

Aerial refueling



USAF [KC-135R Stratotanker](#), two [F-15s](#) (twin fins) and two [F-16s](#), on an aerial refueling training mission

Aerial refueling, also called **in-flight refueling (IFR)** or **air-to-air refueling (AAR)**, is the practice of transferring [fuel](#) from one [aircraft](#) to another during flight. This allows the receiving aircraft to remain airborne longer, and to take off with a greater [payload](#). Usually, the aircraft providing the fuel is specially designed for the task. The requirement to refuel during a flight is primarily a military requirement, and there are no known regular civilian in-flight refueling operations.

History and development



An [F-101A Voodoo](#) (top right), [B-66 Destroyer](#) (top left) and [F-100D Super Sabre](#) refuel from a [KB-50J](#) tanker. Taken in the early [1960s](#)

Some of the earliest experiments in aerial refueling took place in the [1920s](#), when it was as simple as two slow-flying aircraft flying in formation, with a hose run down from a handheld gas tank on one airplane and placed into the usual fuel filler of the other. It was a very dangerous process until [1935](#) when brothers [Fred and Al Key](#) demonstrated the first spill-free refueling nozzle, designed by A. D. Hunter. Nowadays, specialized [tanker](#) aircraft have equipment specially designed for the task of offloading fuel to the receiver aircraft, based on Hunter's design, even at the higher speeds modern [jet aircraft](#) typically need to remain airborne.

In [1947](#) from [February 26](#) to [March 3](#) an American [B29](#) «Lucky Lady» flew around the World in 94 Hours, 1 Min. without stopping. Refuelling was done 3 times during the flight. The flight started and ended at [Fort Worth](#) Texas. Refuelling was done in [West Africa](#), Near [Guam](#) and in the Pacific between [Hawaii](#) and [West Coast](#)

Aerial refuelling systems

The two most common approaches for making the union between the two aircraft are the *boom and receptacle* system and the *probe and drogue* system. Much less popular was the *wing-to-wing* system, which is no longer used.

Boom and receiver



USAF [C-5](#) approaches a KC-135R

The *boom* is a long, rigid, hollow shaft, usually fitted to the rear of the aircraft. (It almost connects the two lower aircraft in the picture at right.) It usually has a telescoping extension, a [poppet valve](#) at the end (the boom nozzle) to keep fuel in and permit it to flow, and small [wings](#), sometimes known as *ruddevators* depending on design particulars (visible in picture below, in the "V" shape), to enable it to be "flown" into the receptacle of the reciever aircraft to be refueled. This *receptacle* is fitted onto the top of the aircraft, usually on its centerline and usually either behind or close in front of the [cockpit](#). The receptacle is a round opening which connects to the fuel tanks, with a valve to keep the fuel in when not being refueled, and dust and debris out. The boom has a nozzle which fits into this opening.

During refueling operations, a tanker aircraft will fly in a straight and level altitude at constant speed, while the receiver takes a standard position behind and below the tanker. Modern tankers have lights which illuminate the areas outside this range, so that if the pilot can see them, he is directed to fly back towards the desired spot. Once in position, the receiver pilot flies formation with the tanker, although this can be complicated by [wake turbulence](#). The crewman operating the boom, called a *boomer* or [boom operator](#) (in the [USAF](#), usually an enlisted [sergeant](#)), then unlatches the boom from its stowed position, and directs it towards the receiver by "flying" it with the attached wings. The telescoping section is then [hydraulically](#) extended until the nozzle fits into the receiver's receptacle. When an electrical signal is passed between the boom and receiver, both valves are hydraulically opened, and [pumps](#) operated by the pilot on the tanker drive fuel through the shaft of the boom, and into the receiver. Once the two are mated, additional lights (pilot director lights (PDIs)) on the tanker

will be turned on if the receiver flies too far to one side, too low or too high, or too near or too far away, activated by sensing [switches](#) in the boom. When fueling is complete, the valves are closed and the boom is automatically or manually retracted by the boom operator. In addition to being used by the US Air Force, the boom method is used by the Netherlands (KDC-10), Israel (modified Boeing 707) and Turkey (ex-USAF KC-135R). All the mentioned nations operate US designed aircraft.

The primary advantage to this method of refueling is that higher volumes of fuel can be transferred in a shorter amount of time. Although tankers equipped with rigid refueling booms can only service one properly equipped aircraft at a time, the transfer capacity is useful for the US Air Force, which operates many very large aircraft such as [strategic bombers](#). With advancements of the probe and drogue system they are now able to deliver the same amount of fuel flow. In some cases, such as the KC-135FR in service with the [French Air Force](#), refueling-boom equipped tankers can be converted to an all probe-and-drogue system. The KC-135FR retains its articulated boom, but has a hose at the end of it instead of the usual nozzle.

Probe and drogue



Tornado GR4 with probe attached to an RAF VC10 tanker over Iraq

The Boom to Drogue Adapter (BDA) or *drogue* (or *para-drogue*), sometimes called a *basket*, is a fitting resembling a plastic [shuttlecock](#), attached to a flexible hose at its narrow end, with a valve where the two meet. The receiver has a *probe*, which is a rigid, but sometimes jointed and retractable, arm placed usually on the side of the airplane's nose.

Again, the tanker flies straight and level, and the drogue is allowed to trail out behind and below it. The drogue can be flown by the boom operator but the receiver pilot must fly his probe directly into the basket to make contact. The boom operator holds the BDA as motionless as possible. After the receiver states "contact" the boom operator triggers contact which allows the tanker pilot to start the air refueling pumps and offload fuel. The receiver maintains his position during refueling, keeping an eye on the hose to make sure he remains in a suitable position. When fueling is complete, he decelerates hard enough to yank the probe out of the basket.

Some boom-carrying tankers have special hoses which can be attached to the nozzle of the boom to allow them to also refuel probe-equipped aircraft. Others may have both a boom and one or more hose-and-drogue assemblies attached to the wing tips known as the Multi-Point Refueling System or MPRS. The U.S. Navy, Marine Corps, and other NATO nations use this system, rather than the boom system. Unlike the boom-and-receiver system, multiple aircraft can be refuelled simultaneously with the probe-and-drogue system.

This system was first used on late models of the [KB-29M Superfortress](#). Its first use in combat occurred on [May 29 1952](#) when twelve [F-84s](#) were refueled during a mission from [Itazuke, Japan](#) to [Sariwon, North Korea](#).

Wing-to-wing

In this method, the tanker aircraft released a flexible hose from its wingtip. An aircraft, flying beside it, had to catch the hose with a special lock under its wingtip. After the hose was locked, and the connection was established, the fuel was pumped. It was used on a small number of Soviet [Tu-4](#) and [Tu-16](#) only (the tanker variant was Tu-16Z).

Strategic and tactical implications



An [F-15 Eagle](#) disengages from a [KC-10 Extender](#)



A [KC-10 Extender](#) from [Travis Air Force Base](#), California, refuels an [F/A-22 Raptor](#)

Strategic uses and considerations

The early development of the [KC-97](#) and [KC-135 Stratotankers](#) was inspired by the desire of the [United States](#) to be able to keep fleets of [B-47 Stratojet](#) and [B-52 Stratofortress strategic bombers](#) aloft during the [Cold War](#), either to retaliate against a [Soviet](#) strike and ensure [Mutual Assured Destruction](#), or to bomb the U.S.S.R. first had it been ordered to do so by the President. The bombers would fly orbits around their assigned positions from which they were to enter Soviet airspace if they received the order, and the tankers kept the bombers' fuel tanks full so that they could keep a force in the air 24 hours a day, and still have enough fuel to reach their targets in the Soviet Union. This also ensured that a [first strike](#) against the bombers' [airfields](#) could not obliterate the U.S.'s ability to retaliate by bomber. A noted example of refueling used in this manner in the movies can be seen in the opening credits of [Dr. Strangelove or: How I Learned to Stop Worrying and Love the Bomb](#) (a fictional movie, but the air-ballet of refueling scenes are from actual B-52s refueling from KC-135s).

A byproduct of this development effort and the building of large numbers of tankers was that these tankers were also available to refuel [cargo aircraft](#), [fighter aircraft](#), and [ground attack aircraft](#), in addition to bombers, for ferrying to distant theaters of operations. This was much used during the [Vietnam War](#), when many aircraft could not have covered the transoceanic distances without aerial refueling, even with intermediate bases in [Hawaii](#) and [Okinawa](#). In addition to allowing the transport of the aircraft themselves, the cargo aircraft could also carry [matériel](#), supplies, and personnel to [Vietnam](#) without landing to refuel. KC-135s were also frequently used for refueling of air combat missions from air bases in Thailand.

The USAF SR-71 "Blackbird" strategic reconnaissance airplane made frequent use of air-to-air refueling. Its home base was at [Beale AFB](#) in central California, but to make actual reconnaissance missions over potential enemies, it was necessary to fly the craft to forward bases on Okinawa or in Europe. Hence, there were lots of trans-Pacific and trans-Atlantic flights. Also, for best performance, it was necessary for the SR-71 to take off with less-than-full jet-fuel tanks. Next, the SR-71 would immediately rendezvous with a special KC-135 to top off its tanks for full extended-range. Then, the SR-71 was capable of flying for many hours on its own. The KC-135 needed to be special, because standard military aircraft use JP-4 kerosene (known as "paraffin" in the U.K.), but the SR-71 needed to use USAF JP-7 fuel. This is thicker, less flammable fuel than the SR-71 used because the SR-71 gets quite hot during its extended supersonic flights, and the SR-71 was also somewhat leaky at lower temperatures. The JP-7 kerosene is so thick that a careless technician would flick a lit cigarette butt into a bucket of JP-7 without igniting it. In fact, it would extinguish the flame. On its numerous overseas deployments to Okinawa, the SR-71 acquired the nickname of "Habu", after the name of a black predatory snake native to Okinawa.

Tactical uses and considerations

The capability of refueling after takeoff conveys two considerable tactical advantages to those with tankers. Most obviously, it allows attack aircraft, fighters, and bombers to reach distances they couldn't otherwise, and patrol aircraft to remain airborne longer. Additionally, since an aircraft's maximum takeoff weight is generally less than the maximum weight with which it can stay airborne, this allows an aircraft to take off with only a partial fuel load, and carry additional [payload](#) weight instead. Then, after reaching altitude, the aircraft's tanks can be topped off by a tanker, bringing it up to its maximum flight weight.

Vietnam War

For airstrikes from Thailand to North Vietnam, it was common for USAF fighter-bombers to refuel from KC-135s on the way out. Besides extending their range, this enabled the F-105s and F-4 Phantoms to carry more bombs and rockets. Tankers were also available for refueling on the way back if necessary, but it most frequently was not. In addition to ferrying aircraft across the [Pacific Ocean](#), Aerial refueling made it possible for damaged fighters to hook up to the tankers and be towed to the point where they could glide to the base and land. This saved numerous airplanes, and is one of the uses of tanker aircraft in that theater. The US Navy frequently used carrier-based aerial tankers like the KA-3 Skywarrior to refuel aloft Navy and Marine fighters and attack planes, like the F-4, A-4, A-6, and A-7. This was particularly useful when a pilot was returning from an airstrike, was having difficulty landing, and was running low on jet fuel. This gave him fuel for more attempts at landing for a successful "trap" on an aircraft carrier. The KA-3 could also refuel fighters on extended Combat Air Patrol and E-2 Hawkeye Airborne Electronic Warning aircraft on extended patrol. USMC jets based in South Vietnam and Thailand also used USMC KC-130 Hercules transports for air-to-air refueling on missions.

Falklands War

Aerial refueling during the British Falklands War was carried out almost exclusively by the [Handley Page Victor](#). These aircraft aided deployments from the UK to the [Ascension Island](#) staging post in the South Atlantic, and further deployments south of attack, transport, and maritime patrol aircraft. The most famous refueling missions were the "[Operation Black Buck](#)" sorties which involved Victor tankers refueling [Avro Vulcan](#) bombers to attack the Argentine-captured airbase at Port Stanley on the [Falkland Islands](#). These missions had the effect of cratering the runways and deterring the Argentine Air Force from deploying fighters and A-4 Skyhawks to the Falklands, and the fighters had to be held back for potential defense of the Argentine mainland, even though in actuality, there were no British air strikes there. Keeping the A-4s off the Falklands limited the Argentine Air Force's ability to launch air strikes against the Royal Navy off the shores of the Falklands.

The Victor tankers were shortly afterwards retired from service, and they were replaced for RAF service by the Lockheed-California built converted L-1011 transports which were bought economically on the second-hand airliner market. These L-1011s have the capability of refueling jets from the RAF, the Royal Navy, and NATO aircraft.

The Persian Gulf War

During the time of Operation Desert Shield, the military build up to the Persian Gulf War, US Air Force KC-135s, McDonnell Douglas KC-10As, and USMC KC-130 Hercules aircraft were deployed to forward air bases in [England](#), [Diego Garcia](#), and Saudi Arabia. Aircraft stationed in Saudi Arabia normally maintained an orbit in the [Iraq-Saudi Arabia neutral zone](#), informally known as "Frisbee", and refueled Coalition Aircraft whenever necessary. This 24-hour air-refueling zone helped make the intense air campaign during Operation Desert Storm possible.

On January 16/17th, 1991, the first combat sortie of Desert Storm, and the longest combat sortie in history, at that time, was launched from [Barksdale AFB, Louisiana](#). Seven B-52Gs flew a thirty-five hour mission to the Persian Gulf region, and back, to launch Boeing Air Launched Cruise Missiles (ALCMs) with the surprise use of conventional warheads. All of this was made possible by in-flight refueling, and by the secret switch away from nuclear warheads on the ALCMs.

An extremely useful aerial tanker in Desert Storm was the USAF KC-10A *Extender*. Besides being larger than the other tankers, the KC-10A is equipped with the USAF "boom" refueling and also the "probe-and-drogue" system. This makes it possible for the KC-10A to refuel USAF aircraft, and also USMC and US Navy jets that use the "probe-and-drogue" system, and also allied aircraft, such as those from the U.K. and Saudi Arabia. The KC-10A was originally designed for the support of NATO in Europe by the USAF. In the case of armed conflict, with a full jet fuel load, the KC-10A is capable of flying from a base on the east coast of the US or Canada, flying nonstop to Europe, transferring a considerable amount of fuel in air-to-air refueling, and then returning to its home base, all without landing anywhere. This could have been very useful in the case when numerous European bases become disabled by Warsaw Pact strikes in Germany, Holland, France, and Great Britain.

Kosovo War

Tanker aircraft by refueling system

Boom and receiver



A B-2 Spirit prepares to refuel from a KC-135R

- [KB-29P](#)
 - adapted from the [B-29 Superfortress](#)
- [KC-97 Stratotanker](#)
 - adapted (heavily) from the [B-29 Superfortress](#)
- [KC-135 Stratotanker](#)
 - adapted from the [Boeing 707](#)
 - can also use drogue adapter
 - MPRS models will have two drogue hose reels (pods) at the wingtips
- [KC-10 Extender](#)
 - adapted from the [McDonnell Douglas DC-10](#)
 - (also has a retractable hose and drogue)
- [KC-767](#)
 - adapted from the [Boeing 767](#)
 - used by [Italy](#) and [Japan](#); not yet in U.S. military service
 - All US models, if ordered, will have fitting for MPRS
- [Airbus A330 MRTT](#)
 - development of Airbus A330 - 5 [Australian](#) aircraft will be equipped with both a flying boom and probe and drogue units. (UK aircraft probe and drogue only.)

Probe and drogue

- [Airbus A330](#)
 - [RAF Future Strategic Tanker Aircraft](#), due in service
- [Airbus A310 MRTT](#)
 - 4 for [Luftwaffe](#)
 - 2 for [Canadian Forces](#) (as [CC-150 Polaris](#))
- [Avro Vulcan](#)
 - specially modified for operations during the [Falklands War](#)
 - no longer in service with the RAF or elsewhere
- [Blackburn Buccaneer](#)
 - Equipped for buddy tanking
- [Boeing 707](#)
 - Used by the [South African Air Force](#) and others
- [KB-29M](#)
 - adapted from the [B-29 Superfortress](#); earlier versions used a "grappling hose" system; later models used a true probe-and-drogue
- [KB-50](#)
 - improved model of the [B-29 Superfortress](#)
- [HC-130 Hercules](#) and [KC-130 Hercules](#), especially in USMC service
 - variants of the [C-130 Hercules](#)
- [Lockheed L-1011](#) Tristar
 - K1 and KC1 variants deployed by the [Royal Air Force](#) and [Canadian Forces Air Command](#)
- [Vickers Valiant](#)
- [Vickers VC-10](#)
- [Handley Page Victor](#)
- [KA-3](#)
- [KA-4](#)
 - Equipped for buddy tanking
- [KA-6](#)
- [KA-7](#)



IAF Ilyushin Il-78 simultaneously refuels 2 [Jaguar](#) aircraft

- [S-3 Viking](#)
 - The current primary carrier-based tanker
- [F/A-18E/F](#)
 - equipped for buddy refueling as "Strike tankers"

- [Il-78](#) *Midas*
 - Standard Russian tanker, adapted from [Il-76](#)
 - the MKI variants currently deployed by the [Indian Air Force](#) (IAF)
- [Myasishchev M-4-2](#)
 - adapted from the M-4 bomber
- [Myasishchev 3MS-2](#)
 - adapted from the 3M bomber
- [Tu-16N](#) (and Tu-16Z with wing-to-wing system)
- [Su-24M](#)
 - equipped for buddy refueling with the UPAZ container as "Strike tankers"