell AFB, Ala.: Air Force Historical Research Agency, HQ, 39th Air Div, Dec 9, 1952), K.720.86101.3 (Aug–Sep 1952). More readily available is René J. Francillon, "High Tide: ANG Pioneers Wing-Strength Combat Air Refuelling," *Air International* (Nov 1995), 302–304.

32. Hist of the 31st Fighter-Escort Wg (Maxwell AFB, Ala.: Air Force Historical Research Agency, Jul 1952).

33. Robert S. Hopkins, *The Boeing KC-135: More Than Just a Tanker* (Leicester, Eng.: Aerofax, Midland County, Ltd., 1997), 24–26.

34. The best discussion of this is John E. Steiner, "Jet Aviation Development: A Company Perspective," in Walter J. Boyne and Donald S. Lopez (eds), *The Jet Age: Forty Years of Jet Aviation* (Washington, D.C.: Smithsonian Press, 1979), 141–83.

35. Four-digit Air Force organizations such as the 4050th and 4060th are established and controlled by major commands (and are different from one-, two-, and three-digit organizations controlled by GHQ Air Force). Although ostensibly temporary organizations, they may be operational for years but tend to leave few footprints in history.

36. "History of the Canadian Refueling Base Program," SAC Hist Monogr No 87, nd. Churchill and Frobisher had been bases on the old Crimson air route of World War II, which was supposed to facilitate the ferrying of airplanes from west coast factories via a great circle route to England, but these World War II runways had to be totally rebuilt to accept 300,000-lb aircraft, and the bases' fuel storage had to be vastly enlarged.

37. Steve Ginter, *North American AJ-1 Savage* (Simi Valley, Calif.: Ginter Publications, 1992).

38. Brian Gardner, "When You Need a Buddy: The Development of Air Refueling in the U.S. Navy," *The Hook* (Fall 1983), 11-24.

39. "KB-50 J & K," *Standard Aircraft Characteristics* (Mar 3, 1958) and "F-100C Super Sabre," *Standard Aircraft Characteristics* (Apr 4, 1958), (Wright-Patterson AFB, Ohio: Air Force Museum Library).

40. By the late 1990s, two generations of Americans had grown to adulthood with scant idea of the effect that the Japanese surprise attack on Pearl Harbor had on the American psyche. Everyone who was ten years old or more on Dec 7, 1941, has some recollection of where they were and what they were doing that day as the news came over the radio. It was not only the surprise attack that stunned the citizenry, but also the military unpreparedness that was revealed thereafter, followed by six months of costly military defeats while the United States mobilized for war. It created the "Pearl Harbor syndrome" among the nation's postwar leaders—a fear of surprise attack and a determination not to let it happen in the atomic age.

41. A dozen or more USAF KC-135s had fueling receptacles for boom refueling, but these were aerial command posts that were expected to remain in the air for many hours beyond a KC-135's normal endurance and were not expected to refuel other airplanes.

42. Wilfrid L. Kohl, *French Nuclear Diplomacy* (Princeton, N.J.: Princeton University Press, 1971), 83, 179-83, 222-23; Hopkins, *The Boeing KC-135*, 81-85; and René J. Francillon, "Du Kérosène dans l'Air," *Air Fan* (Dec 1986), 6-8.

43. Charles K. Hopkins, *SAC Tanker Operations in Southeast Asia* (Offutt AFB, Nebr.: SAC Hist Office, 1979); and "Tri-Level Refueling" in Vernon B. Byrd, *Passing Gas: The History of Inflight Refueling* (Chico, Calif.: Byrd Publishing Co., 1994), 246-54.

44. Hopkins, *SAC Tanker Operations*. These numbers are impressive but only because this life fluid of war was lifted by airplanes and required a great human effort to deliver it. Those offloads over nine years are only 51 percent of the petroleum products that U.S. citizens consumed *daily* in 1972.

45. Earl H. Tilford, *Search and Rescue in Southeast Asia, 1961-1975* (Washington, D.C.: GPO, 1981), 82-85.

46. *Ibid*, 156.

47. The oil scene of 1973 was complicated further by the Organization of Petroleum Exporting Countries concurrently ratcheting up the price of oil. The combination of events created the energy crises of 1973 and 1974, but the two were not politically connected.

48. There was never much love lost between the Azores and mainland Portugal, with the Azoreans often feeling ignored or exploited by Lisbon. A sizable population of Portuguese of Azorean origin reside in Rhode Island, Massachusetts, and Connecticut.

49. To describe the wing in any other terms than "flawed" is to get into the realm of euphemism; the wing simply was not good enough. The flaw resulted from the problem of weight/strength in the aerostructure and the question of who was going to absorb the costs for correcting the problem. Within this simplification were Lockheed optimism; hundreds of engineering change orders by the Air Force which increased the weight; and a bizarre contract formulated by Secretary of Defense McNamara that sounded (and was) too good

to be true, with McNamara choosing to accept a flawed airplane rather than admit he was wrong. It was a badly muddled affair with no "good guys."

50. Richard P. Hallion, *Storm Over Iraq: Air Power and the Gulf War* (Washington, D.C.: Smithsonian Press, 1992), 62–65, 136–39, 188.

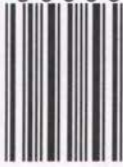
51. *Gulf War Air Power Survey, Vol 5: A Statistical Compendium* (Washington, D.C.: GPO, 1993). This volume of more than 900 pages contains raw data, including a useful 243-page chronology. The 18 percent figure is developed from day-to-day tabular data presented on pages 557–97.

52. See Vago Muradian, "Tankers: Why They're So Important and So Unappreciated," *The Air Force Times* (Feb 6, 1995), 12–19.

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