PETROLEUM ECONOMIST

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The impact of $15 a barrel oil

A *Petroleum Economist* world survey

NORTH SEA SURVEY
1985 — LAST OF
THE GOLDEN YEARS?

War and prices hit Iran's oil exports

SPECIAL REPORT

The military demand for oil (part 2)

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NOTES OF THE MONTH

The role of petroleum in wartime

by Tom Cutler

Our first article on the military demand for oil, published in August 1985, dealt primarily with peacetime requirements. This article considers its significance in wartime, particularly for ground and air forces. A future article in the series will deal with oil's role in the context of naval forces.

THE MILITARY significance of oil falls into three categories, in which it serves as (1) an essential fuel, (2) a commodity transported and distributed by the military (in volumes greater than any other item of supply), and (3) an instrument of war (*e.g.* weapon or target). Industry's routine fulfillment of day-to-day military oil demand belies the fact that even in peacetime the political actions of governments and the commercial decisions of entrepreneurs can affect military oil supply security. At the same time, for its own reasons, the military does not rely entirely upon the private sector to perform all of the fuel services it requires. Instead, specialised military organisations are established to ensure that even under most hazardous conditions in the ground, sea, and air contexts of war, essential fuel needs will be met.

Petroleum first played a major military role in World War I, during which British and French armed forces both consumed more oil than had their entire countries in the years preceeding the war. Winston Churchill later remarked that "the Allies had floated on a sea of oil to victory", while Germany's military strategist General Erich Ludendorff wrote in his memoirs that "it was chiefly because of insufficient oil reserves in the World War that the German staff was forced to sue for peace in November 1918." Just over twenty years later during World War II, military petroleum consumption for the conduct of war in Europe had jumped almost thirty-fold. (Gasoline consumption by US combat forces in World War I peaked in the Meuse-Argonne battle of October 1918 at 150 000 gallons per day as compared with Allied consumption of gasoline in Europe during World War II which reached 4.5 million gallons per day in 1945.) It was also during World War II that Germany's military oil supply vulnerability prompted the establishment of the world's first synthetic oil industry which played a critical wartime role by supplying 90% of the Luftwaffe's aviation fuel needs. Military organisations around the world have since placed a premium upon sufficient supplies of petroleum upon which hinges their success on the battlefield.

The strategic significance of oil in war includes both direct consumption by armed forces as well as the indirect needs of civilian industries essential to military activity. Although oil consumption by defence-oriented industries can exceed direct military consumption, this demand is predominantly for installation uses and hence more suited for substitution of non-oil energy fuels than is the military's use of oil for mobility purposes for which there are no viable substitutes.

In peacetime, the military's direct share of national oil demand averages about 2-3% for most countries, but in war this share can soar to levels in excess of half the market, as is currently the case for Nicaragua. (Were the ongoing guerilla activity in Central America to escalate to full-scale war, then the figure would be even higher). There is considerable variation in national experiences, however, since in the case of the United States, the military's share of the oil market even during a full-scale conventional conflict would not likely exceed 10-15%. The overall size of the commercial market in war is likely to be smaller than in peace, however, and therefore comparisons of percentages during the transition from peace to war can be misleading.

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All military forces anticipate war situations and develop pre-arranged plans to serve as the theoretical basis upon which they will, initially at least, conduct war. These prearranged plans postulate the mix of forces to be employed and include estimates of the fuel required to fulfill selected battle objectives. Tactical plans must not only estimate how much fuel will be needed, but also what type, where, and when. In general, this is based upon the number of oil consuming pieces of military equipment (*e.g.* planes, ships and vehicles); their consumption rates; and the duration/intensity of their use. Military planners also incorporate into their oil plans estimates of how much fuel will be needed to provide the necessary logistical support to acquire, transport and deliver the oil to the combat zone.

REQUIREMENTS BY GROUND FORCES

Factors that have to be integrated into estimates of ground fuel requirements include climate (arctic, tropical, temperate), terrain (desert, jungle, flat plains, rolling hills, swamps, mountains, or urban areas) and operational considerations (use of special vehicles and equipment). Rates of consumption also vary according to the nature of hostilities and the stage of military activity.

The highest consumption rate is always experienced during offensive pursuit operations. Fuel is therefore an important priority at this time. Perhaps the best illustration of this occurred during World War II when the US First Army accorded priority to fuel over ammunition in a tactical move calculated to increase its mobility following its unexpected capture of the bridge over the Rhine at

Remagan in late-June 1944. In combat, fuel and ammunition use by ground forces fluctuates considerably and unexpectedly depending upon military movements. These rates tend to vary inversely with one another because high rates of mobility activity (and fuel consumption) often result from a low scale of enemy resistance and, hence, less firing. Conversely, combat vehicles generally fire their weapons when in a stationary position consuming fuel at an idle rate sufficient to operate their weapon systems and sensors.

Added to the complicated process of estimating fuel needs is the fact that much of the fuel required by armies is not used to fight, but rather by vehicles operating behind the combat zone in support of the battle effort. Indeed, crippling fuel shortages in the front lines are more often due not to availability problems *per se* but rather to an inability to deliver fuel to consuming units at the right place and time.

Logistics

Fuel is the largest single commodity that military logisticians must transport in terms of both volume and weight. In World War II petroleum and coal amounted to half of all military supplies transported. For military forces today it has been estimated that almost two-thirds of the weight of supplies would be for petroleum alone. In the case of the Falklands (Malvinas) conflict where fuel had to be moved over water instead of land, over 70% of the British Naval Task Force in terms of tonnage was dedicated to moving oil along Britain's 8 000-mile supply line to the South Atlantic.

The military must also be prepared to move fuel into remote, difficult, or dangerous locations where suitable commercial facilities may not exist or have ceased to function. This was the case in 1983 when considerable logistical support was required on short notice for the US Air Force to fly AWACS (Airborne Warning and Control System) support (with F-15 escorts) out of Sudan for the French military operating in Chad. Within a matter of days, the US had to arrange for some seventy trucks to move 80 000 gallons per day of military grade jet fuel (JP-4) over 750 miles from Port Sudan to Khartoum since there was no indigenous fuel distribution infrastructure capable of transporting it.

Because of the likely need to operate on a self-sustaining basis in areas where commercial facilities are insufficient to support military operations, many of the world's modern armies have their own modularly designed ground fuel supply systems capable of operating independent of commercial facilities under climatic and topographical extremes. This equipment must be mobile (or easily transportable) to allow for rapid dispersement in the event of attack. In all, a large scale military ground fuel distribution operation can be divided into three sections: the rear staging area, the forward support sector, and the front-line combat zone.

The rear staging area may originate with the off-take of fuel from a tanker, but fuel could also be obtained from a storage depot supplied by tank car or barge, or sourced from a commercial refinery or pipeline. In World War II, the Allies in Europe built military pipelines beneath the English Channel to supply fuel. The forward movement of oil within the combat zone is enhanced considerably by tactical pipelines. For example, Soviet pipelaying construction squadrons are capable of laying approximately 80 km of pipe per day using automatic pipe-layers. These high pipe-laying capabilities and storage levels reflect Soviet offensive doctrine that its armies should have sufficient fuel available to advance at the rate of approximately 100 km per day. Soviet stocks available for operations against NATO's central European region are estimated by the US Department of Defense to be 12 000 km of pipe.

The largest strategic military pipeline in the Free World is the NATO Pipeline System (NPS) in Western and Southern Europe which extends over 6 300 miles (10 000 km) with over 2 million cubic metres of storage capacity (44 440 million Imperial gallons.) This network consists of seven regional networks of small diameter pipe buried underground, and generally with a multi-product capability for jet fuel and/or diesel. Since a NATO decision in 1950 to develop a common military petroleum infrastructure, the Alliance has spent over $500 million on petroleum facilities (currently valued at over $3 billion) for the use of member countries. The target of a rash of terrorist attacks over the past two years, NATO has reinforced its pipeline security measures and benefited from realistic practice in wartime damage assessment and repair.

The pipeline portion of NATO's fuel infrastructure was originally designed to move fuel from tankers at selected sea entry points to military air bases and storage depots. Over the years, however, commercial depots and refineries have been integrated into the system and it is currently connected to more than 25 commercial refineries and more than 85 airbases. Commercial use of the Central Europe Pipeline System (CEPS) and other parts of the NPS has been encouraged since the system's capacity to handle wartime surges is underutilised in peacetime and since the tariffs from commercial usage provide badly needed revenue to maintain the system. According to NATO officials, however, expansion in commercial use is fundamentally limited by differences in specifications between fuels deemed acceptable to the military and those of fuels in common use on the civil retail oil market[1]. In wartime, battleground opportunities to obtain additional fuel supplies through the capture or scavenging of fuel from disabled or abandoned vehicles, supply depots and the like necessitates the involvement of small, specialized fuel inspection teams to identify its technical specifications and determine its military usefulness.

In the forward support sector, many Western armies use collapsible fuel tanks holding up to 200 000 gallons and specially equipped fuel trucks to move fuel from pipeline terminals or bulk storage depots to forward stockholding sites located just to the rear of the combat area. These fuel trucks are invariably of a size, capacity, multi-product capability, and pumping rate different from standard commercial fuel delivery trucks. Tank walls can be thicker than their commercial counterparts and those trucks assigned to carry aviation fuels utilise unusually stringent filter systems.

Because fuel trucks can be targets in war, many armies will refuel only at night and place canvas covers over fuel trucks during the day so that they will resemble standard cargo trucks. Supplies delivered to front-line users are often broken down into smaller batches for ease of handling, such as 5-gallon 'jerrycans,' although care has to be taken since the noise of handling cans risks detection by enemy forces. During World War II in Europe vehicles in the field were refuelled almost exclusively with cans, while in the Pacific

1. See "The NATO Pipeline System" by Major General Homer Smith, USA (Ret.) and Lt. Col. David Simpson, UKAR (Ret.) in *Army Logistician*, January-February, 1985, p. 21.

islands US forces came to prefer 55-gallon drums due primarily to the lack of bulk transportation facilities. In any event, the carriage of fuel in cans or drums is dangerous, particularly for combat vehicles. For instance, it is a Soviet practice for drums with extra fuel to be carried on the front of many of their tanks. During several Middle East wars this proved to be an explosive arrangement since many Soviet-built tanks and their crews have been lost after these drums were hit by gunfire.

In the combat zone, the need to be able to deliver small batches of fuel to front-line users can be a challenging task. This was evident in the Falklands War when problems arose for the British in providing fuel for generators at tactical missile sites. The Rapier missile batteries on average required only 100 gallons of fuel per day, but large tanker vehicles were unable to reach sites located on hilltops or otherwise inaccessible by road. As with the American experience in Viet Nam and confronted now by the Soviets in Afghanistan, this problem was eased by the delivery of portable fuel bladders by helicopter.

REQUIREMENTS BY AIR FORCES

Aircraft account for some two-thirds of the military demand for oil. Oil consumption by air forces, most of which is jet fuel, is determined by the number and duration of air sorties; aircraft fuel consumption rates are dependent upon how they are used (*e.g.* cruising speed on routine patrol requires much less fuel than sustained maximum thrust in combat). The introduction of accurate long-range air-to-air missiles may have taken the close proximity of 'dog-fights' out of modern tactics of aerial combat, but it has not in any way diminished the fundamental importance of petroleum to modern day air power.

A typical base of the US Air Force in peacetime servicing up to 100 aircraft daily will consume an average of 300 000 gallons of jet fuel per day and maintain a 2 million gallon inventory in storage. Upon the outbreak of war, these averages would increase dramatically.

In terms of military logistics, transporting fuel by air is less efficient than by ground or sea. However, in emergencies where time is of the essence or where the ground locations to be refuelled are inaccessible to other means of delivery, fuel airlift can be the most pragmatic action to take as a last resort.

Components of air-transportable fuel systems can include storage tanks of different sizes (including bladders and drums), pumps, multifuel dispensing systems, filtration units, portable lab facilities and additive packages. For instance, when typhoons have damaged fuel supply systems at its island bases in the Western Pacific, such as Guam, the USAF has provided emergency fuels support by flying Hercules C-130 transport planes containing portable fuel storage systems holding 6 000 gallons of fuel each. Often referred to as 'bladder birds', this militarily unique system is specifically designed to deliver bulk fuel to forward operating locations. It can be used at night, as it was in 1980 on a remote desert in Iran by the US Delta commando team planning to rescue the American hostages held in Tehran. Refuelling is dangerous, however, and in this instance, a just-refuelled helicopter had a collision in the fuelling area and the rescue attempt was aborted.

Significance of in-flight refuelling

The fundamental military significance of in-flight refuelling is that it expands an aircraft's range, endurance, and ability to carry heavier payloads. It also alters the source of a plane's fuel, such as when carrier-based aircraft are refuelled in mid-air by land-based aircraft, thereby conserving the carrier's onboard jet fuel supplies. For long-range logistical support and airlift missions, in-flight refuelling reduces the number of enroute support air bases needed, allows for a wider selection of routes, and reduces the drawdown of fuel stored at the plane's destination. There is also less aircraft maintenance required due to a reduction in the number of landings and takeoffs.

In combat, aerial refuelling allows for longer sorties although tactical fighter aircraft often require aerial refuelling just to be able to return to base since combat manoeuvring at peak thrust can deplete fuel supplies in as little as 20 minutes. The array of weapon systems, missiles, and bombs used to equip military aircraft adds considerably to the planes' gross weight. This factor can force choices between partial fuelling or partial arming to reduce weight since it is during takeoff when a plane's carrying capacity in terms of weight is at its lowest.

A fuel's aromatic content can sometimes justify the use of in-flight refuelling. Military aircraft generally use two types of fuel tanks: fuel cells with rubber bladders, or metal tanks. Metal plates are used to construct the latter type of fuel tank and joined together by riveted connector plates with groove sealants applied over the rivets. The greater a fuel's aromatic content, the more the fuel will expand at higher temperatures and concomitantly swell the sealant and reinforce the seal. In the case of specialty aviation fuels, which tend to have abnormally low aromatic contents, such as the USAF JP-7 and JP-TS, there can be fuel leakage from aircraft fuel tanks because of this factor. For example, the high-performance US SR-71 reconnaissance plane's specially constructed wing tanks literally bleed fuel at ground level but do not leak at high speeds as the wings heat up. Thus, SR-71s customarily take off with only a partial load of fuel and are later refuelled by USAF KC-135s modified specifically to carry the unique fuel (JP-7) required by the SR-71. On these and other classified missions, crews will sometimes conduct aerial refuelling at night under radio silence with no lights.

The origins of in-flight refuelling date back to World War I when various individuals began to ponder the military advantages of such systems, including the pick-up of fuel while not landing. In the US, Navy Reservist Godfrey Cabot sought to expedite the delivery of bomber aircraft to France on ships across the Atlantic by instead flying them across the ocean during which they would rendezvous from the air with supply ships on the high seas. His experiments began in 1918 and in 1920 he successfully snatched up a five-gallon can of gasoline using the "pick-up" method by means of a trailing rope to pull it into the air and then haul it into the airplane.

In the aftermath of World War I, stunt pilots emerged as proponents of aerial refuelling in order to set long distance flying records. Military interest waned, although work was continued in Britain by the Royal Aircraft Establishment and Flight Refuelling Limited founded by Sir Alan Cobham. In the Soviet Union, the study of the military applications of aerial refuelling had begun in the early 1930s and was marked by the successful refuelling aloft of a TB-1 bomber by a Polikarpou R-5 in 1933.

It was not until 1944 when the British Air Ministry proposed to convert 600 Lancaster and 600 Lincoln bombers for in-flight refuelling in order to bomb Japan from Southeast Asia that military interest in the significance of aerial refuelling was rekindled. However, the British plan was dropped when forward bases were captured within the bombers' unrefuelled combat radius.[2]

After World War II, the embodiment of long-range intercontinental bombing in US strategic doctrine and the recognition of in-flight refuelling's potential military significance led to the decision in 1948 by the US Strategic Air Command (SAC) to resume efforts to attain a viable refuelling capability. At that time, the 'looped hose' method made in England was the only available system, and this was used for the bombers. Cobham was approached to develop a system suited for refuelling fighter aircraft and the result was the probe-and-drogue system whose feasibility was demonstrated in early 1949 when a US B-50 aircraft was repeatedly refuelled aloft during the first non-stop flight around the world. Today, SAC's fleet of approximately 500 aerial refuelling tankers is nearly double the number of SAC bombers and these tankers support the bombers on all missions.

Despite the introduction of nuclear-armed intercontinental-ballistic missiles (ICBM), the central strategic implications of in-flight refuelling capabilities in both the conventional and nuclear wartime contexts has endured. This is perhaps exemplified best by the contributing role of the Soviet 'Backfire' bomber in the unravelling of the SALT II arms control agreement.[3] Since these times, aerial refuelling has played an important role in global extensions of military power although surprisingly the Soviets have not equipped their fighters and strike aircraft as much as in the West, preferring instead to emphasise aerial refuelling for their long-range bomber force.

Refuelling methods

There are basically two methods of aerial refuelling in use today — the 'probe-and-drogue' and the 'flying boom'. Both require precision flying and are dangerous due to the proximity of the aircraft. Initially developed in England to replace the now obsolete looped hose technique, the probe-and-drogue system entails the tanker plane using power-driven reels to trail a long, flexible, armoured hose which ends in a conically-shaped funnel (the drogue). The probe is a forward-facing aero-dynamically contoured pipe connected to the fuel system that juts out of the fuselage. The receiving plane's probe is usually placed forward of the cockpit so that the pilot can visually manoeuvre the probe into the trailing drogue. When the probe makes a tight connection, fuel is pumped until the receiver is full. Then, the receiving pilot throttles back to disconnect, simultaneously activating self-sealing valves in both the probe and the drogue which automatically close.

The flying boom method was developed by the USAF principally for its heavy bombers and other large planes which do not have the requisite manoeuvring ability for easy aerial refuelling. The tanker plane has an operator seated in a cockpit underneath the rear of the fuselage who operates hydraulic controls to fly the small-winged boom. The boom is extended from a recess underneath the fuselage as the planes position themselves to refuel and it is manoeuvred to just in front of the trailing plane's receiving receptacle. The operator then activates the telescopic boom to make a fuel-tight connection after which a nozzle protrudes and fuel is pumped out. The receiver merely keeps a steady position/course beneath and behind the tanker. An advantage of the boom method is its higher flow rate but, at the same time, tanker planes are limited to carrying only one refuelling boom at a time.

The probe-and-drogue is better suited for naval aviation than the boom because it is more compact (no boom to stow) and it allows for the installation of several fuel delivery systems on tanker planes. Accordingly, some USAF aircraft have been outfitted for both so that in emergencies they can refuel carrier-based naval aircraft equipped only with a receiving probe. "Buddy-Buddy" refuelling planes, used by the military for maritime aviation, are equipped with portable drogues and wing tanks, drop tanks or centre tanks not connected to the plane's fuel system but dedicated solely for providing small amounts of fuel to others in emergencies.

Flying tankers

Unique to military aviation, the practice of in-flight refuelling requires specially designed and/or modified aircraft. The all important aerial tankers serving as the supplier can currently be found in the air forces of Argentina, Australia, Brazil, Canada, France, Iran, Israel, Saudi Arabia, the Soviet Union, the United Kingdom and the United States. Japan, meanwhile, has F-15 fighters equipped to receive fuel but no aerial tankers to supply them as a matter of national defence policy regarding the operational range of the National Self Defence Force.

Propeller-driven tanker planes became obsolete in the 1950s as the increasing number of jet aircraft entering military inventories were inconvenienced by having to drop below their normal cruising altitude and slow to a near stall in order to be fuelled. The second generation of aerial tankers came into being with the introduction of the Boeing KC-135 strato-tanker in 1957. As the only airplane ever designed solely for in-flight refuelling (its airframe was later used for the development of the 707 passenger jet), the KC-135 could cruise at 30 000 feet in excess of 500 mph with a 120 000 pound load of fuel. Fuel could be off-loaded either through its flying-boom or wing-mounted hose and drogue systems, each capable of pumping fuel at a rate of 600 gallons per minute. Introduced some years later and based on the McDonnel Douglas DC-10 commercial jumbo jet, the KC-10 aerial tanker has rubber bladder fuel tanks which can carry 356 000 pounds of fuel. It has an operator-controlled boom system whose large diameter fuel lines can transfer up to 1 500 gallons per minute at altitudes up to 35 000 feet. It also has the probe-and-drogue system capable of a 600 gallon per minute flow rate.

The KC-130 tanker version of the Lockheed C-130 Hercules cargo plane, propeller driven, can deliver up to 65 000 pounds of fuel in flight. It is versatile in that it is fast enough to refuel jet fighters and slow enough to refuel helicopters. Its wing mounted drogues can fuel two aircraft simultaneously at a rate of 300 gallons per minute each.

First generation Soviet tanker planes were mostly equipped for refuelling in a 'wing-tip to wing-tip' flying

2. Military uncertainty about the feasibility of aerial refuelling was in part offset by the fact that it had been conducted on a commercial basis in 1939 when British-based Imperial Airways flew a Harrow tanker aircraft to refuel its "C" class flying boats on their trans-Atlantic runs. (See Tre Tryckare, *The Lore of Flight*, (Gothenburg, Cagner & Co, 1980), p. 358 and Air-Vice Marshall Michael Knight, "The Air Tanker Comes of Age", *Pacific Defence Reporter*, June, 1983, pp. 15-17).

3. Arms control negotiations between the United States and the Soviet Union leading up to the SALT II Agreement categorised the Soviet TU-22M ('Backfire') bomber as a 'medium range bomber' and hence not counted under the arms limitations provisions providing it was not given an inter-continental capability through, *inter alia*, the installation of an in-flight refuelling system. Prior to the signing of SALT II by Presidents Brezhnev and Carter in June 1974, US Intelligence had confirmed that refuelling probes had been removed from the Backfires. One year later, however, probes were seen on Backfires over the Baltic and by December 1980, just before the Soviet invasion of Afghanistan, the prospects for the Agreement to be ratified had all but vanished.

configuration instead of having one plane directly behind another. At first, the complicated task of making fuel connection in flight was avoided by this method since the two planes were apparently connected on the ground. However, the inflexibility embodied in the need for simultaneous take-offs and identical flight patterns prior to refuelling were such that by 1960, Soviet Bear and Bison bombers were refuelled solely by standard probe-and-drogue procedures and only the Badger still used the wing-tip method. Now, the Soviets can also connect the wing-to-wing method in mid-air but it is still not viewed as an efficient system by experts.

Refuelling in combat: Viet Nam

Until the US involvement in the Viet Nam War, aerial refuelling had played only a non-combatant role supporting transport and reconnaisance aircraft, as well as long-range bombers on peacetime patrol. The first combat mission ever for aerial tankers was flown on 9 June, 1964, just two months before the Gulf of Tonkin incident. The chain of events began with a Presidential decision to retaliate against the shooting down of unarmed US reconnaisance aircraft over Laos by deploying for the first time SAC B-52 bombers to Southeast Asia. The bombers were to be based in Guam, from where it was estimated that it would take them 12 hours to hit their targets in Viet Nam and return to base, in excess of their unrefuelled capability. Aerial refuelling was necessary and so the bombers were supported by 30 KC-135 tankers. Six tankers were subsequently deployed to Clark Air Force Base in the Phillipines and on 9 June four of them provided in-flight refuelling over DaNang to eight F-100 fighter bombers enroute to striking Pathet Lao anti-aircraft emplacements on the Plain of Jars. The KC-135s remained over southern Laos and subsequently provided post-strike refuelling to two of the returning aircraft.

Over the ensuing nine years and two months, until US combat operations were halted in August 1973, the KC-135s flew 194 687 sorties, provided 813 878 aerial refuellings and transferred a total of 8 964 million pounds of fuel (*i.e.* 1.4 billion gallons). On average, KC-135 sorties lasted 4.8 hours and provided an average of 4.2 refuellings. The number of tankers deployed for combat peaked at 172 in mid-1972. The monthly record for refuelling sorties was set in September 1972 with 3 902 missions, or over 100 tanker sorties per day.

Refuelling procedures standardised by the USAF reflected peacetime experience in refuelling reconnaissance and transport aircraft inflight, but they had to be modified as combat experience was gained in the Southeast Asia wartime environment. Modification of procedures was particularly necessary for bombers inasmuch as the first refuelled combat mission for B-52s, an attack on 18 June 1965 against a suspected Viet Cong base north of Saigon, was marred after achieving a successful strike when two bombers were lost on the return run after a collision while refuelling. (In all, five KC-135 tankers were lost in Southeast Asia during the course of their deployment).

Refuelling zones delineated by tactical air control systems were designated according to the weather in areas outside enemy fire or under American air supremacy and away from commercial airline traffic. During large-scale B-52 bombing strikes as many as 54 aircraft would be flying in a single refuelling zone 200 miles long. During these periods of peak congestion, three groups of three tankers each would operate at altitudes usually between 27 000-30 000 feet with their separation sometimes being as little as 500 feet. Air traffic control was also necessary since tankers were based in Thailand, Taiwan, Okinawa, Guam, and the Phillipines, and therefore approached refuelling areas from many different directions.

KC-135s normally refuelled bombers at or above 26 000 feet. However, a fighter running short of fuel could little afford the additional expenditure of fuel needed to climb to that height so tankers ultimately flew at lower and, hence, more vulnerable altitudes. In one case tankers refuelled as low as 5 000 feet during what may have been the only three-way aerial refuelling ever consummated. On 31 May, 1967 a SAC KC-135 diverted from its normal mission of refuelling USAF F-104s over the Gulf of Tonkin to assist two Navy A-3 aircraft, themselves 'buddy-buddy' refuellers. Upon rendezvous, one A-3 only had three minutes of fuel left due to internal failure (it also had 14 000 pounds of fuel that it could transfer but not use itself) and the tanker hooked up immediately with the first plane and then the second. At that time, several Navy F-8s arrived, one with so little fuel that it immediately linked up to the A-3 already connected to the KC-135 and being refuelled itself thus forming a three plane fuelling chain. By the end of the emergency, a single tanker had furnished 14 refuellings totalling almost 50 000 pounds to 8 receivers at the unusually low altitude of 5 000 feet.

Another emergency occurred in early 1965 when a tanker used its refuelling boom to tow back to base a fighter that was so shot up that it was losing more fuel than the tanker had been offloading to him. In another instance, in May 1967 two F-105s returning from a mission over Viet Nam found themselves so short of fuel that they could not reach any base without refuelling. Beset by stormy weather in their refuelling area, they radioed for assistance. A KC-135 from another refuelling area found upon its arrival an expiring plane whose pilot was about to eject. Hookup was made in a 20-degree dive just as the F-105 was flaming out for lack of fuel. The tanker refuelled the fighter until it could restart, fuelled the other plane, and then all returned to base safely.

The Falklands War

Air forces must be prepared to increase their peacetime capabilities upon the outbreak of war through cooperation with the commercial aviation industry. Indeed, this was a crucial factor in the Falklands (Malvinas) War when the UK had to mount a massive conversion programme to modify both military and commercial planes for in-flight refuelling in response to the Argentine surprise attack. Both countries possessed aircraft capable of transferring fuel in mid-air but the similarities ended there as each derived a different military advantage during the course of the war.

Argentine forces had relatively short distances to cover (400-500 miles) and so aerial refuelling served their land-based A-4 Skyhawks. Nevertheless, several Argentine planes were lost when they had to be ditched due to a lack of fuel because there was no aerial tanker nearby to refuel them. In contrast, the deployment of UK forces extended some 8 000 miles and required considerable long-range logistical support. The closest land base available to them was Wideawake Field at Ascension Island, 3 000 miles away from the Falklands. Therefore, offensive air operations could not even be launched without inflight refuelling. Following the outbreak of the war the UK first used Victor-class tanker aircraft modified with electronic sensors to carry out long-range martime reconnaissance. Later, the RAF turned to the customary Nimrod wartime patrol craft for reconnaissance (and some Hercules C-130s) once they had been outfitted with probes in order to be refuelled by Victor tankers playing their normal role.

Some Nimrods operating out of Ascension Island flew sorties lasting 19 hours and generally required two outbound and one inbound refuelling. On these missions, the Victor tankers flying support were themselves refuelled by additional Victors assigned for that specific task. The Vulcan bombers often flew 15-hour strike missions involving up to 11 Victor tanker sorties on the outbound leg, plus five sorties to position fuel at the rendezvous point for the return leg. During the three-week war, there was an average of 800 RAF sorties per day, while Victor tankers transferred some 23 million pounds of fuel in 720 sorties. Of all the refuelling attempts during the war, only about 1% failed to connect either because of technical problems or other reasons — including one Vulcan diverted to Brazil when the tip of its receiving probe broke during refuelling.

Helicopters

Military helicopters converted for combat were first used by French forces in the late 1940s and early 1950s in Indochina. In 1956-58 the US conducted helicopter-to-helicopter refuelling trials using both the looped hose and probe-and-drogue methods. The trials demonstrated that refuelling was feasible but concerns over limitations in fuel carrying capacity prompted efforts to find a refuelling solution from the ground. Ship-to-helicopter and ship-to-blimp refuellings were subsequently conducted on an experimental basis.

The refuelling of helicopters in mid-air during flight can be most important at higher altitudes and in warm weather when the rotors cannot provide enough lift to take off with a full load of fuel and armaments. Flying range is also important, as it was essential during US Air Rescue missions in Viet Nam. In the early 1960s the US was flying many helicopter missions behind enemy lines to rescue downed pilots but when carrying a full load of fuel they were unable to hover over mountain areas where many downed pilots deliberately guided their parachutes to avoid capture. To rectify this problem, it was proposed in 1964 that the Hercules multi-purpose cargo plane be modified to provide inflight air refuelling to helicopters and by 1967 refuelling had become a standard feature of USAF air rescue missions.

CONCLUSIONS

The exigencies of war are invariably the mother of invention in the conduct of military oil supply activities, ranging from the acquisition of oil to its distribution to front-line combat users. For example, during World War II, Germany resorted to delivering fuel to North Africa for armoured divisions in Rommel's Afrika Korps via submarines ferrying drums of gasoline beneath the Mediterranean. At the same time, British forces in North Africa sometimes relied on fuel transported by planes in five-gallon cans. Supply reliability, and not cost considerations, is the driving force of military oil operations in war.

The use of oil as a military weapon generally entails capitalising upon political or economic considerations, as with the Arab oil embargo during the October 1973 war against those nations supporting Israel (*e.g.* the US and the Netherlands). A most singular instance of oil being used as a military weapon *per se* was the alleged Israeli construction of fortified oil tanks and spigots along the Suez prior to the 1973 war in order to pour oil into the Canal and set it afire as a defensive measure. (Although Israel denies that it was intended to be an operational system, Egypt claims to have had it 'neutralised' by commandos prior to their attack across the Suez).

The wartime significance of petroleum applies also to diplomatic negotiations, such as during World War II when the US obtained the release of several pilots held in Spain by offering for Texaco to provide gasoline in exchange. Petroleum has been a target of peacetime military espionage, such as during the Cold War years when a spy ring revolving around US Army Sgt Robert Lee Johnson provided samples of secret rocket fuel to the Soviet Union.

The most vulnerable element of a nation's economy to military attack is usually its energy supply system. Power plants and electrical transmission systems are most tempting military targets inasmuch as the destruction of a nation's electricity sector can completely undermine its capability to sustain a successful war effort. But sometimes strategic priorities are such that, as happened in the German campaign against Russia in World War II, efforts are made by an enemy to preserve energy facilities. In this case, the Luftwaffe was initially instructed not to attack Soviet industry, including power plants, so that the facilities would still be intact later on when they came under German control. Later, upon their retreat, the Germans tried to reverse their strategy but planned commando attacks were never carried out. The war between the US and North Viet Nam is one of few modern wars where power plants were not primary targets. North Viet Nam's limited industrial infrastructure, and the small size of its power plants were not seen by US military strategists to have a significant bearing upon its fighting capability.

Instances of oil or oil-related industrial facilities being a military target in conventional wars are too numerous to cite. In the event of a nuclear war, oil facilities are still important military targets. In a study on the effects of a US-Soviet nuclear war, the Office of Technology Assessment of the US Congress selected oil refineries as the designated targets in a hypothetical war scenario postulating the simultaneous launching of ten nuclear armed delivery vehicles (including land and sea based MIRVs) each by the superpowers against one another. Analysis of the impact of this relatively modest nuclear exchange showed that the Soviet attack would destroy 64% of US oil refining capacity, while the US attack would destroy 23% of Soviet refinery capacity.

It is clear that the military role of oil in war as a fuel and commodity for military transport serve as important considerations of military strategy. Also pertinent to a nation's oil and military security is how oil considerations might serve as a catalyst to crisis, or as a direct cause of war. While speculation that access to possible oil reserves in the South Atlantic was an important motivating factor in the Argentine decision to seize the Falklands is not generally accepted, access of supply was an important consideration in the Japanese decision to attack Pearl Harbour in December 1941. More recently, the Iran-Iraq tanker war and the threat other events pose to world oil supplies have prompted nations not directly involved or geographically proximate to the region to take military steps as a precaution against possible deterioration in the security of Free World oil supplies (*e.g.* the US Rapid Deployment Force). These and other military steps taken in peace reflect the fact that the military must plan for the fulfilment of its oil needs under a variety of scenarios in which military force might be needed to safeguard the security of its oil supplies. □