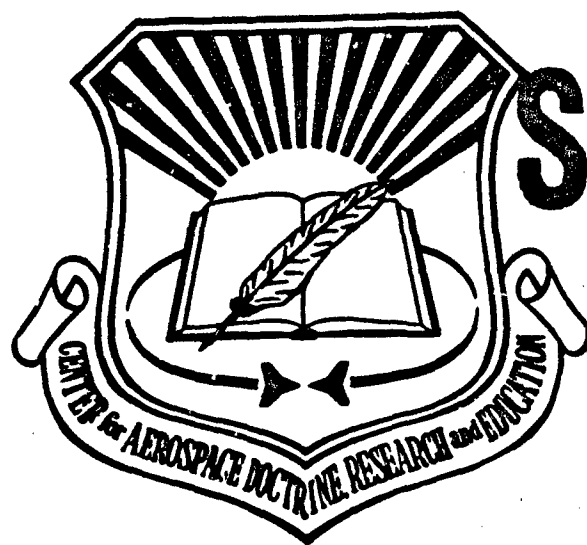


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AERIAL REFUELING
The Need for a Multipoint,
Dual-System Capability

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Report No. AU-ARI-CP-87-3

AERIAL REFUELING
The Need for a Multipoint, Dual-System Capability

by

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DEDICATION

This paper is dedicated to 1st Lt Michael S. Turose,
killed in action in Southeast Asia, 25 September 1972.

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ACKNOWLEDGMENT

I express my acknowledgment to all of the professional people who cooperated and contributed toward my research concerning the subject of aerial refueling. Specifically, I express my additional gratitude to Mr John Snyder, Boeing Military Airplane Company, Production Growth Manager, KC-135; Mr Dexter Kalt, ASD/ENFEF; Lt Col Michael W. Schmitt, AF/RDPN; and Mr Jerome W. Klingaman, AUCADRE/RID.



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ABSTRACT

↙ In view of continuing growth in air refuelable fighters and the likely shortfall in tanker aircraft during large-scale conflict, the United States Air Force should reexamine its current policy of refueling tactical fighters with the boom and receptacle system only. At the present time, all modern Air Force fighters must use the same single boom and receptacle system employed by bomber and airlift aircraft, a system that allows the tanker to service only one aircraft at a time. Because of budget constraints on tanker procurement as well as wartime operational demands on tactical fighters, we must find a more efficient means of employing these vital defense assets.

Such a means is available through a multipoint, dual refueling system in the tanker force with a complementary probe and drogue system installed on tactical fighters. A dual system of wing pod probe and drogue combined with a boom and receptacle capability was supported by the Defense Resources Board in 1986 when it approved incorporation of probe and drogue wing pods on the KC-10 to support Navy refueling requirements. The dual system should be extended to the KC-135, and the new generation of tactical fighters should be equipped with retractable probes. The multipoint capability would greatly reduce fighter refueling times, ensure maximum usable fuel off-load to fighters, and,

Cont'd p. 2

depending on the size of the fighter operation,
significantly reduce the number of tankers required.

AERIAL REFUELING

The Need for a Multipoint, Dual-System Capability

cont'd → This paper examines the evolution of air refueling concepts and doctrines and applies the lessons learned to an argument supporting probe and drogue refueling as the best means of supporting modern tactical fighter operations. The evidence indicates that to provide the most effective, efficient means of refueling tactical fighters, as well as airlift and bomber forces, a multipoint, dual refueling system is needed for the tanker force with a complementary probe and drogue system installed on tactical fighters. (AW) X

Concept of Operations

In January 1986 the United States Air Force chief of staff in response to a Navy requirement for air refueling support stated, "I think we've now sorted out the concept of operations for the air refueling support to your fighter/attack aircraft. . . . We think the KC-10, in a three-drogue configuration, is a system we need."¹

Unfortunately, the chief of staff did not advocate the same system and concept of operations for Tactical Air Command's fighters. The Air Force continues to adhere to a policy established 26 years ago by then Vice Chief of Staff Curtis E. LeMay. In his policy letter of 3 May 1960, General LeMay stated, "The attainment of a single refueling system will [be achieved through] the incorporation of the standard refueling receptacle common to KC-135 boom operation in the F-105 and future tactical aircraft."²

As a consequence of LeMay's policy, all modern Air Force fighters must use essentially the same refueling system employed by larger and heavier bomber and cargo aircraft. At first glance this restriction may appear insignificant, but in today's environment of budget constraints that demand the most effective and efficient employment of national defense assets, limiting Air Force fighters to the single boom refueling system holds dire implications for future warfighting capabilities.

A dual system of wing pod probe and drogue combined with a boom and receptacle capability received full support from the Defense Resources Board in 1986 when it approved incorporation of probe and drogue refueling wing pods on the KC-10 tanker to support the Navy's air refueling requirement. Extending dual-system capability to the KC-135 and equipping new generation tactical fighters with retractable probes would significantly reduce refueling off-load times for fighter operations, ensure maximum usable off-load to the fighters, and, depending on the size of a fighter operation, significantly reduce the number of tankers required. These advantages are discussed in greater detail below. To aid in understanding the advantages and need for a dual refueling system, this paper briefly reviews the history and concepts of aerial refueling and primarily examines developments and applications of air refueling as they pertain to military aircraft.

Background

To the expert in aerial refueling, the advantages of in-flight refueling seem so obvious that even the most casual observer should grasp them. This has not been the case, however. As the history of aerial refueling shows, there has been a lengthy struggle to develop the basic concepts of air refueling and to apply the inherent advantages to flying operations.

Most aircraft histories acknowledge that the first serious attempt at implementing the concept of aerial refueling occurred in 1923 at Rockwell Field, California, when a single-engine Army DH-4B flown by 1st Lts Lowell H. Smith and John P. Richter was refueled in flight. In August 1923 these same pilots set an endurance record of 37 hours and 15 minutes.³ Later that year, Smith and Richter established new speed and distance records by flying from Sumas, Washington, on the Canadian border to Tijuana on the Mexican border, thus demonstrating three fundamental premises of aerial refueling: (1) It significantly increases the time an aircraft can remain airborne; (2) It increases the range of an aircraft; and (3) It reduces the time needed to cover great distances.

However, there was no further application of aerial refueling until six years later when Maj Carl "Tooey" Spaatz and his crew flew the Question Mark for a record 150 hours and 40 minutes in January 1929. In 1930 an endurance record

of more than 25 days was established by Dale Jackson and Forest O'Brine in their monoplane, the Greater St. Louis.

The endurance records established in 1929 and during the 1930s emphasized only one of the fundamental premises associated with aerial refueling (aircraft could remain airborne for long periods of time). Primarily because the Army saw little advantage in air refueling, no attention was given to the concept by the United States until after World War II when the new Strategic Air Command (SAC) decided in 1947 that air refueling was necessary if American bombers were to be able to reach any target anywhere in the world.⁴

The United States was not the only nation exploring the possibilities of aerial refueling during the pre-World War II era. Air refueling concepts were explored by the British in the 1930s with J. H. B. Larrard providing encouragement and much of the conceptual thinking. Larrard foresaw the commercial possibilities of increased range and payload and improved take-off performance through in-flight refueling.

Under the guidance of Managing Director Sir Alan Cobham and Chief Engineer Mr Latimer-Needham of Flight Refueling Ltd (sponsored in the early years by Imperial Airways), experiments were conducted to achieve nonstop journeys using Larrard's concept of aerial refueling. In 1939, after numerous trials, Flight Refueling received a contract to refuel modified Short "C" Class flying boats on scheduled mail flights between Southampton and New York.⁵ The success of this effort convinced Imperial Airways of the benefits of

air refueling, and service was to be expanded and extended. However, the start of World War II ended such plans, and the flying boats were destroyed during the war.⁶

After World War II, the British continued to experiment with aerial refueling for commercial applications on numerous refueling flights between London and Bermuda and between London and Montreal. These experiments proved successful and validated the aerial refueling concept; however, the British were not perceptive enough to carry through with a fully operational refueling program.

At about the same time as the British were conducting their postwar experiments, Americans perceived the need to refuel their bombers to give them global range. On 2 March 1949 Lucky Lady II, a Boeing B-50 bomber, landed at Carswell AFB, Texas, having flown 23,452 miles around the world in 94 hours and 1 minute. All 14 crew members were decorated with the Distinguished Flying Cross. The citation with this award stated in part: "The successful execution of this historic flight demonstrated the feasibility of aerial refueling to extend the operating range of military aircraft and contributed other data of inestimable value to the future of military aviation."⁷

To accomplish this record flight, B-29s were used as tankers and refueling was accomplished by using a hose and drogue system allowing fuel to be transferred by gravity feed.⁸ In rapid succession B-50s and B-29s were replaced with B-47s as bombers and KC-97s as tankers. These aircraft

used the newly developed flying boom system that transferred fuel by pump pressure. With modifications, this system has been used by US heavy aircraft ever since. By 1957 B-52s were replacing B-47s, and KC-135s were replacing KC-97s. In January 1957 another round-the-world flight was conducted by a B-52 that set a record of 45 hours and 19 minutes while flying 24,325 miles.⁹

Thus the flying boom system proved highly successful in refueling the bombers of Strategic Air Command. Tactical Air Command, however, preferred the probe and drogue system that originated with the British. In his book, TAC: The Story of the Tactical Air Command, Leverett G. Richards states, "The Tactical Air Command had been trying officially ever since 1949 to get funds to develop in-flight refueling, using the probe and drogue, which was and is preferred by fighter pilots of all services, including the Navy, which officially adopted the system for its special uses."¹⁰

TAC history is replete with references to its efforts to eliminate the flying boom system from its aerial refueling operations and TAC's desire for the probe and drogue system. In 1957 TAC historians recorded the following:

TAC's KB-29 tankers, in the process of being phased out, appeared in the inventory until November 1957. Subsequent to the date the last single boom tanker was transferred out of the command, KB-50s became TAC's exclusive aerial refueling vehicle. Utilizing three drogues from which three separate receiving aircraft could

receive fuel simultaneously, the KB-50 proved to be much more efficient refueler than the KB-29. All the aerial refueling squadrons had their full complement of aircraft by the end of 1957.¹¹

TAC clearly wanted to maintain its own complement of tankers for its fighters, and the advantages of multipoint probe and drogue refueling were recognized. In testimony before the House Defense Appropriations Subcommittee in 1959, Gen Otto P. Weyland, TAC commander, stated that TAC needed a jet tanker and that he would give its acquisition top priority even though it was not a combat airplane. Such a tanker was needed to provide the mobility to get tactical forces to the right place at the right time.¹²

Although TAC was fighting hard to obtain its own fleet of jet tankers, SAC, which controlled the only jet tankers in the Air Force inventory, was not amenable to releasing any of its tankers to another command. In 1961 the Department of Defense formalized SAC's de facto control of jet tankers when it designated SAC as the single manager for all Air Force KC-135 aircraft, a policy that remains in effect today. Under this single-manager system, TAC began using SAC KC-135s on a limited basis in 1961. Nevertheless, to ensure that TAC fighter and reconnaissance aircraft received sufficient tanker support for long overwater flights, TAC employed four KB-50 aerial refueling squadrons with strategically placed detachments.¹³

During the four years after 1961, TAC experienced serious problems with its KB-50 tanker fleet due to airframe

fatigue and corrosion.¹⁴ Also, lack of propellers caused serious maintenance problems that could not be solved.¹⁵ With the phasing out of KB-50s, TAC became increasingly dependent on the KC-135. SAC was reluctant, however, to provide tanker support for TAC operations. This reluctance is reflected in TAC history.

The stage was being set for the incorporating of the KC-135 into employment plans, but it was obvious that SAC was not enthusiastic. However, JCS interest in Strike Command assured the latter [Strike Command] the support needed for mission accomplishment.¹⁶

TAC recognized at that time that there were distinct advantages to be gained from aerial refueling to include extended combat air patrol and reconnaissance missions, increased loiter time during close air support missions, increased flexibility and capability for fighter aircraft, and increased depth of penetration for fighter and reconnaissance operations.

During the next five years, TAC did not pursue development of a new probe and drogue jet tanker. When aerial refueling was needed for quick deployments, as during the Pueblo incident in 1968, TAC requested and received the necessary support from SAC, but TAC was still interested in acquiring its own air refueling assets.

In 1969 TAC was considering an off-the-shelf aircraft when it formally requested an organic tactical tanker. TAC had determined that available tanker resources could not fulfill the refueling requirements for simultaneous

deployment and employment of strategic and tactical air forces. TAC continued arguing for its own tankers, emphasizing that international political constraints might preclude the use of foreign airspace and operating bases and that aerial refueling was a vital component of weapon delivery systems. Aerial refueling was needed for close air support, air interdiction, combat air patrol, and search and rescue missions. TAC estimated that 200 tankers would be needed to support intense contingency operations. The Air Staff acknowledged the need for additional air refueling support, but included nothing in the budget.¹⁷

When the new advanced tanker concept was being developed in the early 1970s, TAC initially emphasized the need for increased time in the combat zone and considered multipoint refueling essential to flexibility.¹⁸ TAC's initial enthusiasm for the advanced tanker waned as the priority for a lightweight fighter became paramount. TAC realized that budget constraints would not permit allocation of TAC funds for both a fighter weapon system and an organic tanker force. Consequently, TAC rescinded Required Operational Capability 29-69 (ROC 29-69), which formally stated the need for a multipoint refueling system. TAC's interest in air refueling improvements were combined with SAC's ROC #1-77, KC-135 Performance Improvements, which simply stated the need for expanded refueling capabilities.

Since that time TAC has devoted little time or interest toward the employment of aerial refueling concepts for

attaining maximum flexibility and capability in support of theater operations. TAC's primary interest in air refueling has centered on deployment of fighters and logistics support. Once they are deployed, TAC assumes that modern fighters with their longer range capabilities will be able to satisfy all employment options without the use of aerial refueling.

TAC's apparent lack of interest in tanker support of theater operations may be based to some extent on the anticipated vulnerability of tankers to enemy fighters and surface-to-air missiles (SAMs), especially in a central European scenario. In that setting, the vulnerability problem poses a strong argument against in-theater tanker operations during general war. Multipoint refueling would probably have offered great advantages in Southeast Asia where the United States had total air superiority in the refueling zones, but those advantages may be completely neutralized in central Europe, where tankers would be at great risk to MiGs and SAMs.

There are two major points, however, that must be considered before passing final judgment on present Air Force tanker doctrine. In the first place, multipoint refueling allows the refueling operation to take place at a greater distance from the combat arena. Because a greater number of fighters can be refueled at one time with the multipoint system, the total refueling time is reduced considerably. Each fighter leaves the refueling station

with a larger amount of fuel and range capability. In some cases, that range capability may be sufficient to place the refueling operation outside the range of MiGz and SAMs. This issue is discussed in greater detail below. Second, tanker vulnerability will probably vary considerably from theater to theater and from conflict to conflict. There are potential theaters of operation where tankers will incur far less risk than in central Europe. In many parts of the PACOM region, for instance, tankers will probably play an important role supporting fighter combat operations because of the greater distances involved and because MiG and SAM threats will probably be much less in the refueling zones. Aerial refueling would also allow fighters to operate from bases considerably outside the ground combat zones, thus reducing their vulnerability to enemy offensive counterair actions.

Clearly, if US fighter capabilities are to be fully exploited in theater operations, the fighters will need the capability that tankers offer as a force multiplier. The use of tanker aircraft to support employment of fighter aircraft in theater operations is reviewed in the following section to show the vital role that air refueling operations have played in recent combat situations.

Employment Operations

The most extensive aerial refueling operations for combat employment since the introduction of the KC-135 were

performed in Southeast Asia during the Vietnam War. Aerial refueling by KC-135 tankers in that area commenced in mid-1964, and by mid-1965 there were approximately 45 tankers in Southeast Asia (70 percent were used to support bomber aircraft and 30 percent supported tactical fighters).¹⁹ By mid-1972 the average number of tankers at any one time was approximately 170 of which nearly 70 percent supported tactical fighter aircraft and the rest provided support for bombers, reconnaissance aircraft, and other PACAF assets.²⁰

This reversal of refueling support between bombers and fighters for theater operations should not go unnoticed. It is highly significant that tactical fighters relied heavily on aerial refueling to accomplish their combat missions. Not only did the KC-135s extend the range of tactical aircraft so that they could strike even the most remote targets, but, equally important, tankers assured the safe recovery of the fighters after the battle. This aspect of refueling operations saved precious lives and valuable aircraft. Estimates of the value of aircraft saved by last-minute air refueling run to the hundreds of millions of dollars.²¹

The Southeast Asia conflict brought about many changes in tactical operations, but the major change was in tactical doctrine. Before the war, TAC used aerial refueling primarily for deploying tactical aircraft to forward operating bases. In Southeast Asia, air refueling became a

necessary component in the employment of tactical air forces.²²

There are at least four paramount advantages resulting from air refueling during fighter employment. First, air refueling increases a fighter's radius of action. Second, it allows an increase in the amount of ordnance that fighters can carry. Third, it permits flexibility in targeting. Fourth, air refueling allows fighters increased loiter time in the target area.²³

In Southeast Asia, fighters normally operated in formations of several aircraft, and each formation received its fuel from a single tanker. The fighters formed a queue on the tanker and received their fuel one at a time. Queues of six aircraft or more were common. The impact of such queuing on tactical operations can be severe, since the range and endurance of the formation is determined by the fuel state of the first aircraft to refuel. This restriction is often referred to as the "boom intensity problem."

The ability to simultaneously refuel two or three receivers from a single tanker can provide significant operational advantages in the employment of tactical forces.²⁴ For example, one tanker refueling six fighters sequentially requires six refueling contacts and six additional contacts to replenish fuel used by the fighters during initial refueling. If the tanker were equipped with two wing pod drogues to permit multipoint refueling, the

time for the initial six contacts would be cut in half, reducing, if not eliminating, the need for additional replenishment contacts. Refueling three fighters simultaneously from wide-body tankers may be feasible and would allow a further reduction in the time required to refuel a formation.

Several tactical advantages can be derived from multipoint refueling. Refueling en route to a target in minimum time reduces the time available to enemy radar to detect the incoming formation, thus reducing the advance warning time to enemy defenders. Additionally, a tanker can maneuver freely and is less vulnerable when not refueling. Moreover, the tanker becomes available sooner for supporting additional missions or airborne emergencies.

The second significant aerial refueling combat operation in the recent past is associated with the Falkland Islands War. Caught unprepared in that situation, the British devised a makeshift hose and reel system to refuel their bombers on combat missions in defense of the distant islands. The major lesson from this event is that aerial refueling is an essential component for supporting employment of air assets in defense of national interests that exist in far corners of the world.

M. J. Armitage and R. A. Mason give the following description of the flexibility British forces achieved by using aerial refueling in defending the Falkland Islands:

The campaign showed how a single aspect of air power flexibility can produce operational effectiveness across a broad field of capabilities. In this case the key factor was air-to-air refueling. Although expensive in terms of resources, this capability made possible vital air drops to the fleet by transport aircraft operating well beyond their normal radius of action; it facilitated the air reinforcement of an aircraft carrier at extreme range; it enabled Victor aircraft modified for the photographic and maritime reconnaissance roles to assess Argentine disposition around South Georgia before that dependency was reoccupied; it made possible Nimrods; and not least, in terms of demonstrating the potential impact of long-range air power to the Argentine garrison of the Falklands, it led to the attacks by Vulcans on Port Stanley itself.²⁵

Certainly there are many other lessons to be learned from these combat employment operations, and such lessons should be incorporated in the doctrine, strategy, and tactics used by those who plan and make decisions affecting the way we will fight future wars. For example, how would US fighters defend against a Soviet attack in northern Norway, particularly if the attack were part of a major effort to take control of and secure the Scandinavian peninsula? What kind of strike packages would be required to regain and maintain control of NATO's northern flank? Certainly, this scenario would require extensive aerial refueling support despite the increased range capabilities of modern fighters. The employment of tactical fighters in such an operation might be reminiscent of the large fighter formations used in Southeast Asia. Major problems then were the serious operational limitations and inefficiency caused

by being able to refuel only one fighter at a time with a single-boom tanker.²⁶

The problems of aerial refueling for fighter combat employment can be substantially reduced by incorporating the probe and drogue multipoint refueling system on tankers. Aside from the multipoint issue, the question is: Should Air Force aircraft rely on one refueling system or two? The following section examines the development of the two aerial refueling systems used by modern aircraft.

Systems Development: One System or Two?

Another brief look at the history of air refueling provides an interesting background to the development and use of both the boom and the probe and drogue refueling systems. During and immediately after World War II, developments in aerial refueling were limited to a single system for fuel transfer. This system involved a hose-only connection between two aircraft. The fuel transfer rate was only about 600 pounds per minute primarily because fuel flow depended on gravity. Using this system, a tanker flying above and behind the receiver aircraft extended a weighted line attached to an internal hose. The receiver trailed a horizontal line with a grapnel attached. When the two lines crossed and made contact, the receiver aircraft hauled in the line with the attached hose from the tanker, establishing connection and allowing fuel to be transferred.²⁷ Slight modifications for establishing the

hose connection between the two aircraft were developed, but the fuel transfer rate remained at about 600 pounds per minute.²⁸ The major problems associated with the hose method of aerial refueling were the slow transfer rate, difficulty in making contacts between tanker and receiver, the weight of the refueling equipment, and the slow airspeed of the tanker during refueling.²⁹

Between 1948 and 1949, aerial refueling was greatly improved by the development of two distinctly different refueling systems. The British developed the probe and drogue system, and the Americans developed the revolutionary boom and receptacle system.

The British probe and drogue system evolved from the hose-only method. The probe and drogue system allowed refueling to be completed in less time because of the reduced complexity of the air refueling equipment and because initial contact could be established quickly. Although this refueling system was less complex and of lighter weight, its fuel transfer rate remained approximately 600 pounds per minute because it still depended on gravity to induce fuel transfer. Thus, once the tanker was linked to the receiver, off-loading large amounts of fuel, especially to strategic bombers on long-range missions, required a lengthy period. TAC still officially maintained the position that it wished to develop an air refueling system using probe and drogue.³⁰ The Air Force ordered probe and drogue equipment from the British, but at

the same time contracted with Boeing to design a better refueling system.³¹

In 1949 the Boeing Military Airplane Company developed the "flying boom." Because this system used a pump to transfer fuel, its transfer rate increased to more than 4,000 pounds per minute. This revolutionary method was incorporated on the B-29 (the modified aircraft was designated the KB-29 tanker). It was also incorporated into the C-97 with the production of more than 800 KC-97 tanker aircraft.³² The boom refueling system worked exceptionally well for refueling bomber aircraft. The airspeed of the KC-97, however, was not great enough to refuel jet bombers at high cruising airspeeds. This problem was rapidly solved by the introduction of the KC-135 in 1956. This aircraft was equipped with a similar flying boom that could transfer fuel at a rate of more than 6,000 pounds per minute and could cruise at airspeeds compatible with B-52s. By 1956 Strategic Air Command was rapidly acquiring the KC-135 and the aerial refueling system that supports its strategic bombers today.

Although SAC was convinced of the merits of the flying boom system, the Royal Air Force, the US Navy, and Tactical Air Command still saw advantages in the probe and drogue system. TAC transformed the British system of using only one drogue per tanker into a system of three drogues per tanker allowing refueling of three receivers simultaneously.³³ This system made aerial refueling fast and

flexible, and it was readily accepted by fighter pilots of all services as the preferred refueling method.³⁴ In 1952 this system was proved operational when KB-29s equipped with wing tip and tail hose and drogues ferried F-84Es to Japan and Korea.

In 1954 the US Navy began operating the R-3Y seaplane as a tanker by using four hose and reel wing pod units mounted under the wings. The R-3Y was capable of refueling four fighters simultaneously with fuel transfer rates of about 1,500 pounds per minute to each fighter.³⁵ The Navy understood the advantages of multipoint refueling, but the concept was not fully exploited, and it became dormant when the aircraft was phased out of the inventory.

In 1956 TAC received KB-50 tankers equipped with probe and drogue refueling capability.³⁶ Most B-50 bombers were converted to KB-50J and KB-50K triple-point probe and drogue tankers. These multipoint refueling aircraft operated successfully with TAC until their retirement in 1965.³⁷ Although TAC had been promised the new KC-135 jet as a replacement tanker to support its jet fighters, none were received and no delivery date had been set by late 1961.³⁸

Since the KC-135s were needed to support strategic bombers dedicated to the single integrated operational plan (SIOP), the commander of Strategic Air Command, at that time Gen Curtis E. LeMay, rightly established that the number one priority of the KC-135s would be supporting his command. Later, as vice chief of staff, General LeMay established the

policy that the Air Force would use a single refueling system featuring only the boom and receptacle method. TAC was directed to develop future fighters compatible with boom refueling and to use a boom-to-drogue adapter as an interim measure.³⁹ The adapter was considered adequate, but it was certainly not the most desirable method for refueling fighters. Nevertheless, the single refueling system policy established in 1960 has continued to date.

Thus at the present time nearly all Air Force fighters are designed to use the boom and receptacle refueling system. On the other hand, the Navy has relied on the probe and drogue system and currently possesses more than 3,600 probe-equipped receiver aircraft.⁴⁰ The Navy requires a highly reliable, modern probe and drogue refueling system that fully satisfies the fuel transfer rates needed by fighter-type aircraft. Due to the unique nature and requirements for refueling Navy carrier aircraft, the Air Force and Navy did not work together in developing aerial refueling systems until a formal memorandum of understanding was signed in 1981. Consistent with this agreement, the new advanced tanker-cargo aircraft, the KC-10, was equipped to be compatible with both independent refueling systems: the boom and receptacle and the probe and drogue.⁴¹

Now the Air Force is confronted with the question: Should its aerial refueling capability consist of one or two systems? It would appear by almost any analysis that two aerial refueling systems are required to meet the needs of

aircraft assigned to the Department of Defense. Therefore, SAC, as the single manager of aerial refueling assets, should ensure that all tanker aircraft be equipped with both independent refueling systems to fully satisfy defense requirements. To fully consider this question, this study next examines some of the advantages and disadvantages of the two systems presently in operation.

Systems Advantages and Disadvantages

In reviewing the development of air refueling systems, the contribution of refueling to employment operations, and aerial refueling concepts, the author believes that a strong case has already been made for modifying all tanker aircraft to include probe and drogue as well as boom and receptacle systems. For such heavy aircraft as bombers and airlifters with their large fuel requirements, the boom and receptacle system is the most advantageous due to the high fuel transfer rates required. For such lighter, smaller aircraft as jet fighters, the probe and drogue system is most effective, and future tactical fighters should be probe equipped. To strengthen the argument, the following sections examine the advantages and disadvantages of the two systems when they are used in conjunction with tactical fighter operations.

Boom and Receptacle System

One advantage claimed for the boom and receptacle system is that the fighter pilot is only required to position himself within the refueling envelope. The tanker boom operator controls the refueling operation, including "flying" the boom to connect with the refueling receptacle. Whether this is really an advantage is not clear-cut. The refueling envelope is a relatively small space in contrast to the maneuvering envelope available in probe and drogue refueling. To achieve the advantage of maneuvering in a larger envelope, however, the fighter pilot must establish his own refueling connection with the drogue. The advantage of one system over the other is largely a matter of individual pilot preference.

It is worth noting that a flying boom fitted with a hose and drogue attachment offers the fighter pilot even less maneuvering room than the straight boom and receptacle system. With a hose and drogue attachment on the boom, the boom is stationary (the operator does not fly the boom) during refueling, and the fighter takes fuel from a hose that is much shorter than the one on a full hose and reel system. The fighter pilot must make the connection and maintain position within the relatively small envelope permitted by the short hose.

A second advantage of the boom and receptacle refueling system is that the boom operator is able to control the movement of the boom to avert mishaps and to handle any

emergency situations that may develop. This system has been proved reliable, although mishaps continue to occur due to systems malfunctions, boom operator error, or pilot error.

The major disadvantage of boom and receptacle refueling for fighters is that there are often six or more fighters in a coordinated strike package, each patiently waiting its turn to connect with the boom to obtain fuel. This queuing phenomenon is the boom intensity problem discussed earlier.

Other disadvantages for the boom and receptacle refueling system are the high costs and complexity associated with this sophisticated apparatus. These aspects do not directly affect the fighters, but they do impact on the present availability and future procurement of tankers.

Probe and Drogue System

One of the main advantages of the probe and drogue system is its capability for overcoming the boom intensity and excess time problem by attaching two wing pod drogues to the tanker. As already mentioned, by refueling two fighters simultaneously, the time that the fighters spend refueling can be reduced by approximately 75 percent. This reduced refueling time, in turn, would enable the tanker to have considerably more fuel available to off-load to other receivers. Also, by reducing the time that fighters have to remain with tankers, the fighters could remain in the combat area or on patrol longer.⁴²

The less fuel burned by either the tanker or the receivers during aerial contact, the more that is available to conduct the fighter mission. An example illustrates this point. At fighter refueling speeds, a KC-135A burns something in excess of 200 pounds per minute. Reducing the air refueling time from 40 minutes to 10 minutes (75 percent) makes approximately 6,000 pounds of additional fuel available. That amount of fuel could easily be enough to service another receiver aircraft. In this example, the fuel savings in a four-tanker cell (formation) could be enough to refuel an extra flight of four fighters or allow the same mission to be accomplished with one less tanker.

Another advantage achieved by having two wing pod drogues on one tanker is redundancy. If one of the drogues should malfunction, the second drogue is still capable of providing fuel. At first glance this may seem like a minor advantage, but when contrasted with boom refueling that requires an additional tanker for redundancy, the multipoint wing pod system is highly advantageous.

A third advantage of the probe and drogue system is that it does not require a boom operator. Most fighter pilots have no difficulty establishing contact with the drogue and using other visual references to keep within the refueling envelope. With proper training in probe and drogue refueling, the refueling operation is simplified for both the receiver pilot and tanker crew.

A fourth advantage of probe and drogue is its interoperability for joint and combined fighter operations. By 1990 the US Navy is expected to have 3,638 aircraft equipped with receiver probes. Other free world air forces, including those in NATO, are projected to have 3,729 probe-equipped receiver aircraft.⁴³ Synergistic effects could be achieved if TAC fighters were probe equipped to permit interoperability with the refueling systems and tactics of the Navy and free world allies.

A disadvantage of the probe and drogue system is that since the hose is more flexible than a boom, a potential exists for damage to the receiver aircraft during disconnects. If the hose is moved outside its stabilized position in the airstream and a disconnect is made, the hose and drogue can move rapidly up or down and damage the receiver aircraft. Normally, however, proper training in probe and drogue techniques is sufficient to prevent pilots from allowing their fighters to be damaged by the hose and drogue.

From the foregoing discussion, the reader can see that for refueling tactical fighters, the advantages of the probe and drogue refueling system far outweigh its disadvantages when compared to the boom and receptacle refueling system. Therefore, the author believes the Air Force should return to the probe and drogue refueling system for fighters while retaining its boom and receptacle system for heavier aircraft. Beginning with the next generation of fighter

aircraft, Air Force fighters should be probe equipped. During the transition period, the older fighters equipped for boom refueling can still use the boom as long as all tanker aircraft are dual equipped with boom and receptacle and probe and drogue refueling systems.

The sections that follow provide a cursory look at other aerial refueling operations, contributing factors to the tanker shortfall, force structure problems, and future considerations for tanker development. These topics are included in this paper to delineate additional concerns that must be addressed when shaping the doctrine, strategy, and tactics for future aerial refueling.

Navy Employment and the Land-Based Tanker

Aerial refueling operations in the Navy have been unique since Navy fighter patrols and other fighter operations required only small amounts of transferable fuel to loiter or reach their targets. These refueling operations were handled by KA-6s or other Navy fighter aircraft equipped for buddy refueling.

Until recently the Navy has been able to conduct offshore strike operations with aircraft carriers standing close to land. With foreign nations acquiring modern, long-range shoreline defenses, the Navy has come to realize that a larger tanker would significantly enhance the employment of carrier aircraft and contribute to carrier survivability. To this end, the Navy developed an

operations proposal in 1984 to procure four land-based tankers equipped with multipoint probe and drogue refueling systems. This initiative was quickly attacked by the Air Force as an infringement upon the single manager concept under which SAC is the single manager for aerial refueling. Additionally, there were suspicions that the requested Navy tanker would more likely be used as a VIP aircraft since its cargo area was to be equipped for such use. When the Navy lost its fight to procure its own land-based tankers, it requested the new KC-10 tanker be modified to support Navy carrier operations.

A 1981 Air Force-Navy memorandum of understanding required the KC-10 to be compatible with probe-equipped aircraft. The original KC-10 was equipped with one center-line hose and reel drogue system to satisfy the memorandum. At the time the KC-10 was being developed and procured, additional hose and reel units were suggested for the wing tips, but SAC would not allocate any of its scarce funds for more than a single hose and reel system. Also, the Navy was not inclined to allocate any of its limited budget for wing pod refueling systems at that time. Modifying the KC-10 with wing tip pods will require the purchase of 40 hose and reel refueling kits that can be attached to the aircraft in about one hour minimum. Unfortunately, it will cost substantially more to modify the KC-10s with wing pod refueling kits after they are delivered to the Air Force.

When the wing pod refueling kits are available for the KC-10, the multipoint tanker will be a great asset in support of carrier operations. The KC-10 will enable aircraft carriers to remain at a safe distance from shoreline defenses, while permitting carrier aircraft to reach their targets. The KC-10 has the capability to remain on station for a lengthy time and is itself refuelable, which means KC-10s could receive additional fuel from other tankers to increase their utility.

Specialized Operations

Air Force KC-10 tanker support for the Navy is new, but it is not the only specialized aerial refueling operation. Within the Air Force, HC-130s provide aerial refueling to helicopters for search and rescue missions. These refueling operations use the probe and drogue system, and they are performed at much slower speeds than used in refueling jet fighters and bombers.

The Marines use KC-130s to refuel their Harrier aircraft as well as their rotary wing receivers. One aspect of aerial refueling that is slowly being developed by Marine planners is the employment of low-speed, low-altitude refueling primarily for helicopters. For the Marine, aerial refueling in amphibious and intratheater operations provides flexibility and a force multiplier in terms of increased ranges, increased payloads, decreased deck time, and more rapid initial ground refueling.⁴⁴

As previously mentioned, the Navy has retained control of its carrier aerial refueling operations using the KA-6 as its primary tanker aircraft. The KA-6 carries approximately 10,000 pounds of transferable fuel that is off-loaded to carrier-based jet fighters using the probe and drogue refueling system.

Other specialized aerial refueling operations involve the E-3A airborne warning and control systems (AWACS) aircraft, reconnaissance aircraft, and airborne command and control aircraft. Some of these refueling operations use air refuelable tankers. Also, certain of these operations require specialized fuels for the receiver aircraft.

Most of these specialized refueling operations lack interoperability, and some of them (AWACS and reconnaissance, for instance) contribute to the tanker shortfall problem. There are, however, refueling philosophies and capabilities that could and should be combined to achieve the most efficient employment of tanker aircraft. One is the Navy probe and drogue concept, which should be applied to tactical fighters owned and operated by TAC, PACAF, and USAFE.

Tanker Shortfall

Competing requirements among the services and Air Force commands have created a distinct shortfall of tanker assets. This was made vividly clear during the Yom Kippur War of 1973 when the Military Airlift Command (MAC) required

extensive aerial refueling to support the airlift of much-needed equipment to Israel. International politics created operational problems and placed a great strain on tanker resources when some nations refused to grant clearance for Air Force aircraft to overfly their territories. The tanker shortfall problem was compounded by MAC's decision to make more of their C-141 airlifters air refuelable, since additional tankers are needed to support additional refuelable MAC aircraft.⁴⁵

Growth in air refuelable aircraft has not been limited to MAC airlifters. The numbers of air refuelable fighters of TAC, PACAF, and USAFE have increased substantially. Statistics compiled by SAC show that in 1960 approximately 2,000 air refuelable aircraft existed in the Air Force inventory (approximately 300 fighters and 1,700 strategic bombers). Twenty years later, SAC statistics show approximately 4,500 air refuelable aircraft (approximately 3,500 fighters, 500 airlifters, and 500 strategic bombers).⁴⁶

The shortfall of tanker aircraft was recognized in the early 1970s; however, political considerations and budgeting priorities persuaded the Air Force to focus on the procurement of the B-1 at the expense of the immediate and continually increasing need for tanker aircraft.

By 1984 the tanker shortfall problem reached a critical stage but was momentarily reduced by adding the KC-10. The Air Force is also reducing the tanker shortfall by re-engining the KC-135A and designating it the KC-135R.

The combined KC-10 and KC-135R programs, however, will not satisfy the tanker shortfall forecast for the next 15 years.⁴⁷

An additional strain on tanker assets will be Navy requirements, which were not considered in the Air Force forecast. In essence the Department of Defense has more refuelable aircraft than can be refueled effectively in a large-scale conflict. Remedying this situation would require purchase of more tankers to support general-purpose forces, specifically Air Force and Navy fighters, which constitute the largest portion of air refuelable aircraft. This should be of primary consideration when developing the future tanker force structure.

Force Structure

The tanker force requires restructuring if one adheres to the philosophy that TAC fighters should use probe and drogue refueling and that bombers and airlifters should use the boom and receptacle system. This would require all SAC tankers to maintain both refueling systems. It would require funding to install multipoint probe and drogue systems on all SAC tankers, and it would require that all future fighters be equipped with refueling probes rather than receptacles. There are important cost advantages to this approach, however.

For financial as well as operational reasons, the Air Force must carefully weigh the merits of quality versus

quantity in planning the future tanker force structure. Because of severe budgeting constraints and competing priorities, planning should be based on projected wartime refueling scenarios rather than on simply fulfilling the need for more tanker aircraft. Allocating funds to install the multipoint probe and drogue system on all tanker aircraft would result in a quality tanker force that could be expanded to support refueling requirements if a large-scale conflict occurred. Expansion is achieved more easily with a multipoint probe and drogue system than it is with the boom and receptacle system simply because the multipoint system essentially doubles or triples the number of fighter aircraft that can be refueled at one time. If pressed by wartime demands, the number of probe and drogue refueling points can be tripled with the tail drogue adapter installed.

The Air Force is presently purchasing new tankers because these aircraft incorporate advances in aerial refueling and aircraft technology and because they help fill the current and forecast tanker shortfall. The Air Force should also purchase new tankers for well-defined reasons dictated by the employment concepts needed to support Air Force strategy, doctrine, and tactics, as well as for the reason of tanker shortfall problems. As stated earlier in this paper, the multipoint probe and drogue system greatly enhances operational capabilities for wartime employment.

Future Considerations

Aerial refueling should primarily support warfighting by increasing receiver aircraft endurance, increasing receiver aircraft range, and permitting flexibility to respond quickly to any target location. Planners need to look at employment options that further enhance warfighting capabilities. One option is employing tankers with multipoint refueling systems for fighter aircraft. Another option is to use air refuelable tankers to support both Air Force and Navy logistical and tactical operations for better use of fuel consumed and transferred. As with any weapon system, increasing capabilities requires more money. Priorities must be established to maintain an effective defense for today as well for tomorrow.

In addition to these considerations, future research should address such issues as low-altitude refueling, tanker defenses, application of "stealth" technology to tanker aircraft, and prelaunch survivability in time of general war. These issues are not subjects of this paper but are suggested for others to research.

Conclusion

During the late 1950s and early 1960s, the Air Force acquired a fleet of B-52 bombers and KC-135 tankers that fulfilled the requirement of defending the United States, as well as protecting US global interests. Aerial refueling

was revolutionized with the development and mating of the flying boom with jet tankers.

After the Strategic Air Command was designated the single manager for aerial refueling, coordination with other commands and services was centralized and effective; however, SAC could not meet the total requirements for aerial refueling demanded by TAC and the Navy. This is not to blame SAC, since it seems that neither TAC nor the Navy cooperated to the extent of providing their own funds to develop a quality tanker. Apparently, both TAC and the Navy preferred to spend funds for their particular weapon systems rather than shift funds to SAC to fully equip a quality tanker to support their fighter operations.

Thus, since neither TAC nor the Navy wanted to spend its funds on a SAC tanker, neither has been willing to place significant requirements on tanker assets that would force it to provide funds for specific refueling systems not common to SAC aerial refueling capabilities, that is, multipoint probe and drogue refueling.

This issue must be faced now. TAC must decide whether it will seek to enhance its fighter employment operations by returning to the probe and drogue system that was considered essential 20 years ago or will remain limited in its employment operations by relying on the single-boom tanker. The Navy has apparently decided to commit itself to improving its refueling operations for carrier fighter aircraft by requesting wing pod probe and drogue systems for

the KC-10s. It is time for TAC to analyze the strategy and tactics associated with aerial refueling and to change to a refueling system that will enable its fighter aircraft to be best employed in the combat theater.

NOTES

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2. Air Force vice chief of staff to SAC and TAC, letter, subject: USAF Tanker Policy, on file with the Office of the Historian, Headquarters Strategic Air Command, Offutt AFB, Nebr., 3 May 1968.

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5. Latimer-Needham, Refueling in Flight, 9.

6. Ibid., 10-11.

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8. Ibid.

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31. Ibid., 147.

32. Pedigree of Champions: Boeing Since 1916, 6th ed. (The Boeing Co., 1985), 42-43.

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39. Air Force vice chief of staff to SAC and TAC, letter, subject: USAF Tanker Policy, 3 May 1968.

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41. Memorandum of Understanding between the Department of the Navy and the Department of the Air Force, para 3.a.(1). "As a minimum, all general support tanker aircraft (example - KC-10) will be equipped with aerial refueling systems compatible with both probe and receptacle equipped receiver aircraft," 18 July 1981.
42. See figure 1, "Multipoint Aerial Tanker--Tactical Employment," Boeing Wichita Co., Wichita, Kans.
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46. See figure 2, "Growth of Air Refueled Aircraft Inventory," Headquarters Strategic Air Command, Offutt AFB, Nebr.
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