AIR POWER STUDIES CENTRE

PAPER 78

Month Year

THE OTHER SIDE OF THE HILL

By

P.J. McCarry

About the Author

The ...

INTRODUCTION

Military commanders have always wanted to know what the enemy is going to do next – what attacks are about to be made. In the age of two-dimensional warfare, generals wondered what was on *the other side of the hill* and admirals wondered what lay *over the horizon*. Without timely warning of enemy activities, they could miss opportunities or be taken by surprise.

When warfare entered the third dimension, the air, the problems for surface warriors became far more complex. Air reconnaissance could see what was on the other side of the hill, but air power was a 'double-edged sword'. Air attacks could fall upon troops or ships with great fury and with virtually no warning. When the only means of detecting incoming air attacks was the human eye, warning times were a few minutes at best. At night or in bad weather, incoming aircraft were virtually undetectable.

In the 1930s, technology provided a means of extending the range of detection way beyond that of the human eye, even through bad weather or in the dark. Radio Detection and Ranging (radar) could give early warning of approaching attackers, on the surface or in the air.

Radar systems transmit electromagnetic energy (radiation), which bounces off solid objects (illumination). Some of that reflected energy returns to the radar receiver and is recognised as a target (detection). The trick is making sense of the radar return. Early radars transmitted powerful waves of energy and the image on the display screen was often just a blob or blip. Operators had to interpret such blips. It was more an art than a science.

Radars in the 1930s and 1940s transmitted and received in the microwave frequency band. The 'laws of physics' dictate that microwave radars can only 'see' along a direct line, also called 'line-of-sight'. They cannot see around corners or over the hill or over the horizon. At sea level the 'radar horizon' is only about 15 kilometres away, so a ship's radar cannot see another ship as close as 20 kilometres away. Because of the curvature of the earth the other ship is over the horizon, so there is no direct line-of-sight.

During the Battle of Britain in 1940, the Royal Air Force (RAF) used a coastal chain of microwave radars to give early warning of incoming Luftwaffe bombing raids.[1] The RAF early warning system could determine the altitude, speed and direction of the German formations, but not the exact number or type of aircraft. The Germans usually approached at high altitude and could be detected far enough out to give RAF fighters time to take-off, climb to altitude and intercept the bombers before they reached their targets. The 'God's eye view' of the battlespace that the RAF got from radar enabled them to use their scarce fighters efficiently. The fighters did not have to waste time searching huge volumes of airspace for targets, but were guided to within visual range, by fighter controllers on the ground. The early warning radar system gave the RAF a decisive advantage. Without it, the RAF would probably have lost air

[1] The RAF 'Chain Home' radar system operated on the 'continuous wave' principle. A set of transmitters radiated continuously, while a separate set of receivers detected the returns.

superiority over the English Channel and south-east England. Air superiority was the essential precondition for a German invasion of England.

Radar gives ample early warning of high-flying aircraft; however, if aircraft approach at low level, the radar horizon is reduced to less than 20 kilometres. Warning time is thus reduced to the point where defending fighters do not have enough time to intercept the bombers before they reach the target. In order to postpone detection until the last possible moment, aircraft often fly at very low level - as little as 50 metres. This is the reason why so many air raids since 1940 were flown at low level. The aircraft were flying 'under' enemy radar.

THE HIGHER, THE BETTER

The obvious solution to the horizon limitation is to get the radar higher. A radar sitting ten kilometres above the surface of the earth can 'see' everything from directly below out to a range of hundreds of kilometres. Low flying aircraft cannot 'sneak up' to within a few kilometres by approaching below the radar horizon. Early radar equipment was very large and bulky and required massive amounts of power. In 1939, no aircraft could carry such radars. Only the largest ships, battleships and aircraft carriers had the space and power. Early radar had to be land-based.

Land-based radar has several advantages over airborne radar. Large numbers of operators, interpreters, controllers and maintainers can be co-located with a land-based radar, so operations can be conducted continuously and indefinitely. Aircraft have limited crew numbers, so relatively few operators, interpreters, controllers and maintainers can be carried. Aircraft have limited endurance, so continuous operation requires large numbers of aircraft and becomes expensive. Radar bases on land can have 'spare' radar transmitters and receivers and extra personnel for overall system redundancy. Aircraft rarely have the luxury of redundancy, either in terms of hardware or personnel. The amount of electrical power available dictates the power of the radar, which in turn dictates its range and ability to overcome jamming. Land-based radar can draw electrical power from the national power grid, but aircraft have limited electrical power available.

As World War II progressed radar became more compact and therefore more widely used, both on land and at sea. Events in 1940 and 1941 proved that ships were very vulnerable to air attack, so early warning radar became essential for warships.[2] Each of the warring powers faced its unique strategic situation and had its unique operational requirements and cultural bias, so each developed and used radar in its own way.

[2] In 1940, British aircraft sank Italian battleships in harbour at Taranto. In 1941, Japanese aircraft sank US battleships in harbour at Pearl Harbor and British battleships at sea, off the coast of Malaya.

THE AMERICAN WAY

Tactical Early Warning and Control

The war in the Pacific from 1941 to 1945 was characterised by mass air strikes on fleets of warships. Warships rarely made visual contact with enemy vessels. Most of the action took place in littoral areas, as the Japanese first overran South-East Asia and the islands of the South Pacific in 1942 and then tried to prevent the inexorable advance of the American 'island hopping' counter offensive, from 1943 onwards. The centrepiece of the American strategy was the US Navy (USN) Carrier Battle Groups, whose air groups substituted for land-based air power and took the war to the Japanese heartland. The Japanese plan was to use air and naval forces to keep the enemy away from the Japanese heartland, by defeating attacks in the air-sea gap to their south.

The Japanese had hoped for a quick victory, but when the war became a drawn out affair Japan was at a severe disadvantage. America had vastly superior natural resources, much greater industrial capacity and twice the population. In 1942 and 1943, Japanese losses of ships, aircraft and pilots were catastrophic - way beyond their capacity to replace. By 1944, US forces had overwhelming numerical and qualitative superiority.

Given the futility of continued conventional air operations, the Japanese resorted to the desperate innovation of suicide attacks – the infamous Kamikaze. The Kamikaze were normal combat aircraft, usually fighters, which were packed with high explosive. The pilots intentionally flew them into the target, in a suicidal one-way mission. A Kamikaze can be seen as a guided air-to-surface glide bomb, much like modern 'smart bombs' such as the GBU-24 in service with the Royal Australian Air Force (RAAF) today.[3] The guidance system of the Kamikaze was organic, the human pilot, rather than electronic. The principle is the same.

The Kamikazes inflicted heavy losses on Allied forces. In just ten months they sank 34 warships and damaged another 288. The ships lost included three small aircraft carriers and many destroyers.[4] The depleted, low quality remnants of Japanese air power could never have inflicted such casualties by conventional tactics.

The Kamikazes tended to attack in groups of five or six aircraft, as experience had shown that small groups had the best chance of penetrating the defences. They would often approach their targets at low level. The US ships' radars were unable to detect low flying aircraft until they had closed to within 20 kilometres, giving inadequate warning time to arrange interception by US fighters.[5]

The climax of the Kamikaze campaign came during the US invasion of Okinawa from April to June 1945. The highest value targets in the US force were the aircraft carriers. A 'picket line' of expendable destroyers, equipped with radar, was placed between the

[3] The GBU-24 is a standard low drag 2,000 pound bomb, fitted with a guidance kit on the nose and winglets on the tail.
[4] Barker, A.J., *Suicide Weapon*, Ballantine Books Ltd, London, 1971, p 159.
[5] *ibid*., p 90.

Carrier Battle Groups and the expected source of the Japanese strikes. The 'radar pickets' were far enough away from the carriers to give adequate warning time for carrier-based fighters to intercept the Kamikazes before they could get at the carriers.[6] Of course, the radar picket destroyers got little warning and many were sunk or damaged. It was a very expensive solution.

Had there been no radar picket line, the Carrier Battle Groups would have been forced to dedicate a much larger proportion of their Air Groups to self-defence. Concentric hemispherical shells of fighters would have needed to be airborne around the clock, relying on the human eye for visual detection. Few aircraft would have been left to undertake offensive operations in support of the invasion. Early warning radar was therefore a force multiplier.

Ideally, the USN required airborne early warning (AEW) radar, to provide the early warning of low flying aircraft, without putting radar picket destroyers in harm's way. Fortunately, the pace of technological development during the war was so rapid that AEW became feasible.

In February 1944, the USN initiated Project Cadillac, under which the Massachusetts Institute of Technology Radiation Laboratory was contracted to develop the world's first operational AEW radar – the APS-4.[7] About 40 single-engine Grumman Avenger torpedo bombers were fitted with the APS-4 radar, in small pods under their wingtips. Delivery of the two-man aircraft began in March 1945. The radar 'picture' detected by the AEW Avengers was transmitted back to the Combat Information Centre (CIC) onboard a nearby warship, where the interpretation and intercept control were performed.[8]

To this day, there is argument over whether it is better to simply transmit the radar picture back to a surface station such as a warship's CIC or a land base or process the information on the aircraft and act on the information 'on the spot'. Modern datalink systems can transmit great volumes of data, but modern radar systems provide so much data that the transmission capacity of the frequency band can sometimes be exceeded. This is usually called the bandwidth problem. It restricts the effectiveness of remote processing.

Project Cadillac was not able to provide sufficient AEW capability in time to influence the outcome of the war in the Pacific. Japan was overwhelmed by the sheer mass of American forces. However, the Kamikaze threat had focussed the USN on the need for radar picket or AEW aircraft. Development continued after the war.

Soon after the defeat of Japan, the Soviet Union emerged as a new enemy. The economic wellbeing of the Western democracies depended on the free flow of international trade, which required freedom of the sea. In the event of a Soviet invasion of Western Europe, US reinforcements would have to cross the Atlantic, which would require control of the sea. The centrepiece of US maritime strategy remained the Carrier Battle Groups.

[6] Natkiel, R., *Atlas of World War Two*, Bison Books, London, 1985, p 134.
[7] Early airborne radars operated on the 'pulse' principle. With inadequate space for separate transmitters and receivers, the radar array had to send out a pulse and then pause to 'listen' for a return.
[8] Allport, D., 'AEW Aircraft Survey', *Air International*, March 1995, p 169.

In the late 1940s, the German U-Boat threat was replaced by the rapidly growing Soviet submarine fleet. The first generation of post-war Soviet submarines were little more than copies of U-Boats. In the 1950s, the Soviet submarine fleet grew to over 300 boats. Just as air power had been decisive in defeating the U-Boats, it was a central element of the western response to the Soviet submarine threat. NATO acquired hundreds of land based anti-submarine warfare (ASW) aircraft and the USN dedicated over a dozen heavy aircraft carriers to ASW. The radar detection of surfaced submarines and the periscopes or snorkels of submerged submarines had been crucial in World War II, so ASW aircraft continued to carry radar. These ASW radar equipped aircraft became the basis for later AEW radar equipped aircraft.

In 1950, the single-engine Grumman Guardian entered service. It was an enlarged Avenger, with the larger APS-20 radar, in a squat, circular radome, conformal to the belly. The crew of three, a pilot and two radar operators, sat in cramped cockpits. The radar picture was transmitted back to a warship's CIC for interpretation and intercept control.[9]

The USN formed AEW squadrons and began developing AEW procedures and tactics. In the mid-1950s, the British, Canadians, Dutch, French and Japanese acquired small numbers of 'second-hand' AEW Avengers and AEW Guardians. The French actually used some in the Suez operation in 1956.[10]

Shortly after the Guardian entered service, an AEW version of the Douglas Skyraider began phasing in as a replacement. The Skyraider was a more modern single-engine attack aircraft. It had a more compact and robust airframe, a more powerful engine and better overall performance than the Guardian. It carried the same APS-20 radar, in the same manner as the Guardian. The crew of three, a pilot and two radar operators, sat in cramped cockpits. The radar picture was still transmitted back to a warship's CIC, for processing and action. The USN acquired 156 AEW Skyraiders.[11]

Radar was becoming so important and widespread on the modern battlefield that there was a need to engage in what could be termed 'radar warfare', to guarantee the effective use of radar to friendly forces while denying it to the enemy. This form of warfare is called 'Electronic Warfare' (EW).[12] The USN went so far as to dedicate squadrons of aircraft to the activity. An EW version of the Skyraider entered service soon after the AEW version. It was a precursor to the modern EA-6 Prowler and EF-111 Raven. The USN acquired 54 EW Skyraiders.[13] An EW squadron was assigned to every USN aircraft carrier.

The AEW Skyraider was a great advance on its predecessors, but experience indicated that a more powerful radar would be preferable, with more operators to better exploit the radar data. This would require a larger airframe.

[9] *Jane's All the World's Aircraft 1955/56*, Jane's Information Group, Couldson UK, pp 265-266.
[10] Treadwell, T., *The Ironworks : Grumman's Fighting Aeroplanes*, Airlife Pub Ltd, Shrewsbury, 1986, p 52.
[11] Yenne, B., *McDonnell Douglas: A Tale of Two Giants*, Bison Books, London, 1985, pp 52-53.
[12] The common Electronic Warfare terms are listed at Annex A.
[13] Yenne, *McDonnell Douglas: A Tale of Two Giants*, p 52.

In the late 1950s, the Soviet cruise missile threat emerged as a variation on the theme of the Kamikaze. By 1957, Soviet bombers were carrying AS-1 Kennel air-to-surface missiles (ASM) and Soviet destroyers were armed with SS-N-1 Scrubber surface-to-surface missiles (SSM). By 1958, large numbers of coastal patrol boats were fitted with SS-N-2 Styx SSMs and Soviet submarines were carrying SS-N-3 Shaddock SSMs. These cruise missiles carried nuclear warheads, so just one was capable of disabling or even sinking an aircraft carrier. By the early 1960s, hundreds of Soviet bombers, warships and submarines had been modified to carry cruise missiles and were dedicated to attacking the carriers.[14] The need for AEW aircraft became more urgent.

In 1958, the twin-engine Grumman Tracer entered service. It was a development of the cargo version of the Tracker ASW aircraft. The Tracer had a larger airframe and greater engine power than its predecessors, the AEW Guardian and AEW Skyraider. It could support the very large APS-82 radar in a 'tear drop' radome, nine metres long and six metres wide, mounted over the aircraft's back. The Tracer carried a crew of four, including three mission specialists. The USN acquired 88 Tracers.[15]

For the first time in an operational AEW aircraft, the mission crew sat in a compartment, which was much more spacious than previous cockpits. The Tracer provided a more comfortable environment which induced less fatigue, thus making the it a more effective platform for long missions. The crew size and layout of the Tracer made it possible for the interpretation of the radar picture and intercept controlling to be performed on the aircraft. The Tracer was the first carrier-based aircraft to be designated Airborne Early Warning *and Control* (AEW&C).

The Tracer overcame a major limitation of its APS-20 equipped predecessors. The APS-20 gave a bearing to the target, but could not determine the altitude of the target, so its radar 'fix' was two dimensional. The target might be at low, medium or high altitude. The Tracer had a height finding capability, so it could fix the target in three dimensions. Another limitation of the APS-20 was that it was virtually useless over land. The radar could not pick targets out from the 'ground clutter' of trees, hills and moving land vehicles. The Tracer's radar equipment had some overland capability, which later AEW&C aircraft would improve upon.

In 1964, the USN's first purpose-designed AEW&C aircraft, the Grumman Hawkeye, entered service. The Hawkeye had the APS-96 radar in an eight metre diameter saucer-shaped radome mounted over the wing. The whole radome rotated, hence the term 'rotodome'. The Hawkeye had a crew of five, including three mission specialists.[16] The USN has since acquired over 140 Hawkeyes.

The Hawkeye set the pattern for AEW&C aircraft for the next three decades, with the radar mounted in a rotating 'saucer' above the wing near the centre of gravity and the mission crew in a relatively comfortable compartment behind the cockpit. The Hawkeye is the largest aircraft that can be operated from an aircraft carrier, so crew size cannot be increased. The Hawkeye's radar system is capable of detecting

[14] Gunston, B., *Rockets & Missiles*, Salamander, London, 1979, pp 79-80, 134.
[15] *ibid*., p 67.
[16] *Jane's Aircraft 1995/6*, pp 617-618.

thousands of targets and tracking hundreds of them simultaneously. The only way that the small mission crew can manage the mass of data is through high levels of automation in the target classification function and presenting the data in a well-organised format. The alternative would be to datalink the radar picture to a warship's CIC, where larger numbers of operators could manage the data manually.

In operations off the coast of North Vietnam, the presence of Hawkeyes enabled Carrier Battle Groups to have fewer fighters on Combat Air Patrol (CAP) during daylight hours and fewer on alert on the flight deck during the hours of darkness. This reduced aircrew fatigue and aircraft maintenance requirements, 'freeing up' aircrew and aircraft for offensive missions. Hawkeyes often diverted fighters from planned missions to deal with MiGs that were detected attempting to attack US forces. Hawkeyes facilitated the destruction of many MiGs.[17]

Since entering service, the Hawkeye has been continuously developed from the E-2A, through the E-2B to the E-2C. The original APS-96 air surveillance radar carried by the E-2A was replaced by the APS-120 on the E-2C in 1974. The E-2C was later upgraded, with the APS-125 in 1976, the APS-138 in 1983, the APS-139 in 1989 and finally the current APS-145 in 1991. Over the same period, other systems on the aircraft, such as the EW, have been upgraded to keep pace with the threat.

The Hawkeye is the most widely used AEW&C aircraft in the world, with production exceeding 180. Hawkeyes have been acquired by Egypt (six in 1987), France (two in 1997), Israel (six in 1978), Japan (13 in 1982), Singapore (four in 1987) and Taiwan (four in 1995).

The constant trends over the two decades between the Avenger and the Hawkeye were larger more powerful radars, greater computer processing power, larger crews to manage the data and longer endurance. These trends are quantified in Table 1.

Table 1 - Trends in AEW&C Capability

Aircraft	Radar	T/O Weight	Crew	In Service
Avenger	APS-4	18,000	2	1944
Guardian	APS-20	25,000	3	1950
Skyraider	APS-20	25,000	3	1951
Tracer	APS-82	27,000	4	1958
Hawkeye	APS-96	55,000	5	1964

The USN is developing an improved version of the E-2, the Hawkeye 2000. The mechanically scanning (rotating) radar will be replaced by an electronically scanning radar, which will still have full 360 degree coverage, but will revisit targets more frequently than the current system. An Infra Red Search and Track system may be fitted, for the detection, tracking and targeting of theatre ballistic missiles. There will also be improvements to the EW systems, to provide better detection and

[17] Treadwell, *The Ironworks*, p 155.

identification of enemy radar emissions. The communications suite will be integrated and upgraded, to enable the Hawkeye to participate in 'cooperative engagements'. In a cooperative engagement, one aircraft or ship may launch a weapon at a target that it has not detected, because another aircraft or ship in the battle group has detected the target and can guide the weapon to an intercept. The Hawkeye 2000 is expected to extend the service career of the Hawkeye to the year 2020.[18]

Strategic Early Warning and Control

The US Army Air Forces had no perceived need for AEW in World War II. At the strategic level, the wide expanses of the Atlantic and Pacific oceans and the absence of enemy bases on the North American continent had the effect of ensuring that there was no direct air threat to the United States. At the tactical level, the Army had no major force element as concentrated (and therefore critically vulnerable) as an aircraft carrier. Traditional combat air patrols (CAP), fighter sweeps and anti-aircraft artillery (AAA) were adequate for air defence of the Army's forces in the field. As the war progressed, US ground forces usually enjoyed the luxury of air superiority, if not air supremacy, so the enemy air threat was not significant.

In the late 1940s, as the Cold War intensified, the newly independent US Air Force (USAF) became responsible for the air defence of the continental United States (CONUS). By the early 1950s, Soviet bombers were capable of delivering nuclear weapons to targets in the CONUS. The traditional arithmetic of air defence, based on the warning times provided by extant early warning systems, was invalidated. It was no longer acceptable for a small percentage of enemy bombers to 'leak through' the defences. Just a few nuclear strikes would be devastating.

The USAF created the world's first continental scale, integrated air defence system – the North American Air Defence (NORAD) system. NORAD included a coastal chain of land-based microwave radars known as the Distant Early Warning (DEW) line, squadrons of interceptor aircraft astride the approaches to the CONUS, and batteries of surface-to-air missiles (SAMs) near the major cities. All were linked to a central command and control organisation.[19] The plan was to keep the enemy away from the American heartland by defeating attacks in the air-sea gaps of the Arctic, Atlantic and Pacific oceans.

The radar horizon problem remained. As at Okinawa, surface based radar could 'see' only a few kilometres at low altitude. As the speed of incoming bombers increased, early interception became a more critical issue. To increase warning time, the DEW line was extended out into the Atlantic and the Pacific, where the Soviet bombers would be transiting at high altitude. However, the USAF had no long range AEW platform available, so the USN had to resurrect its radar picket ships. The US Joint Chiefs of Staff authorised the emergency measure in 1949 and about 30 destroyers and 12 submarines were quickly converted. Each radar picket acted as '…a radar station, a fighter control station and a collection point for information gathered by long-range patrol aircraft.' The whole picket fleet was dedicated to the sole purpose of

[18] Wall, R., 'Upgrades proposed for Enhanced E-2C', *Aviation Week & Space Technology*, 26 April 1999, p 82.
[19] Peebles, C., *Guardians : Strategic Reconnaissance Satellites*, Ian Allen Ltd, London, 1987, p 305.

maintaining the picket line, 365 days a year, from 1950 to 1965.[20] It could be characterised as *Sea*borne Early Warning and Control. It was a very expensive solution.

AEW aircraft had several obvious advantages over radar picket ships. A bomber sized aircraft with a crew of 15 or 20 was a cheaper radar platform than a 2,000 tonne destroyer with a crew of hundreds. Aircraft could deploy to their stations much faster than ships and could quickly redeploy in reaction to changed situations. An airborne radar can cover a much larger volume of low level airspace than can a surface-based radar. A radar sitting on the surface has a radar horizon of about 15 kilometres and can 'see' about 250 square kilometres at the surface. An airborne radar, cruising at an altitude of 10,000 metres, has a radar horizon of about 320 kilometres and can maintain surveillance over a surface area of 400,000 square kilometres and a column of air of similar dimensions.[21] Figure 1 illustrates the point. Aircraft could also fly above or around bad weather which could seriously degrade the stability and effectiveness of a ship's radar.

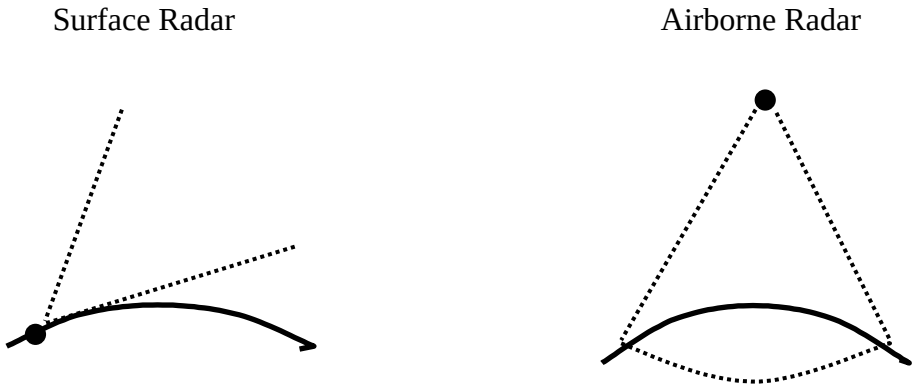

Figure 1 - Radar Horizons

Towards the end of World War II, the USN had modified a few Boeing B-17 Flying Fortress four-engine bombers, under Project Cadillac II. This involved fitting an APS-4 radar, as used on the AEW Avenger. The AEW B-17 could carry a larger crew and had greater endurance, but it was tied to land bases, so it was of little use in the final stage of the war against Japan. Nonetheless, it was recognised that an advantage of large AEW aircraft was their capability to process the radar data and control intercepting fighters from the aircraft, rather than merely relaying the radar picture to the CIC of a nearby warship for further action.

In 1947, an AEW version of the Lockheed Super Constellation four-engine airliner entered service with the USN. The WV-2 'Warning Star' was capable of carrying a large crew in relative luxury, in a cabin fitted out as a CIC. Crew size depended on the mission but could be as many as 30. The aircraft carried two large radars. A search radar was housed in a squat, circular radome, five metres in diameter, conformal to the belly. A height finding radar was housed in a radome on the aircraft's back, in a

[20] Friedman, N., *U.S. Destroyers: An Illustrated Design History*, Arms & Armour Press, London, 1982, pp 229-233; *Janes Fighting Ships 1956/57*, Jane's Information Group, Couldson UK, pp 397-401.
[21] Browne, J., and Thurbon, M., *Electronic Warfare*, Brassey's, London, 1998, p 149.

fat dorsal fin, two metres high and three metres long. One experimental version of the Warning Star had a surveillance radar in a rotodome mounted above the rear fuselage. In the early 1950s, the USN ordered over 240 Warning Stars.[22]

In 1951, the USAF followed suit and introduced its own AEW version of the Super Constellation, the RC-121. After a 'turf battle' with the Army and Navy, the USAF secured a monopoly of large aircraft within the US military and became the sole operator of long range multi-engine AEW platforms. Over the period 1951 to 1955, the USAF acquired 124 RC-121s, many of which were operated by NORAD to fill gaps in the DEW Line. All RC-121s were redesignated EC-121s in 1962.[23] The EC-121 carried nearly six tonnes of radar and electronic equipment, which was almost the total weight of the original AEW Avenger.

Strategic Command and Control

In the mid-1960s, the bomber threat was supplemented by the Inter-Continental Ballistic Missile (ICBM) threat. Warning times were cut from hours to minutes. Defence against ICBMs was technically difficult and financially impossible, so an offensive deterrent strategy was adopted, based on the principles of Massive Retaliation and Mutual Assured Destruction. The strategy depended on a high reliability early warning system, a robust command and control system, and a guaranteed 'second strike' capability of sufficient power to exterminate the enemy. The system included multiple redundancy.

An element of the redundancy in the command and control system was a fleet of Airborne Command Posts (ACPs). Their function was to ensure that, even if the conventional land-based command and control system had been obliterated by a Soviet first strike, rendering the national government incapable of issuing commands, the orders would still get through for strategic forces to launch a retaliatory strike.

The USAF Strategic ACP was the 'Looking Glass' version of the EC-121, which entered service in 1952 and could communicate with USAF bomber and ICBM forces. The EC-121 was later replaced by the Boeing EC-135.[24]

The USN Strategic ACP was the EC-130 version of the Lockheed Hercules, which entered service in 1964 and could communicate with the Polaris nuclear missile submarines. The EC-130 was later replaced by the E-6 'Mercury', which was based on the ubiquitous Boeing 707 airframe. In 1996, the USAF and USN missions were merged in a single platform – the USN E-6.[25]

At an even higher level, the USAF operated a small fleet of EC-135 National Emergency Airborne Command Posts (NEACP or 'Kneecap'). The EC-135s were designed to act as the headquarters for the President and the Commander-in-Chief of

[22] Yenne, B., *Lockheed*, Bison Books, London, 1987, p 57.
[23] *ibid*., p 57.
[24] The C-135 family, which includes the KC-135 Tanker and the EC-135 EW aircraft, are very similar to the Boeing 707, but have a narrower fuselage and less wing span. The USAF designation for the Boeing 707 is C-137.
[25] Francillon, R.J., 'Messenger of the Gods: The Boeing E-6A Mercury', *Air International*, January 1995, pp 19-24.

Strategic Air Command in a nuclear war. In 1975, the E-4 replaced the EC-135 in the Kneecap role. The E-4s are modified Boeing 747s, fitted with 13 communications systems, including SHF, LF and VLF.[26] A total of 50 antennae festoon each aircraft. An E-4 can remain on station for 72 hours, carrying three times the payload of the EC-135. Throughout the Cold War, a Kneecap was always on alert at Andrews AFB, near Washington DC.[27]

Only the superpowers have operated dedicated ACPs to control their strategic forces. No other nation has perceived the need for the instantaneous contact, the redundancy and the security of an airborne platform. However, with new technology making electronic systems smaller and more capable, the strategic ACP function could be performed at a single console on a 'tactical' ACP or AEW&C aircraft. In an age when weapons of mass destruction and ballistic missiles proliferate and warning times are getting shorter, other nations may yet see the value of a strategic ACP capability to 'back up' conventional land-based systems.

Tactical Command and Control

The war in Vietnam gave the USAF its first practical experience at integrating AEW&C and ACPs into large-scale combat operations. The EC-121 AEW&C aircraft and the EC-130 ACPs were used extensively in Vietnam.

Between 1965 and 1974, EC-121 'College Eye' aircraft of the 552nd AEW&C Group operated out of bases in Thailand. Their mission was to support strike operations into North Vietnam such as 'Rolling Thunder' and 'Linebacker' by providing radar surveillance of North Vietnamese airspace and controlling intercepts when required.[28] The EC-121s flew over 13,900 combat sorties, issued 3,300 MiG warnings, assisted in 25 MiG kills and coordinated 80 Combat Search and Rescue (SAR) missions for the rescue of downed aircrew from enemy territory.[29]

The tactical ACP role was performed by the EC-130E Airborne Command & Control Centre (ABCCC), which was a standard Hercules with a 12 metre long ABCCC capsule inserted into the cargo bay. The ABCCC managed tactical air resources, directed close air support and provided integrated communications support. The self-contained capsule was fitted with 20 radios (HF, VHF, UHF and FM), two secure teletypes and a 14 channel voice/data recorder. In addition to the standard cockpit crew of four, the ABCCC carried a 'battle staff' of 12. A total of 10 C-130s were configured as ABCCC, but only nine remain in service, the other having been lost in the unsuccessful hostage rescue attempt in Iran in 1980.[30]

The ABCCCs helped coordinate airstrikes. By 1972, Hanoi had become the most heavily defended place in the history of air warfare. The success of Operation Linebacker II was largely due to the ability of the AEW&C and ACPs to coordinate

[26] The various radio bands in the electromagnetic spectrum are listed at Annex B.
[27] Redding, R. & Yenne, B., *Boeing : Planemaker to the World*, Bison Books, Greenwich Connecticut, 1983, pp 156-160.
[28] *ibid.*, p 57.
[29] Drendel, L., *TAC : A History of the USAF Tactical Air Forces 1970 – 1977*, Squadron/Signal Pub, Inc, Michigan, 1978, p 59.
[30] *Jane's Aircraft 1984/85*, p 435.

large numbers of B-52 bombers and supporting aircraft attacking Hanoi from multiple directions and altitudes, almost simultaneously, to overwhelm the North Vietnamese air defences and minimise US losses. For example, on 26 December 1972, 116 B-52s attacked Hanoi over a 15 minute period. They were supported by over 100 other aircraft. The lumbering B-52s had the radar cross section of a barn, but the strike was so well coordinated that the defences were overwhelmed and only one B-52 was shot down.[31] In the 11 day operation, the North Vietnamese launched 1,242 SAMs at the American bombers, but only 26 B-52s were lost.[32]

AEW&C and ACP operations also supported tactical air strikes and SAR in South Vietnam, Cambodia and Laos. Typical of these operations was the interdiction of the infamous Ho Chi Minh Trail, which included the use of innovative air-dropped seismic and acoustic ground sensors. A squadron of USN Lockheed P-2E Neptune ASW aircraft were modified to drop the sensors. ACPs received and processed data from the sensors and then guided strike aircraft to the targets identified.[33] Hundreds of trucks were destroyed in the campaign. Such a system could be characterised as indirect surface surveillance.

Surface Surveillance

As well as being ideal for air surveillance, airborne radar platforms can also be used for surface surveillance. Air surveillance radars tend to operate in the UHF frequency range, on D, E or F band, whilst surface surveillance radars tend to be in the higher SHF frequency range, on I or J band. A radar will therefore be optimised for air *or* surface surveillance. It may still be able to perform other tasks, albeit much less effectively.

Surface targets are usually either stationary or slow moving and the surrounding area is cluttered, with trees and hills on land or waves at sea. Surface surveillance radars tend to operate in two modes - moving target indicator (MTI) and synthetic aperture radar (SAR). In the MTI mode, the computer software is set to automatically ignore fast movers and only track slow movers. The SAR process involves illuminating the target from several angles and overlaying the set of pictures to build a three-dimensional picture. It can take up to 15 minutes to build up a SAR picture, so SAR is useless for tracking fast moving aircraft.

The Ultimate Surface Surveillance Platform

In the early 1990s, the E-8 Joint Surveillance and Target Acquisition Radar System (JSTARS) entered service with the USAF. The E-8 is a modified Boeing 707 fitted with a ground surveillance radar, in an 12 metre long canoe-shaped radome conformal to the front half of the aircraft's belly. There are 18 operator consoles onboard. The USAF plans to acquire 13 JSTARS.[34]

[31] Drendel, L., *Air War Over South East Asia*, Squadron/Signal, Carrollton, Texas, 1984, p 38.
[32] Scott, C., 'Forcing the Peace', *RAF Air Power Review*, Spring 1999, p 33.
[33] Mersky, B., and Polmar, N., *The Naval Air War in Vietnam*, Nautical & Aviation Pub Co, Annapolis, 1981, pp 172-177.
[34] *Jane's Aircraft 1998/99*, pp 694-696.

JSTARS is the most capable surface surveillance aircraft ever built. It combines a very large side-looking SAR of unprecedented power and advanced software for processing the data. The system includes ground stations which perform data fusion. Using Link 16 datalink, JSTARS can receive radar pictures and EW data from other platforms, such as reconnaissance aircraft and unmanned aerial vehicles (UAVs). The data can be rapidly fused into useable form, thus generating a master 'Recognised Ground Picture', the sum of all the partial views from all the platforms in the area. JSTARS can then distribute that picture to all participants, giving them greatly enhanced situational awareness. JSTARS was designed to do for ground operations what AEW&C does for air operations.

JSTARS was still in the prototype stage when two E-8As were deployed to participate in Operations Desert Shield and Desert Storm in 1990/91. They flew 54 combat missions totalling 600 flying hours.[35] Though still not fully operational, JSTARS was credited with eliminating much of the 'fog of war' for Coalition forces. The large scale Iraqi surprise attack at Khafji was detected and defeated as a result of JSTARS surveillance and 'real time' reporting. The situational awareness that JSTARS gave to Coalition forces significantly reduced the confusion and 'nasty surprises' for friendly forces.[36]

JSTARS can detect stationary and slow moving vehicles but it cannot identify and classify such targets. Experience has shown that the data on enemy radar and communications emitters collected by EW surveillance aircraft can be 'overlaid' with the SAR and MTI pictures generated by JSTARS. The combination of JSTARS data and EW data can produce more complete target identification and threat assessment.[37]

In 1997, an E-8C was used in a major multinational exercise in Korea. The JSTARS fused information from its own sensors, UAVs and other surveillance aircraft to provide timely warning of enemy activity. The information provided by the JSTARS enabled 'friendly' attack helicopters to launch from their main base, intercept a large 'enemy' ground force convoy (100 kilometres from the helicopter base) and destroy most of the vehicles in the convoy. The engagement upset the 'enemy' operational plan and facilitated a quick overall victory for 'friendly' forces.[38]

JSTARS is optimised for operations over land where there are often a huge masses of slow moving targets, such as cars, trucks and armoured vehicles. An AEW&C aircraft can detect such movement, but it clutters the screen and confuses the operators, so AEW&C mission systems automatically filter out slow moving targets and only aircraft are shown. Helicopters sometimes fly very low and slow, so AEW&C aircraft often have difficulty tracking helicopters.

The JSTARS multi-mode radar interleafs MTI mode with its SAR mode to detect moving targets. In recent operations in Yugoslavia, E-8Cs have been able to detect

[35] Browne and Thurbon, *Electronic Warfare*, pp 159-160.
[36] Friedman, N., *Desert Victory : The War for Kuwait*, US Naval Institute Press, Annapolis, 1992, pp.197-203.
[37] Wall, R., 'Army Intelligence Aircraft to Support Ground Forces', *Aviation Week & Space Technology*, 10 May 1999, p 39.
[38] Veres, A., 'JSTARS Shines in FOAL EAGLE 97', *Asia Pacific Defence Forum*, Summer 98, p 35.

and track low flying helicopters.[39] JSTARS can thus augment AEW&C in the air surveillance role. Working together, JSTARS and AEW&C aircraft can detect and track everything moving on or above the Earth's surface.

Electronic Warfare Surveillance

In addition to detecting and tracking targets, there is a need to identify them, to distinguish friend from foe and to classify the target which may be an armoured vehicle, a fire control radar for a SAM battery or an air traffic control radar at an airport. Targets can often be identified by means of their electromagnetic emissions. Communications intelligence (COMINT) is technical data or intelligence information gleaned from electromagnetic communications transmissions such as radio, telephone or computer nets. Electronic intelligence (ELINT) is technical data or intelligence information gleaned from non-communications electromagnetic transmissions, such as radar. Signals intelligence (SIGINT) is the fusion of ELINT and COMINT.

The US Army

Over the period 1967 to 1975, the US Army used about 90 Beech King Air twin turboprop utility aircraft in the SIGINT role, designated RU-21 Ute. The most numerous variants, the RU-21 D and RU-21 H, were the primary platforms for the Guardrail SIGINT and Direction Finding (DF) system. The primary purpose of the Guardrail system is to detect, locate and jam selected enemy radar systems, usually as part of operations to suppress enemy air defences, to facilitate US air operations over enemy territory. Each Ute carried two cockpit crew and six to ten systems operators, in a compartment behind the cockpit. Utes were used extensively in the Vietnam War.[40]

In 1975, the RC-12 Huron version of the King Air entered service with the US Army and later the USN and US Marines. It has since been the platform for the Guardrail SIGINT/DF system. Each Guardrail carries two cockpit crew and six systems operators. Guardrails were used operationally in West Germany, to monitor critical border areas as part of the NATO effort to 'map' Warsaw Pact radars and to provide early warning if Warsaw Pact forces had ever attempted to launch an attack. Guardrails are still used along the border between North and South Korea, to 'map' North Korean radars, monitor the shaky truce and provide early warning of any North Korean attack.[41]

Today, the US Army operates a fleet of 50 Guardrails. The National Security Agency has another 12, operating in Central America. A replacement for the Guardrail is to be acquired over the period 2000 – 2006, under a project titled Aerial Common Sensor.[42]

[39] Wall, R., 'Joint-STARS Changes Operational Scheme', *Aviation Week & Space Technology*, 3 May 1999, p 26.
[40] Harding, S., *US Army Aircraft Since 1947*, Airlife Pub Ltd, Shrewsbury UK, 1990, pp 21-23.
[41] *ibid.*, pp 24-26.
[42] *Air International*, April 1999, p 198.

The USAF and USN

The USAF and USN also operate large EW surveillance aircraft. Since the end of the Cold War, their focus has changed, but they are kept as busy as ever.

The USAF operates a fleet of 16 RC-135 Rivet Joint SIGINT aircraft. The Rivet Joint is the largest SIGINT aircraft in US service, with a range of 7,000 kilometres and an endurance of over eight hours, so it is suitable for the global EW role. Since entering service in the 1960s, RC-135s have mapped the location and type of air defence radars and other emitters of many hostile nations and regularly eavesdropped on their communications. Rivet Joint can thus establish an enemy's electronic order of battle and patterns of usage.[43]

The USN operates a fleet of 12 EP-3 Aries SIGINT aircraft, based on the smaller Lockheed Orion airframe. The aircraft has 12 mission consoles, with six dedicated to ELINT and six dedicated to COMINT. During the Cold War, the EP-3s complemented the RC-135s in the global SIGINT role.[44]

When the data provided by the Rivet Joint, Aries and Guardrail SIGINT aircraft is fused with that provided by AEW&C and JSTARS, the product is an unprecedented level of situational awareness. The EW and radar surveillance platforms constitute a potent team.

American AEW&C Today

By the mid-1970s, the value of AEW&C in a wide variety of applications was beyond doubt. As the older generation aircraft (USAF EC-121s and USN Tracers and early model Hawkeyes) wore out, they were replaced by far more capable systems.

In 1977, the EC-137D Airborne Warning and Control System (AWACS) entered service in the USAF. It is based on the Boeing 707 which had ample room for the largest electronics fit and mission specialist crew ever carried by an AEW&C aircraft. The air surveillance radar is carried in a six and a half metre diameter rotodome, mounted above the rear fuselage. There are 14 colour mission consoles in the cabin of the AWACS. A Tactical Director controls the activities of a Surveillance Team of five surveillance controllers who build and maintain the recognised air picture and a Weapons Team of up to nine weapons controllers who control friendly aircraft operations. There is also a small team of technicians, consisting of two communications specialists, a software specialist and a radar maintainer. More specialists can be carried, including an entire reserve crew.[45]

The USAF operates a fleet of 33 AWACS. Their services are in great demand all over the world. Recent AWACS operations have been concentrated in the Balkans, the Caribbean, Iraq and Korea.

---

[43] Fulghum, D., 'Electronic Intelligence', *Aviation Week & Space Technology*, 5 May 1997, pp 48-50.
[44] *ibid*., pp 51-57.
[45] O'Dell, R., 'Boeing E-3 Sentry Variants and Capabilities', *RAF Air Power Review*, Summer 1999, London, 1999, pp 91-105.

Early in the program the EC-137D was redesignated the E-3 Sentry. It was such an advance on its predecessors that it was subsequently acquired by Britain (seven in 1990), France (four in 1990), NATO (17 in 1982) and Saudi Arabia (five in 1986).[46] The AWACS is the most widely used large AEW&C aircraft in the world today. Production has totalled 66 aircraft.

What Next?

The US military appears to have plans to migrate the AWACS and JSTARS capabilities into space, using space based radar (SBR).[47] There are several significant technical problems to overcome, but the solutions are just a matter of time and money.

Due to atmospheric distortion and sensor resolution, surveillance satellites need to be in low earth orbit (LEO), but this gives them a limited field of view. Such satellites are in position to conduct surveillance of a given target area for a few minutes at a time, a few times a day, as their orbit brings them over the target area. For most of the day they will be passing over areas of little or no interest.

AEW&C aircraft are more flexible in their ability to conduct continuous surveillance of a given area and to shift their focus to a new area on short notice. Current surveillance satellites are too large and expensive to deploy in sufficient numbers to replace the flexibility of aircraft based systems. However, emerging technologies offer the potential for a constellation of hundreds of cheap mini-satellites in LEO. Such a constellation of SBR satellites would give continuous global coverage and obviate the need for AEW&C aircraft deployments. Small satellites orbiting at speeds of over 20,000 kph and altitudes in excess of 100 kilometres are much more difficult to find and shoot down than large, slow transport aircraft flying at an altitude of 10 kilometres. Furthermore, there are no geographic or political limitations on where satellites can overfly.

Meanwhile, less wealthy nations will have to settle for aircraft platforms. There is a growing world market for such aircraft in two distinct size brackets – the medium size airliner size such as the Boeing 737 and the small business jet size such as the Gulfstream V.

The US has been encouraging its allies to standardise on a mid-range capability AEW&C, consisting of a current technology Hawkeye radar and mission system mounted on a C-130J platform. The US rarely exports fighter aircraft or missiles with the latest capabilities, preferring to release platforms fitted for older weapons (AIM-7 Sparrow AAM, rather than the latest AMRAAM[48]) and 'second rate' or 'downrated' avionics. The same appears to be the case with the Americans' preferred export AEW&C. The policy maintains the US capability edge while generating economies of scale and revenue for the US aerospace industry. The proposed 'standard' AEW&C Hercules on offer is significantly less capable than the version proposed (unsuccessfully) for Australia's Project Wedgetail.

[46] Simpson, R., 'Boeing E-3 Sentry', *Air Pictorial*, March 1987, p 97.
[47] Moorman, T., 'The Explosion of Commercial Space and the Implications for National Security', *Airpower Journal*, Spring 1999, p 19
[48] AIM is the US abbreviation for Air Intercept Missile, AMRAAM is the Advanced Medium Range Air-to-Air Missile.

DIFFERENT STROKES FOR DIFFERENT FOLKS

Rule Britannia: AEW&C on a Shoestring Budget

The British emerged from World War II virtually bankrupt and exhausted, so they chose not to maintain the global force structure necessary to police the Empire and began the process of divesting themselves of their colonial liabilities, starting with India in 1947. With very limited resources, the British needed every force multiplier they could get as cheaply as possible. They continued their habit, formed during the war, of tapping into the American 'cornucopia' for new capabilities.

The Royal Navy

After World War II, the Royal Navy (RN) Fleet Air Arm operated a small fleet of aircraft carriers and attempted to maintain a balanced force, with the full range of capabilities. In the 1950s, AEW versions of the Grumman Guardian and Douglas Skyraider were acquired from the Americans as interim AEW aircraft.[49]

In 1960, an AEW version of the British Gannet torpedo bomber entered service. The Gannet was a large aircraft with a twin turboprop engine generating 3,600 shaft hp, driving huge contra-rotating propellers. The AEW version had an APS-20 radar, in a circular radome conformal to the belly of the aircraft, similar in configuration to the AEW Guardians and AEW Skyraiders. The crew consisted of a pilot and two radar operators. The RN operated a fleet of 44 AEW Gannets.[50] In 1978, the RN retired its last conventional take off and landing (CTOL) aircraft carrier 'Ark Royal' and the AEW Gannets lost their sole remaining platform at sea. They were retired from service without replacement.[51]

Only four years later, the RN sent the light aircraft carriers 'Hermes' and 'Invincible' to the Falklands war, armed with Harriers and helicopters, but no AEW aircraft. During that war, the British recognised the operational need for AEW and an emergency program was undertaken to fit the Searchwater radar (as fitted to the Nimrod ASW aircraft) to a few Sea King helicopters. It was a 'quick fix', with the radar mounted in an inflatable radome that swings out below the fuselage after take-off. The AEW Sea Kings did not enter service until after the war.

Eventually 13 Sea Kings were converted to the AEW role. The crew consists of one or two pilots and three mission specialists. The RN retains this rudimentary AEW capability at sea today.[52]

Royal Air Force: Air Surveillance

The RAF was a late entry into the land-based AEW business. In the early 1970s, a dozen ancient Avro Shackletons were converted into AEW aircraft. The Shackleton was a World War II vintage, four-engine bomber, which had been converted to the

[49] *Jane's Aircraft 1956/57*, pp 270-272.
[50] *Jane's Aircraft 1959/60*, p 42.
[51] Allport,'AEW Aircraft Survey', p 170.
[52] *ibid*., pp 212-213.

maritime patrol role. The AEW Shackleton carried an APS-20 radar in a circular radome, conformal to the belly, just ahead of the bomb bay.[53] The APS-20 had been fitted to the USN Guardian in 1950, so it had taken the RAF over 20 years to field an AEW capability to match what the USN had introduced in the early 1950s.

Studies conducted in the mid-1970s showed that a modern AEW&C capability would triple the effectiveness of British air defences. The RAF considered the existing American systems, the USAF AWACS and the USN Hawkeye, and an indigenous proposal.[54]

In 1977, Hawker Siddeley Aviation proposed an AEW version of the Nimrod Maritime Reconnaissance (MR) aircraft. The concept was novel, in that the AEW Nimrod would not have one radar with 360 degree coverage, but two radars. There would be one radar in the nose and another in the tail, each with 180 degree coverage. The new GEC Avionics dual mode radar had good performance for maritime surface surveillance and was believed to have the 'potential' to 'also satisfy the requirements of central Europe' for air surveillance.

Rather than buy a proven American AEW&C system, the British government decided to develop an advanced system, with capabilities beyond anything then in service. They accepted the risk inherent in a new project with unproven technology. There were political advantages in selecting a British company, including the creation of jobs in Britain, supporting the British aerospace industry and keeping the money in Britain.

Hawker Siddeley was awarded a contract to produce a dozen AEW Mk 3 Nimrods. The first prototype was a converted Comet airliner, which first flew in the AEW configuration in June 1977. The large, bulbous radomes in the nose and tail, required to accommodate the radars, increased aircraft length by three metres, but testing revealed no significant aerodynamic or mechanical problems. Eleven of the original 46 MR Mk 1 Nimrods were withdrawn from service and set aside for conversion to AEW Mk 3. The remaining 35 MR Mk 1 aircraft were upgraded to MR Mk 2 and continued in service as maritime reconnaissance aircraft.

The first 'production' AEW Mk 3 Nimrod was delivered to the RAF in December 1984, but initial operational capability was deferred, pending 'solution of technical problems concerning the avionics'. The problem areas included the radars, the mission computer and systems integration.

In the air surveillance mode, the radars performed well over water but not over land, especially over large urban areas with heavy concentrations of moving land vehicles. The tracking accuracy, track number capacity and track life were inadequate and the built-in test capability and general maintainability were also inadequate.[55] The radars also failed to meet range requirements and a new radar aerial had to be designed and fitted.[56]

[53] *Jane's Aircraft 1972/73*, p 202.
[54] Palmer, J., 'AEW Aircraft - The GEC Avionics Proposal', *Air Power : Global Developments and Australian Perspectives*, Pergamon-Brassey's, Sydney, 1988, pp 265-276.
[55] *ibid*., pp 265-268.
[56] *ibid*., p 275.

The original mission computer, a GEC 4080, was not powerful enough. In 1986, a new computer was introduced which was twice as powerful as the 4080. Even that was not enough and another computer, three times as powerful as the 4080, was proposed.[57]

The various avionics systems worked in isolation, but integration on the aircraft was unsuccessful. A further problem was the man-machine interface, which was too complex, so simpler display symbology and better keyboards had to be introduced.[58]

Hawker Siddeley became part of the British Aerospace (BAe) conglomerate, which claimed that the RAF and government bore part of the blame for delays by not giving the program adequate priority. BAe further claimed that the technical problems could be solved, but more time was needed. The problems were not resolved in time and the government decided to stop throwing good money after bad.[59]

The AEW Nimrod project was cancelled in December 1986, after the expenditure of 900 million pounds (over two billion dollars). All 11 MR Mk I Nimrods set aside for conversion had been converted to AEW Mk 3 configuration. They never re-entered RAF service, were put into storage and used as a source of spare parts for the MR Mk 2 fleet. In 1991, the RAF acquired seven Boeing E-3D Sentry AWACS.[60]

The story of indigenous British AEW did not end with the Nimrod fiasco. BAe tried to recycle the GEC radar and avionics package on a series of smaller aircraft, including the four-engine Lockheed C-130 Hercules and the BAe 748 twin turboprop. None of the proposed export variants of the GEC system ever entered service with any nation.

Royal Air Force: Surface Surveillance

The British are currently developing an airborne surface surveillance radar system, designated Airborne Stand-Off Radar (Astor). The three contenders, Lockheed Martin, Northrop Grumman and Raytheon, are offering similar solutions. Each carries a dual mode (MTI/SAR) radar in a long canoe-shaped radome under the forward fuselage, in the same manner as JSTARS. The platform will be a twin-engine, long range business jet - either a Gulfstream V or a Bombadier Global Express. The crew will consist of two pilots, a mission controller and three image analysts. Their colour displays will show moving target data, synthetic radar images and digital ground maps, in any combination and overlayed.[61]

Astor is designed to perform a function similar to the American JSTARS. It will detect stationary or slow moving vehicles and helicopters and classify SAM threats.

[57] *ibid.*, p 270.
[58] *ibid.*, p 276.
[59] *Jane's Aircraft 1986/87*, p 295.
[60] Allport, 'AEW Aircraft Survey', p 171.
[61] Pocock, C., 'The Eyes Have It', *Air International*, April 1997, p 228. Astor evolved out of the British Army's Corps Airborne Stand-Off Radar (CASTOR) program, which began in the late 1970s.

Astor will rely on datalinking to ground stations, where much of the data processing and command and control of functions will be performed.[62]

The RAF plans to acquire four or five Astor aircraft. There is already another potential customer. NATO has a requirement for up to 12 airborne surface surveillance systems and has decided not to accept an American suggestion to acquire JSTARS.[63]

The Sincerest Form of Flattery: The Russian Way

Imitation is said to be the sincerest form of flattery. The Soviets were slow to realise the benefits of AEW&C, but once the Americans had proven its value, the Soviets followed the American model, closely.

The Russian Air Force

The first Soviet AEW&C aircraft was the Tupolev Tu-126 (NATO codename Moss), which entered service in 1971. It was based on the Tu-114 four engine turboprop transport, itself a development of the Tu-95 Bear bomber, Soviet equivalent of the American B-52. The air surveillance radar was carried in a seven metre diameter rotodome mounted above the aircraft centre of gravity, behind the wing. The crew numbered about 12. The Soviet Air Force operated a fleet of 12 aircraft.[64]

The Tu-126 may have been used in combat. After the Indo-Pakistan War of November/December 1971, Pakistani sources reported that India had used some type of AEW&C to coordinate the air defence of India and direct strikes into Pakistan. The AEW&C aircraft were codenamed 'Spider' and usually flew 'race tracks' well inside Indian territory. It has been speculated that the Indian AEW&C aircraft must have been Tu-126 aircraft, manned either by Russian crews or mixed Russian/Indian crews.[65] The Indians were understandably secretive about their capabilities and operations and would neither confirm nor deny. Certainly, in the mid-1970s and early 1980s, the Indian Air Force had a Communications Squadron which included two Tupolevs - either Tu-124 ACPs or Tu-126 AEW&C.[66]

The next generation Soviet AEW&C was the Beriev A-50 Mainstay, which entered service in 1984. It was based on the Ilyushin Il-76 transport, Soviet equivalent of the American C-141 Starlifter. It carried a development of the Moss radar in a ten metre diameter rotodome mounted in the usual location. The A-50 also has a weather radar in the nose and a very large ground mapping radar under the nose. The ground mapping radar may give the A-50 some surface surveillance capability. The crew

[62] Pocock, C., 'ASTOR', *RAF Yearbook 1999*, RAF Benevolent Fund Enterprises, UK, 1999, pp 56-58.
[63] Morrocco, J., 'UK's Astor Eyed as NATO Springboard', *Aviation Week & Space Technology*, 8 March 1999, pp 33-34.
[64] Nemecek, V., *History of Soviet Aircraft*, Willow Books, London, 1986, pp 203-204.
[65] Nordeen, L., *Air Warfare in the Missile Age*, Smithsonian Institute Press, Washington DC, 1985, p 109.
[66] *Pacific Defence Reporter*, Annual Reference Edition, 1980/81, Peter Isaacson Publications Pty Ltd, Melbourne, 1980, p 69.

numbers 12 and a fleet of 16 aircraft still operate with the Russian Home Defence and Tactical air forces.[67]

During Operation Desert Storm the Russians maintained a continuous (24 hour a day) patrol of two Mainstays over the Black Sea. They apparently monitored Coalition air operations out of Turkey and ensured that US cruise missiles did not stray into Russian airspace.[68]

The Russian Navy

In the late 1980s, the Soviet Navy built its first 'supercarrier', with a large flight deck and steam catapults, capable of operating CTOL fixed wing aircraft. Having observed US aircraft carrier operations around the world for decades, the Russians developed a compact AEW aircraft, based on the An-72 twin turbofan short take-off and landing (STOL) light transport. The prototype of the An-71 Madcap first flew in 1985. It had a large radar in a saucer fixed directly to the top of the vertical tail and was 50 per cent larger than its USN equivalent, the Hawkeye. The project was cancelled in 1990 as the Soviet Union was collapsing. Since 1995, the Antonov 'company' has been promoting the An-71 as a land-based AEW aircraft. No sales have been confirmed.[69]

Perhaps inspired by the RN AEW Sea King, the Russians are currently developing an AEW version of the Kamov Ka-31 ASW helicopter. It carries a large, slab shaped, rotating radar under the fuselage which folds down for operation after take-off. There is no radome.[70]

The Russians are also developing an AEW version of the Yakolev Yak-44 twin turboprop STOL transport, which is a virtual clone of the Hawkeye. The AEW Yak may eventually operate off the Russian aircraft carrier 'Kuznetsov'.[71]

Russian AEW&C aircraft have never been used in combat against the Western alliance. We may never know how effectively they could have performed their missions. We do know that their intended function was exactly the same as that of their US and NATO counterparts.

We also know that the Soviets appreciated the force multiplier value of US/NATO E-3 AWACS. Soviet war plans included allocating fighters to dash into NATO airspace and destroy the E-3s. The mission was expected to be suicidal, but each AWACS was considered to be worth the sacrifice of a fighter squadron.[72] The Kamikaze spirit was not dead.

[67] Browne & Thurbon, *Electronic Warfare*, p 152.
[68] *Jane's Aircraft 1997/98*, p 370.
[69] *ibid*., pp 513-514.
[70] *ibid*., p 363.
[71] Lake, J., 'The Hawkeye Abroad', *Air International*, December 1997, p 347.
[72] SQNLDR J. Kearney (ex RN officer) interview on 20 July 1999. At a meeting in 1993, Russian Air Force officers confirmed that Regiments of MiG-29 fighters had been dedicated to the anti-AWACS mission, armed with the AA-9 Amos ARM.

Sun Tzu's AEW&C: Smoke and Mirrors

Technologically, the Chinese have lagged behind the Western powers for decades. The standard Chinese main battle tank is a copy of the 1950s technology Soviet T-55. The bulk of the ships in Chinese Navy are copies of 1950s technology Soviet coastal patrol vessels. The standard Chinese fighter aircraft is a copy of the 1960s technology Soviet MiG-21 and even the latest Chinese fighter is just an improved version of the MiG-21. Though China's forces are huge and dwarf those of Taiwan, few analysts believe that China could successfully invade and conquer Taiwan, particularly if the US Pacific Fleet became involved.

The Chinese have attempted to modernise their decrepit war machine with an infusion of Western technology, but plans to update hundreds of fighter aircraft and other platforms with state-of-the-art electronics, engines and weapons systems have failed for lack of foreign exchange (cash). In the late 1980s, *Air International* aviation magazine published a photograph of a Chinese Tu-4 Bull bomber, fitted with an AWACS-style saucer. The Tu-4 was the Soviet copy of the Boeing B-29, which first flew in 1943. The AEW Tu-4 was never put into operational service, so it was probably just a proof-of-concept aircraft or test bed.

The acquisition of Hawkeyes by Taiwan in 1995 appears to have sparked an AEW arms race reaction from China. There have been unconfirmed reports that the Chinese have begged, borrowed or stolen Russian Mainstay AEW&C aircraft or Russian electronic systems for fitting to locally produced versions of the Antonov An-12 or even AEW Nimrod radars. There seems little doubt that the Chinese perceive themselves to be at a disadvantage against the Taiwanese and Russian air forces and want their own fixed wing AEW&C.[73]

The Chinese are developing a rotary wing AEW aircraft, based on the Z-8 heavy lift helicopter, a licensed copy of the French Super Frelon. Whether it is a quick fix like the British Sea King or a more elegantly integrated system remains to be seen. It is expected to enter service with the Chinese Navy early in the next century.[74]

French AEW&C

In the 1980s, the French Army and the French Navy fielded indigenous airborne radar systems on converted platforms. The small size of the platforms limited the size of the radar arrays and the amount of supporting electronic equipment and operators that they could carry.

The French Army: Surface Surveillance

In the late 1980s, the French Army experimented with the 'Orchid' targeting radar which was intended to support the Hades nuclear battlefield missile. The radar array was mounted underneath the belly of an Aerospatiale Puma helicopter. It was a mechanically rotating rectangular slab, so large that it had to fold down after take-off

[73] Arnett, E., (Ed), *Military Capability and the Risk of War: China, India, Pakistan and Iran,* Oxford University Press, London, 1997, p 47.
[74] *Jane's Aircraft 1998/99*, pp 57-58.

and could not be covered by a radome. There was enough space in the helicopter for a few operators who would datalink their radar picture to a ground station.[75]

The demise of the Soviet Union ended the need for a tactical nuclear capability and the Orchid system was almost cancelled in 1990. The system was deployed to Operation Desert Storm and proved to be useful for surface surveillance, so the requirement was subsequently redrafted in post Cold War terms. The revised system was named 'Horizon'.[76]

The first operational Horizon system, mounted on an Aerospatiale Cougar helicopter, was delivered in 1994. The French Army now operates four such aircraft and two ground stations.[77]

The French Navy: Air Surveillance

After World War II, the French Navy operated a small fleet of light aircraft carriers. In the 1950s, this force was heavily committed to operations intended to preserve French imperial interests in North Africa and South East Asia. The French initially satisfied their AEW requirement by acquiring surplus AEW Avengers from the US.

In the early 1980s, the French Fleet Air Arm converted 28 of its large single engine turboprop Alize ASW aircraft into rudimentary AEW aircraft. The conversion included a Thomson-CSF 'Iguana' radar, with integrated IFF and an ESM system. The radar was the same as that carried by the twin-engine land-based Atlantique ASW patrol aircraft. It was mounted in a small, retractable, drum-shaped radome that extended beneath the aircraft's belly after take-off. The crew of three (a pilot and two operators) sat in a cramped cabin. Their radar picture had to be datalinked to the CIC onboard a warship.[78]

The AEW Alizes operated off the French aircraft carriers 'Foch' and 'Clemenceau'. The AEW Alizes are being replaced by the vastly more capable American Hawkeye which will operate off the new French aircraft carrier 'Charles De Gaulle'.

Recent European Developments: Smaller, Cheaper, Less is More

In the late 1980s and early 1990s, the Ericsson company developed the PS-890 ERIEYE air surveillance radar system for the Swedish Defence Department. The radar consists of two fixed, back-to-back, electronically scanning radars, in a ten metre long bar, mounted above the spine of the aircraft. The radar alone weighs 1,300 kilograms. Each array scans a 180 degree arc. The system therefore covers 360 degrees.[79]

There are two versions of the system. In the Airborne Surveillance / Ground Control (ASGC) version the aircraft is just a radar platform, acting as a reporting unit only, transmitting its radar picture to a ground station by tactical datalink. All data

[75] Pocock, C., 'The Eyes Have It', *Air International*, April 1997, p 228.
[76] *ibid.*, p 228.
[77] *ibid.*, p 228.
[78] *Jane's Aircraft 1985/86*, p 65.
[79] Nicholls, M., 'Embraer's New Stars', *Air Forces Monthly*, July 1999, pp 48-49.

processing and fighter controlling is done by the ground station. In the Air Surveillance / Airborne Control (ASAC) version the aircraft performs the full AEW&C role, acting as a flying Control and Reporting Unit (CRU).[80]

The ERIEYE system has been purchased by three air forces. It has been fitted to six Swedish Air Force Saab 340 aircraft and five Brazilian Air Force Embraer EMB-145 aircraft and four Greek Air Force Embraer EMB-145 aircraft.[81] The Swedes have chosen the ground control version but the Brazilians and Greeks have opted for the airborne control version. The mission crew consists of at least three (a Tactical Co-ordinator, an EW operator and an intercept operator) but up to eight mission crew can be carried.[82]

The most interesting aspect of this development is that a limited AEW&C capability is now within the financial reach of almost any nation. Recent developments in signal processing and data processing have made it possible to fit a useful AEW&C capability on a relatively small platform. The adoption of commercial off the shelf (COTS) computers with open architecture and relatively cheap civilian business jets has made it possible for customers to mix and match sensors, systems and platforms to meet their specific requirements.[83]

THE AUSTRALIAN WAY

Few people are aware that Australia's first experience of AEW was a brief experiment in the late 1960s. The RAAF's Number 10 Squadron was equipped with Lockheed SP-2H Neptune ASW aircraft, which carried the APS-20E radar in squat circular radomes under their bellies. As the APS-20 had been the standard US AEW radar, the Neptunes had a theoretical AEW capability.

During Exercise HIGH MARS in November 1967, two RAAF Neptunes performed the AEW role, in support of the air defence of Darwin. The aircraft flew eight AEW sorties, each of up to nine hours. During Exercise CASTOR OIL in January 1970, RAAF Neptunes flew at least ten AEW sorties, each of up to seven hours, in support of the air defence of Darwin. The AEW activities were at the initiative of local commanders and AEW did not become a regular role of the RAAF Neptunes.[84]

The APS-20 could detect attacking RAF Vulcan bombers at ranges of up to 160 kilometres and RAAF Mirage fighters at ranges of up to 120 kilometres. In the absence of specialised consoles and avionics, the Neptune could act as a reporting unit only. The crew reported the bearing and track of incoming aircraft by radio to the Control and Reporting Unit (CRU) on the ground at Darwin, which then arranged a response. Detection was possible only while the target aircraft were over water. The

[80] *Jane's Radar & EW Systems 1996/97*, Jane's Information Group, Couldson UK, pp 231-232.
[81] Browne & Thurbon, *Electronic Warfare*, pp 151-152.
[82] Nicholls, 'Embraer's New Stars', p 48.
[83] Hewish, M., 'Lords of the Skies', *Jane's International Defence Review*, July 1999, p 18.
[84] Reminiscences and Log Book entries of WGCDR K. Brent, former 10SQN Navigator, interview conducted on 8 June 1999.

APS-20 could not detect aircraft over land, nor could it determine the altitude of the targets.[85]

Since then, the Australian Defence Force (ADF) has lagged behind its peers in terms of air surveillance capability. Australia cannot afford the space-based capabilities currently operated by the US. However, the ADF is catching up, with many new surveillance capabilities entering service.

The Jindalee Over-the-horizon Radar Network (JORN) has been under development for many years and is expected to be operational soon. Unlike conventional microwave radar, JORN *can* see around corners. By bouncing its beams off the upper atmosphere, JORN can detect targets over the horizon. Two or three JORN sites will monitor activity out into the archipelago to the north of Australia, providing early warning of approaching aircraft and ships in the air-sea gap.

The information provided by JORN will not be sufficiently precise to guide fighters to an intercept, but it will be a vital early warning and cue for more precise systems. The ADF has several projects underway that will provide a spectrum of air and surface surveillance capabilities to complement JORN.

The RAAF: State-of-the-Art AEW&C

The ADF plans to acquire seven medium sized AEW&C aircraft, with the first to be delivered in the year 2004. Under Project Wedgetail, the AEW&C design offered by Boeing was selected. The AEW&C Boeing 737 is fitted with two fixed back-to-back electronically scanning American radars, in a bar-shaped radome along the aircraft's back, giving 360 degree coverage (two by 180 degrees).

The tasks envisaged for the Wedgetail include surveillance, air defence, fleet support, force coordination and civil support.

Surveillance

The surveillance tasks include wide area surveillance, in which an area as large as Papua New Guinea could be covered, and focal area surveillance, in which the approaches to a vital asset such as Darwin would be covered. In peacetime surveillance will be the most common task performed by the Wedgetails. It will probably take the lion's share of the allocated flying hours.

Air Defence

The air defence tasks include the detection, tracking and classification of airborne targets and air intercept control. This is the traditional role of AEW&C and will probably be the most complex and demanding task, requiring the most crew training. It will also include the broader early warning and battle management functions.

[85] Brent.

Fleet Support

The fleet support tasks include maritime surveillance, maritime air defence, maritime strike support and maritime combat search and rescue. Whist supporting the fleet, the Wedgetail may shelter in the SAM envelope of an anti-air warfare ship, such as a destroyer or frigate, thus relieving the pressure on the RAAF fighter force to protect the high value AEW&C platform. The Wedgetail could also accompany a naval task force out beyond the range of land based air cover, where it would rely totally on the anti-air warfare ships for protection.

Force Co-ordination

The force coordination tasks include airspace management, land strike support, land operations support, search and rescue, special operations support, tactical intelligence collection, reconnaissance support, peace enforcement support, assistance in regional crises and training, with both ADF and regional forces. These tasks may not absorb much crew time or require specialist crew. They could include helping F-111 strike packages enter and leave enemy airspace, rendezvous with tankers or fighter escorts and deconflicting various aircraft packages.

Civil Support

The civil support tasks include the usual Defence Aid to the Civil Community (DACC) and Defence Force Aid to the Civil Power (DFACP) roles. These include search and rescue, fisheries protection, Exclusive Economic Zone (EEZ) protection, disaster relief, support for government agencies such as Coastwatch, Police, Customs and Immigration, evacuation of Australians from overseas locations and peacekeeping.

As with the force coordination tasks, civil support tasks may take up only a small part of the Wedgetails's time and effort. However, the requirement to provide support for civil operations will often be unexpected and urgent. Round-the-world solo yachtsmen may call 'Mayday' at any time. Tsunamis, cyclones and earthquakes cannot be scheduled. Those planning coups or civil wars in other countries rarely inform Australia in advance and illegal fishermen and smugglers usually try to avoid detection.

The Australian Army

The ADF plans to introduce several new aircraft types into Army service within a decade. The new types will have significant EW and surface surveillance capabilities. One type will be an armed reconnaissance helicopter. The other type will be for Focal Area Airborne Surveillance (FAAS) and Broad Area Airborne Surveillance (BAAS), using a mix of small manned aircraft and UAVs.

Armed Reconnaissance Helicopters

The armed reconnaissance helicopter (Project Air 87) will be chosen from a short list of three aircraft, including the American Boeing AH-64 Apache, the Franco-German

Eurocopter Tiger and the Italian Agusta Scorpion. The final decision will probably be made in the year 2000.

Light Aircraft and Unmanned Aerial Vehicles

Joint Project 129 is still in its initial phase. DSTO scientists are conducting modelling and operational analysis to determine the ideal sensor mix and platform mix, as well as platform numbers, required for the various national defence strategies - Defeating Attacks on Australia, Defence of Regional Interests and Defence of Global Interests.

The sensor mix is likely to include radar and EW sensors. The radars will be for surface surveillance, probably including synthetic aperture radar (SAR) and ground moving target indicator (MTI), giving a capability analogous to the USAF JSTARS. The EW sensors will probably include ESM and DF, giving a capability similar to the US Army Guardrail system. The BAAS/FAAS fleet will probably be a mixed fleet of manned aircraft and UAVs. The types of aircraft and UAVs are yet to be decided

Focal Area Airborne Surveillance

Focal area surveillance is the continuous surveillance of a relatively small area, where there is an expectation of locating specific targets of interest. The area covered may only be a few hundred square kilometres. The FAAS platform is likely to be a small tactical UAV.

The UAVs will usually deploy with an Army Task Force or Brigade Group and provide the ground commander with much better situational awareness than is currently possible using existing reconnaissance assets, such as Landrovers, light armoured vehicles and light helicopters. FAAS UAVs will probably operate at low to medium altitude, predominantly over land or littoral areas.

UAVs would be more survivable than larger manned aircraft and more expendable than manned platforms. However, at a cost of several million dollars each, UAVs will not exactly be ‘throw away items’. The UAVs will be capable of operating further from base and for longer periods than reconnaissance helicopters and will be a more economical means of surveillance than the larger Wedgetails.

Though not primarily intended for the FAAS role, the armed reconnaissance helicopter will carry EW sensors and a small radar. The radar will be capable of detecting moving targets in the air or on the ground, along its line-of-sight. As the helicopter will usually operate at low altitude, its radar picture will cover only a small area – perhaps less than a hundred square kilometres.

The ADF will have a range of options for each FAAS task. The armed reconnaissance helicopter will be a much more capable and survivable platform than the Australian Army’s current generation helicopters and light aircraft. It will be able to conduct surveillance and reconnaissance in high threat areas, which would be too dangerous for the more vulnerable manned aircraft currently in use. The UAVs will have greater range and endurance, be cheaper to operate and be more expendable than the helicopters.

Broad Area Airborne Surveillance

Broad area surveillance is the continuous surveillance of a larger area to establish overall patterns of activity, not necessarily in the expectation of detecting a specific target of interest. The area covered may be thousands of square kilometres. The BAAS platforms may be either light manned aircraft, such as the Gulfstream V or Learjet, or large, long range UAVs, such as the Global Hawk or Predator. The BAAS task will involve operation at medium to high altitude over land or sea, even out into the air-sea gap.

Recently, the Minister for Defence announced that Australia will join the US in an $100 million project to improve the Teledyne Ryan Global Hawk UAV. The improvements will enhance the UAV's ability to meet Australian operational requirements. They will include increasing the ability of the UAV's radar to detect moving targets, a maritime mode for the UAV's sensors and enhanced interoperability with ADF and US forces.[86]

The Global Hawk is a very large and complex UAV, designed for very long range and endurance measured in days rather than hours. It can generate a ground picture to complement the air picture that will be generated by the AEW&C Wedgetail. Australian involvement in the Global Hawk program increases the likelihood that such a UAV may be selected for the ADF BAAS requirement.

In peacetime, the activities of the BAAS platforms may complement Coastwatch operations and the activities of other agencies, including Police, Fisheries, Customs and Immigration. In wartime, such agencies may complement ADF broad area surveillance.

Wide Area Surveillance

In peacetime, the JORN will enable the ADF to build a regional Recognised Air Picture (RAP) and its surface equivalent, the combination of which is termed the Wide Area Surveillance Picture (WASP). The situational awareness conferred by JORN would be many orders of magnitude more expensive to acquire by means of a chain of conventional microwave radars. The ADF's situational awareness will range across all seasons, making it easier to notice changes and recognise threats, in an environment cluttered by masses of legitimate air and sea traffic.

In wartime, the JORN will give unprecedented early warning of approaching threats out in the air-sea gap. However, the information provided by the JORN is not precise or timely enough to guide fighters or warships to intercepts. It will be a cue for other more precise sensors.

The Wedgetail AEW&C is the essential link between the regional situational awareness provided by JORN and the precision required for air intercept control, strike control, tanker control, search and rescue and the other coordination tasks. In areas remote from fixed land-based CRUs and slow moving DDGs, only an AEW&C

[86] *Air International*, April 1999, p 194.

capability can provide detailed surveillance and the precise control required for effective air operations.

Multi-Tiered Surveillance

JORN, AEW&C, small manned aircraft, UAVs and armed reconnaissance helicopters will be integrated into the continental Air Defence Ground Environment (ADGE), with centralised command and control. The ADF will have an integrated, layered, surveillance capability with the ability to see *and act* in 'real time'. The three projected scales of surveillance capability - wide area, broad area and focal area - will cover the full surveillance spectrum, for the first time in Australian history.

JORN will provide continuous regional surveillance, an essential element of the national intelligence gathering effort. However, JORN will not provide real time information. There will be a time delay between the JORN providing raw data, the intelligence community processing the data into useful intelligence and ADF operational units being informed and able to react.

Broad area and focal area surveillance platforms will economically cover areas not worth expensive AEW&C coverage and feed radar and EW data back to ground stations in near real time, for fusion with AEW&C data into the larger mosaic of the operational/tactical picture - the 'big picture'. Other platforms such as ships at sea or Army reconnaissance teams will contribute their small scale views of the battlespace for inclusion in the 'big picture'.

The Wedgetail will act as a relay station and a control point. As a relay station, it will collect other platforms' data, forward it to ground stations for processing (data fusion) and distribute the subsequent recognised air picture to all participants. As a control point, it will control the close battle in the air and contribute to the surface battle.

The choice of platform will depend on the urgency and importance of the requirement, the size of the area requiring surveillance and the level of threat. The ADF will be able to match the platform to the task, without overkill or overtasking. The forms of surveillance will include visual, radar and electronic warfare. The ADF has never had the luxury of so many choices.

Command and Control

At the tactical level, air operations in northern Australia and the air-sea gap will be controlled from the Northern Regional Operations Centre (NORTHROC) at RAAF Base Tindal and air operations in eastern Australia will be controlled from the Eastern Regional Operations Centre (EASTROC) at RAAF Base Williamtown. The masses of data provided by the various mobile sensor platforms will be datalinked to the Regional Operations Centres for fusion.

The Air Defence Ground Environment (ADGE) is the ADF's ground-based early warning and control system. The radars, operators' consoles and computers at the heart of the ADGE are decades old. Over the next few years, a series of projects will replace all the radars, consoles and computers with state-of-the-art equipment. By the time that the AEW&C Wedgetails are flying, the modernised ADGE will have the

personnel and computing power to perform the data fusion required to generate the 'Recognised Air Picture' (RAP) in real time. The ROCs will distribute the RAP, forward to forces in the field and back to higher headquarters. The ADGE will also perform the overall command and control function for continental air defence.[87]

At the operational level, NORTHROC and EASTROC will be linked to the Air Operations Centre at Headquarters Air Command (HQAC). HQAC is the Air Component of Headquarters Australian Theatre (HQAST), which is the ADF's operational level headquarters.[88] An agency of HQAST, the Australian Theatre Joint Intelligence Centre (ASTJIC) will fuse data from the ROCs with data from the JORN and other national intelligence sources to enhance the RAP, in *near* real time.

Intelligence

At the strategic level, the national intelligence sources available include satellite imagery, shared intelligence from allies and inputs from government departments such as Foreign Affairs, Customs and Immigration and agencies such as ASIO, ASIS and Coastwatch. These and other sources provide Australian Defence Headquarters and Strategic Command with their intelligence. This intelligence is also available to the ASTJIC for integration with operational level data.

The combination of the data from mobile sensor platforms, the ADGE, JORN and the intelligence community with the value added by the command and control function will provide the ADF with significant situational awareness. This situational awareness should amount to 'knowledge dominance' and could be decisive in enabling ADF units to perform their missions efficiently and effectively.

LIGHTER-THAN-AIR SURVEILLANCE SYSTEMS

Strictly speaking, the first airborne surveillance platforms were tethered balloons, which were used occasionally in the Napoleonic Wars in Europe (1800-1815) and frequently in the American Civil War (1861-1865). The balloons were used for visual surface surveillance, to enable soldiers to see what lay on the other side of the hill.

Prior to World War I, German rigid airships (Zeppelins) completed 1,600 flights, carrying 35,000 passengers and travelling 160,000 kilometres, without an accident.[89] During World War I, the Germans used Zeppelins for long range reconnaissance, maritime surveillance and strategic bombing. The British used smaller non-rigid airships (blimps) as coastal ASW escorts and to deter low level air attacks on London.[90] All the belligerents used blimps as artillery observation platforms.

Though widely used as observation platforms, airships proved to be unreliable combat platforms. After the flight across the North Sea to bomb Britain, prevailing winds prevented many Zeppelins from recovering to German territory. Of the 80 Zeppelins

[87] O'Donoghue, R., 'EASTROC Construction Begins', *RAAF News*, June 1999, p 23.
[88] *ibid.*, p 23.
[89] Gilbert, M., *First World War Atlas*, Weidenfeld & Nicolson, London, 1970, p 64.
[90] Hillsdon, R., 'Lighter-than-Air Surveillance Systems', *Air Power: Global Developments & Australian Perspectives*, Pergamon-Brassey's, Sydney, 1988, p 399.

used by the German Navy in World War I, 31 were lost in accidents or storms and 23 were lost to enemy action.[91]

Several spectacular and widely publicised disasters in the 1920s and 1930s, involving many fatalities, gave airships a bad reputation for safety. The rapid development of heavier-than-air aircraft over the same period made airships seem obsolete. Unmanned tethered blimps (aerostats) were used by the Americans and British in World War II to deter low level air attacks on high value targets, such as the London CBD and the invasion beaches at Normandy and to assist in ASW in the Atlantic.[92]

After the war there seemed to be no place for slow, clumsy balloons in the jet age. However, in the 1950s, the USN used a few AEW airships to fill gaps in the DEW Line.[93] In 1962, the USN discarded its last blimps, replacing them with EC-121 AEW&C aircraft. In 1975, the USN began studying the utility of airships for airborne surveillance. In the 1980s, several nations began similar studies, noting that modern engines and materials technology had solved the historical technical problems of airships. In the late 1980s, airships appeared to be on the verge of a renaissance.[94]

Airships have several obvious advantages as AEW platforms. There is plenty of room inside an airship for a large radar. Compared to conventional heavier-than-air aircraft, airships are much cheaper to produce and operate, for a given payload of radar, avionics and crew. Airships have only a tiny fraction of the radar and infra-red signature of similar sized conventional aircraft. An aerostat can lift a radar to the ideal altitude and transmit its data along a fibre optic cable to a ground station, for processing and action, with none of the bandwidth or emission problems of radio datalink.

The unusual permanence of airships is particularly attractive to navies. Unlike conventional aircraft, airships can accompany ships into the open ocean, far from air bases on land and independent of aircraft carriers, remaining on station for extended periods. A USN study indicated that an airship could remain in support of ships for up to 60 days, refuelling from the fleet every four or five days.[95]

Airships have made a limited comeback. The USAF currently operates 15 Tethered Aerostat Radar Systems (TARS) along the Mexican border as part of the effort to prevent illegal entry by air.[96] Israel is also reported to be operating a few airships in the AEW role.

The war roles that airships could perform include airborne early warning, maritime surveillance and reconnaissance, electronic warfare, anti-submarine warfare, mine counter measures and command, control and communications. In peacetime, civil support tasks could be performed, including fisheries and EEZ protection, law enforcement and search and rescue.[97]

[91] Gilbert, *First World War Atlas*, p 68.
[92] Hillsdon, 'Lighter-than-Air Surveillance Systems', p 399.
[93] *ibid.*, p 399.
[94] *ibid.*, p 400.
[95] *ibid.*, p 408.
[96] Browne & Thurbon, *Electronic Warfare*, p 142.
[97] Hillsdon, 'Lighter-than-Air Surveillance Systems', pp 410-416

The disadvantages of airships include relative fragility, very low speed, lack of manoeuvrability and inability to operate in inclement weather. The disadvantages have usually been seen to outweigh the advantages and few airships have found their way back into the operational inventories of modern armed forces.

The ADF considered aerostats for the AEW role in northern Australia and the air-sea gap beyond. A report by the Defence Science and Technology Organisation (DSTO) pointed out that in the 'wet season' aerostat operations would be possible only one day in three. The weather limitation was a major factor in the ADF decision against using aerostats in the north.[98]

THE IMPACT OF AEW&C ON RECENT OPERATIONS

Recent history is replete with examples of the profound impact of AEW&C on operations of all kinds. The following case studies illustrate classic applications of AEW&C which may be relevant to Australia's situation.

Fight Outnumbered and Win: Israeli Air Force Operations

In the late 1970s, the Israelis acquired four E-2 Hawkeyes to monitor Arab airspace and control Israeli air operations.[99] Israel was a tiny nation, surrounded by enemies and Israeli air bases were only a few minutes flying time from enemy air bases. In such a crowded environment, the ability of AEW&C to detect enemy aircraft just after take-off is crucial.[100] Unfortunately, in overland operations, the effectiveness of the systems on the Israelis' early model Hawkeyes was degraded by the mass of ground traffic.

Like the ADF, the Israelis are usually outnumbered, have a very low tolerance for casualties and cannot afford to lose many aircraft. The Israelis are understandably secretive about their combat operations, but their Hawkeyes are generally believed to have been instrumental in most of their successful air operations in the 1980s.

Israel versus Iraq

In the late 1970s, the Iraqis made no secret of the fact that they were trying to develop and deploy the first 'Arab Atomic Bomb'. Iraq already had Scud SSMs which could strike any point in Israel. To the Israelis, the prospect of Saddam Hussein having SSMs *and* nuclear warheads was unacceptable. The combination of diplomatic efforts and sabotage only delayed the construction of a large French-designed reactor that was capable of producing weapons-grade fissionable material. The reactor was built at Osirak near Baghdad and it was nearly complete in June 1981.[101]

[98] Duus, A., *Aerostat Availability in Northern Australia*, DSTO Client Report AOD 96/05.
[99] Ripley, T., 'Israeli Air Power into the 1990s', *Air International*, September 1993, p 131.
[100] Chamish, B., 'Phalcon – Israel's AWACS', *Air International*, April 1994, p 218.
[101] Drew, D., 'Air Power in Peripheral Conflict', *The War in the Air : 1914-1994*, RAAF Air Power Studies Centre, Canberra, 1994, pp 249-251.

On 7 June 1981, an Israeli strike force of eight F-16 Falcons (bomb carriers) and six F-15 Eagles (fighter escort), perhaps supported by Hawkeyes, attacked the facility at Osirak. The target was deep in Arab territory, 850 kilometres from Israel, well beyond the range of land-based radar in Israel. The Iraqis had very large numbers of fighters, SAMs and AAA available. There was the further complication that the Iran-Iraq War was raging and the Saudis had their AWACS aircraft on station in northern Saudi Arabia monitoring the situation. The Israelis had to overfly Jordan or Syria (and perhaps north-western Saudi Arabia) on the way to Iraq and avoid detection by any Arab.[102]

The operation would have been far more risky without the 'God's eye view' of Arab dispositions and activity provided by the Hawkeyes. Over the preceding years, their AEW&C capability had enabled the Israelis to develop a Recognised Air Picture of much of the Arab airspace through which the raid would have to pass. The Israelis knew the pattern of Arab air patrols and radar coverage and could recognise any unusual activities which might indicate Arab awareness of the raid.[103] Without that situational awareness, the Israeli force could have been ambushed, heavily outnumbered and destroyed. Whether a Hawkeye actually accompanied the strike force is not known. Even if the Hawkeyes stayed in Israeli airspace, they could help the strike force slip through Jordan or Syria, during ingress and egress.

The Israelis destroyed the target without losing any aircraft. Though the raid was widely condemned at the time, it probably prevented Iraq from becoming a nuclear power prior to the invasion of Kuwait. None of the nations in the Coalition that liberated Kuwait in 1991 regretted the absence of Iraqi nuclear weapons. The strategic effect of a raid by a handful of aircraft was disproportionate and far reaching.
It is probably not coincidental that, only a few years after the Israeli attack, the Iraqis acquired two Soviet Ilyushin Il-76 AEW&C aircraft (locally referred to as Adnan). The Iraqi post-mortem of the Israeli operation may have highlighted AEW&C as a decisive difference between the Iraqi and Israeli air forces.

Israel Versus Syria

In 1982, the Israelis launched Operation Peace for Galilee. This was an invasion of southern Lebanon, to take control of territory from which the PLO had been subjecting northern Israel to harassing fire by mortars and rockets. The Israeli invasion force was an Army mechanised corps, supported by the Air Force. The Lebanese were incapable of resisting such a powerful attack, but the Syrians could be expected to offer matching force.

The Israelis planned a conventional Blitzkrieg campaign, requiring the Israeli Air Force (IAF) to establish air superiority over the battlefield as a precondition to successful ground action. The first phase of the air campaign was an offensive

[102] *ibid.*, pp 251-252.
[103] Ripley, 'Israeli Air Power into the 1990s', p 131.

counter air (OCA) effort. The IAF could probably have defeated the Syrian Air Force by dint of its superior aircraft and pilots, but this qualitative edge was not sufficiently overwhelming to guarantee low Israeli losses.

The Israelis' decisive edge was high technology command and control and intelligence. The Israelis had access to US satellite imagery, giving them significant strategic information superiority. They used UAVs for reconnaissance and decoying, giving them tactical information superiority. The Israelis' Hawkeyes provided Command & Control superiority and Electronic Warfare superiority.

On the ground, the Syrian Ground Based Air Defence (GBAD) system was neutralised by a combination of clever electronic warfare and aggressive use of anti-radiation missiles (ARMs). In the air, the Syrian Air Force was subjected to one of the most absolute defeats in the history of air warfare. The Israelis claim to have achieved 85 air-to-air victories while losing no aircraft themselves.[104]

Even allowing for some exaggeration, the Syrian Air Force was clearly outclassed and neutralised. The IAF was then able to move to the second phase of its campaign, devoting some aircraft to Air Defence against the remnants of Syrian air power, and focussing most of its effort on Close Air Support (CAIRS) and Battlefield Air Interdiction (BAI) to help the Army achieve its objectives. The breathtaking scale of the Israeli victory owed much to the 'unfair advantage' that AEW&C gave them over the Syrians.[105]

Israel versus the PLO

In 1985, the IAF attacked the headquarters of the Palestine Liberation Organisation (PLO) in Tunisia. As with the Osirak raid in 1981, the raid into Tunisia involved a long transit and the penetration of enemy airspace. Without AEW&C, there would have been the danger of blundering into another aircraft or a radar's field of view, thus losing the element of surprise and compromising the security of the strike force. As in Iraq, the Israeli's avoided detection, destroyed the target and escaped without losing any aircraft. AEW&C had again provided a decisive edge.[106]

Home Grown AEW&C

The Israeli Hawkeyes are no longer in service. They are in storage awaiting disposal. They were replaced by the much larger and more capable Israeli-developed Phalcon system, which was first publicly displayed in 1993.

Phalcon is a contraction of PHased Array, L band, CONformal radar. The Phalcon is a Boeing 707, fitted with an eight metre long slab radar along one side of the fuselage, extending from the nose to the wing leading edge. The radar does not rotate mechanically – it points its beam electronically. The coverage provided is through an arc of up to 180 degrees. There is also a large bulbous radome in the nose and many

[104] Anglim, S., 'Boyd Loops, Ace Factors and Fighter Combat', *RAF Air Power Review*, Summer 1999, p 62.
[105] Lake, 'The Hawkeye Abroad', p 346.
[106] *ibid.*, p 346.

blade aerials along the aircraft's back and belly. Inside the cabin are 13 operator consoles. The roles of the Phalcon 707 include AEW&C and SIGINT.[107]

The Phalcon employs a relatively new concept in AEW&C. A traditional AEW&C aircraft carries a rotating radar, to give 360 degree coverage. The Phalcon has only 180 degree coverage and the aircraft must physically turn to point the radar elsewhere.

Those who prefer the fixed, 180 degree radar argue that the threat is usually expected from a specific direction, so 360 degree coverage is wasteful. They also argue that a 360 degree scan takes twice as long as 180 degrees, so the interval between illuminations of a target is shorter with the 180 degree system. The Hawkeye's radar rotates every ten seconds, while the Phalcon's beam scans a given point every five seconds. The Israelis argue that the extra five seconds could be crucial in 'close quarters' engagements with supersonic aircraft and missiles.[108]

Those who prefer rotating radars argue that the Phalcon cannot fly in the same direction for very long and must turn to stay in its operating area. Whether the Phalcon flies 'race tracks", 'lazy eights' or circles, it will have its 180 degree radar pointing the wrong way for several minutes at a time several times per hour. A Hawkeye, with its 360 degree radar, will have that radar pointed at the target six times per minute, for as many hours as it remains airborne. Given that modern AEW&C radars can 'see' over 300 kilometres, a five second difference in revisit rates will not often be significant.

In 1995, the Israelis sold the Phalcon AEW B707 to Chile. There have been no further sales. Chile are Brazil the only nations in South America with operational AEW&C aircraft.

Air Defence

Iraqi forces invaded and occupied Kuwait in August 1990. The US government decided to prevent further Iraqi advances by deploying a blocking force into Saudi Arabia. The first US forces deployed to Saudi Arabia were five E-3 AWACS and 24 F-15 Eagle fighters which deployed from the CONUS and arrived in Saudi Arabia only 34 hours after the order to move. The USAF contingent joined the Saudi Air Force's five AWACS and 42 Eagles. The combined force of ten AEW&C aircraft and 66 fighters provided a sufficiently potent defensive counter air (DCA) capability to deter the Iraqi Air Force from attempting any strike or reconnaissance operations into Saudi Arabia or the Persian Gulf.[109]

Coalition forces were then able to deploy, unmolested. US Army airborne troops, USN aircraft carriers, US Marine light divisions and US Army heavy divisions followed the USAF. As the available bases in the theatre became crowded, aircraft and vehicles were parked in closely packed rows, out in the open. The unchallenged and unchallengeable air umbrella obviated the need for dispersal, revetments, hardened aircraft shelters or camouflage. General Horner, the Coalition Air

[107] Chamish, 'Phalcon – Israel's AWACS', p 218.
[108] *ibid.*, p 218.
[109] Mann, E.C., *Thunder and Lightning : Desert Storm and the Airpower Debates*, Air University Press, Maxwell Alabama, 1995, pp 130-131.

Component Commander, assured General Schwarzkopf, the overall Commander in Chief, that … 'Not one airplane will get through' (my air defences).[110] None ever did.

Behind the impenetrable curtain of air defence, Coalition forces were able to deploy inland and launch the main ground force thrust, from a point and in a direction that the Iraqis had not anticipated. Just one Iraqi reconnaissance aircraft could have tipped off the Iraqis and led to enemy redeployment and heavier friendly casualties.

An air defence force of ten AEW&C aircraft and 66 fighters was able to keep at bay an enemy air force of some 500 aircraft, which operated from bases only a few kilometres away. The RAAF will soon have an air defence force of seven AEW&C aircraft and about 50 fighters. Such a force should be able to defend Australia from any foreseeable regional air threat.

Suppression of Enemy Air Defences (SEAD)

In the Vietnam War the USAF developed and perfected its Electronic Combat (EC) triad, to suppress enemy air defences and facilitate US strikes. Suppression of Enemy Air Defence (SEAD) has been a vital art ever since. In the 1970s, the USAF EC triad consisted of the EF-111 Raven, the EC-130H Compass Call and the F-4G Wild Weasel. The EF-111 jammed selected enemy early warning and acquisition radars, thus preventing enemy air defence units from detecting US aircraft and pointing fire control systems at them. The EC-130 aircraft jammed selected enemy command, control and communications links, thus preventing the enemy from distributing information and instructions among their air defence units, in order to bring anti-aircraft weapons to bear on US aircraft. The F-4G identified and located specific fire control radars and physically attacked them with Anti Radiation Missiles (ARMs).[111]

Since the Vietnam War, the USAF SEAD has expanded into Joint SEAD (JSEAD) and the EC triad has expanded into a constellation, with new aircraft. Now USAF RC-135 Rivet Joint and Navy EP-3 Aries electronic surveillance aircraft identify and locate specific radar emitters. Army RC-12 Guardrail aircraft can assist in detection and location and also supplement EC-130H jammers. Navy EA-6 Prowlers have replaced the EF-111s and can also supplement F-4Gs in physical attacks with ARMs. USAF E-3 AWACS and EC-130E ABCCC ACPs coordinate all of the aircraft involved, while juggling responses to the dynamic airborne and surface-based threats. Navy E-2 Hawkeyes can supplement AWACS. Above it all, satellites are performing more detection and location tasks and may ultimately replace AWACS with Space Based Radar.[112]

In 1990, Iraq had one of the most comprehensive Integrated Air Defence Systems (IADS) that money could buy, from the Soviets, French and other sources. The US JSEAD constellation effectively mapped, blinded, dissected and destroyed the Iraqi IADS in a matter of days. In the course of the air campaign against Iraq, only a tiny percentage of Coalition sorties were lost to enemy air defences. After the first few

[110] *ibid.*, p 131.
[111] Brungess, J., *Setting the Context : SEAD and Joint War Fighting in an Uncertain World*, Air University Press, Maxwell AFB, Alabama, 1994, p 104.
[112] *ibid.*, p 104.

days, Coalition aircraft roamed at will over most of Iraq. The AWACS and Hawkeyes were an essential link in the SEAD chain and remain so today.

Law Enforcement

The military is not the only user of AEW&C aircraft. In America's 'War on Drugs' the US Coast Guard and US Customs Service have used many AEW&C aircraft. An example of the effectiveness of AEW&C in drug interdiction operations (and a measure of the scale of the problem) was Operation *Thunderbolt* in 1991. In a period of nine weeks, 97 drug couriers were arrested, 45 aircraft and seven boats were impounded and 12 tonnes of marijuana was seized.[113]

AEW&C and the Coast Guard

The US Coast Guard has operated three types of AEW&C. These have included Grumman Hawkeyes, the one and only Lockheed AEW Hercules and radar-equipped tethered aerostats.[114]

In January 1987, the USN loaned two Hawkeyes to the Coast Guard. Two more Hawkeyes that had been on loan to the US Customs Service were redirected to the Coast Guard in August 1989. The Hawkeyes, based first in Virginia and later in Florida, were used for drug interdiction in the Caribbean. The Hawkeyes were all returned to the USN in October 1991. The Coast Guard could not afford to operate them permanently but can still borrow Hawkeyes for specific operations.[115]

In November 1991, the Coast Guard began operating the one and only AEW Hercules. The AEW Hercules is a C-130H fitted with a Hawkeye APS-145 radar, rotodome and avionics suite and designated EC-130V. The Coast Guard experimented with the AEW Hercules in a variety of roles, including EEZ enforcement, SAR, drug interdiction and disaster relief operations. In disaster relief, AEW&C aircraft have facilitated initial relief operations by substituting for devastated telecommunications and providing Air Traffic Control at unserviceable or makeshift airheads. The AEW Hercules was withdrawn from service in April 1993. It was too expensive for the Coast Guard.[116]

AEW&C and Customs

The missions of the US Customs Service include the detection, classification and interception of suspicious aircraft entering the United States. Customs operates a large 'air force', which includes three AEW Orions.

The original AEW Orion was a P-3B that had served in the RAAF. It was used as a 'proof-of-concept' aircraft and was fitted with a Hawkeye APS-125 radar, in a

[113] Lake, 'The Hawkeye Abroad', p 345.
[114] *ibid.*, p 345.
[115] *ibid.*, p 345.
[116] Reade, D., Frisbee Hercules, *Air International*, November 1993, pp 279-280.

rotodome above the rear fuselage and a standard Hawkeye avionics suite, including Identification Friend or Foe (IFF) and passive EW.[117]

The AEW Orions entered Customs service in 1986 and have since been upgraded with APS-138 radars. They operate along the Mexican border and in the Caribbean. Their prime task is drug interdiction, but they also get involved in disaster relief, as on-site airborne command posts in devastated areas. The AEW Orions have been instrumental in many successful Customs operations.[118]

Peace Enforcement

Peace Keeping and Peace Enforcement are usually seen as a low intensity 'police' operations, involving predominantly infantry forces, perhaps backed up by a few light armoured vehicles and helicopters. However, in the chaos in the former Yugoslavia during the 1990s, air power has been the force of choice of Western governments, for whom the main attraction is the perception that air forces usually suffer far fewer casualties than ground forces. Air power is also perceived to produce apparent results far more quickly than ground forces. Spectacular video footage of bridges being dropped, tanks being blasted and buildings being demolished, with apparent surgical precision, create a better impression than masses of infantry scattered through the countryside, wandering around the forest in small groups.

This harks back to the promises of the great air power theorists of the 1920s. Douhet, Trenchard and Mitchell argued that air power could bypass another bloody stalemate in the trenches, by leaping over the obsolete conventional surface forces to achieve the desired effect at the opponent's centre of gravity, his heartland, without having to hack through many layers of defence.

The use of air forces to substitute for ground forces is also reminiscent of the RAF technique of 'air policing' in Mesopotamia during the 1920s. In Palestine and Iraq, a few squadrons of RAF bombers, supported by small numbers of motorised infantry, substituted for tens of thousands of traditional British Army colonial infantry. RAF bombers coerced tribesmen into behaving as the British desired, for a fraction of the cost in 'blood and treasure' that a full scale Army offensive would have incurred. Air policing did not address the underlying problems. It merely suppressed the overt symptoms, at an acceptable cost, thereby creating the appearance of success and placating British public opinion.[119]

In the early 1990s, Western public opinion demanded some sort of action be taken to end Serbian attacks on Bosnians. The Serbs had inherited most of the aircraft, tanks and heavy artillery of the defunct Yugoslav armed forces, so they had the advantage over the Bosnians, who had only infantry and light weapons. In the late 1990s, the situation was the same in Kosovo, where the heavily armed Serbs were again seen as the aggressors and the Kosovars had only infantry and light weapons.

[117] Reade, D., 'US Customs Service P-3 Air Force', *Air International*, May 1993, p 225.
[118] *ibid.*, pp 226-227.
[119] Scott, C., pp 27-38.

Put simply, NATO governments felt compelled to act, but remained conscious of their constituents' sensitivity to friendly casualties, so operations in support of the Bosnians in 1995 (Operation *Deliberate Force*) and Kosovars in 1999 (Operation *Allied Force)* were predominantly air operations. In the enforcement of the 'No Fly Zones' and in the bombing campaigns, NATO deployed large numbers and many types of aircraft. Co-ordination of the air campaigns (battle management) was critical to their success.

Operation Allied Force was the largest air campaign since Desert Storm. The NATO bombing campaign began on 24 March 1999, with aircraft operating out of bases in Italy and off aircraft carriers in the Mediterranean. By early May there were 1,000 aircraft involved, including over 100 tankers.[120] In the first month of the campaign, over 10,000 sorties were flown, of which about 30 per cent were strike missions.[121] Only two aircraft, an F-117 and an F-16, were lost in the first eight weeks.

USAF AWACS and ABCCC aircraft provided the critical coordination. At least one AWACS and one ABCCC were always airborne while air operations were underway.[122] AEW&C tasks performed included air surveillance, air intercept control, strike control, tanker control, combat SAR control, EW management and airspace management, to deconflict large numbers of flights in a confined area. The ABCCC was an extension of the Joint Force Air Component Commander (JFACC) and acted as the direct link between the Combined Air Operations Centre (CAOC) in Italy and the aircraft on task. The ABCCC mission crew included two technical intelligence gatherers, an analyst, three strike controllers, a tactical air controller and two communications controllers. They had access to an electronic copy of the Air Tasking Order (ATO).[123] The ABCCC and AWACS used the Joint Tactical Information Distribution System (JTIDS) and Situational Awareness Data Link (SADL) data sharing networks to ensure that all platforms involved had access to 'the big picture'.[124]

Large numbers of NATO aircraft operated for an extended period over hostile territory with insignificant losses while conducting a devastating bombing campaign. The coordination of such a massive operation would have been impossible without the AWACS and ABCCC aircraft.

As the campaign progressed, the four USAF C-130 ABCCC aircraft in the theatre became so overworked that they had to be supplemented by the USN Hawkeyes from aircraft carriers in the Mediterranean. The Hawkeyes were less suited to the role of battle management than the ABCCC. They had fewer mission specialist crew (four as opposed to twelve), fewer radios and lacked the USAF-preferred Link 16, being fitted with the Link 11 system, commonly used in the USN. The Hawkeye crews were not trained in the ABCCC role. The Hawkeyes also had to rely on paper versions of some

[120] *Aviation Week & Space Technology*, 3 May 1999, p 25.
[121] Mann, P., 'Belgrade called Victor in War's First Phase', *Aviation Week & Space Technology*, 26 April 1999, p 28.
[122] Wall, R., 'New ABCCC Tactics used in NATO Air Strikes', *Aviation Week & Space Technology*, 26 April 1999, p 32.
[123] The Air Tasking Order (ATO) is a written order from the superior headquarters to all air units involved in an operation. It provides details of targets to be attacked, weapons to be used, recommended tactics, rules of engagement and any other relevant information. The ATO lists all missions to be flown over a 24 hour period.
[124] Wall, 'New ABCCC Tactics used in NATO Air Strikes', p 32.

important computer databases, such as the ATO. In spite of their limitations, the Hawkeye AEW&C aircraft were able to perform the battle management role and relieve the pressure on the ABCCC ACPs.[125]

OPERATIONS WITHOUT AEW&C

British Operations in the Falklands: Okinawa Redux

On 2 April 1982, Argentine troops landed on the Falklands, hoping to settle by force the longstanding dispute with Britain over ownership of the islands. The token British garrison, 22 Royal Marines, was overwhelmed and ejected and the British government was presented with a *fait accompli*. The British response was to dispatch a naval task force, including an amphibious force of two light infantry brigades, to retake the Falklands.

The naval task force consisted of two light aircraft carriers, seven anti-air warfare cruisers and destroyers (armed with long range SAMs), ten anti-submarine warfare frigates (armed with short range SAMs) and a few submarines. The carriers could only operate aircraft capable of vertical or short take-off and landing (V/STOL), such as Harriers and helicopters. There were no AEW aircraft embarked, as the RN had none and those operated by the RAF were too big to operate off the carriers.

The major surface combatants had to protect a motley assortment of fleet replenishment ships, amphibious warfare ships, passenger ships and cargo ships, many of which were commercial vessels, leased for the duration. The highest value targets were the aircraft carriers, as their embarked air power was essential to any operation in the South Atlantic. The amphibious warfare ships, passenger ships and cargo ships were also important, as they carried the ground force and supplies needed to retake the islands. After all, reconquest was the reason for sending the Task Force.

At Okinawa in 1945, the USN made up for its lack of AEW by deploying a screen of radar picket destroyers some distance from the carriers in the direction from which enemy air strikes were expected to come. The destroyers gave sufficient warning to the carriers, but were themselves very vulnerable and many were sunk or damaged. At the Falklands in 1982, the RN found itself in the same situation.

The RN Task Force Commander (Admiral Woodward) realised that his greatest weakness was … *'a serious gap in our air defences. We lacked Airborne Early Warning.'*[126] His only option was … *'To keep the Argentine strike aircraft at arm's length from the carriers, we have no option but to keep the Type 42 destroyer pickets, with their long range radar, out in front. I might have to regard them as expendable, however reluctantly.'*[127]

[125] Wall, R., 'E-2Cs become Battle Managers', *Aviation Week & Space Technology*, 10 May 1999, p 38.
[126] Woodward, J., *Memoirs of the Falklands Battle Group Commander*, Book Club Associates, London, 1992, p 3.
[127] *ibid.*, p 174.

The loss of the destroyer HMS *Sheffield* was reminiscent of the action along the radar picket line at Okinawa, 37 years earlier. *Sheffield* '*had been a front-line (radar) picket ship positioned far out on the Battle Group's most remote outpost.*'[128] The Argentine strike aircraft that sank HMS *Sheffield* had approached at low level, to avoid detection by the ships' radars and engagement by long range Sea Dart SAMs. Admiral Woodward had to admit … '*What can we do about that ? Without Airborne Early Warning, not a lot*'.[129]

The British campaign was ultimately successful, if a surprisingly 'near run thing'. At best, Argentina was a third rate power, with no combat experience in the 20th century, while the RN was supposed to be a first rate navy, with extensive combat experience in both world wars, Korea (1950-1953) and Suez (1956), and a key member of the technologically dominant NATO alliance. Yet, the RN lost two of its best destroyers, two modern frigates and an amphibious landing ship. The British also lost the major cargo vessel, the Atlantic Conveyor, which was carrying many of the ground force's precious transport helicopters, their spare parts stocks and huge quantities of small arms ammunition and cluster bombs. Several other RN ships were badly damaged. Many of the Argentine bombs and missiles that hit RN ships failed to detonate, so the British were very lucky not to lose more ships. After the war, Admiral Woodward and the ground force commander (General Moore) admitted that their forces had been on the verge of collapse when the Argentines surrendered.

At the height of the Argentine anti-ship campaign, Admiral Woodward noted in his diary … '*Surface ships must have AEW … for survival in open water.*'[130] A few British AEW aircraft would have transformed the campaign.

OPERATIONS WITHOUT EFFECTIVE AEW&C

The Accidental Shootdown of US Army Black Hawks in Iraq

After the liberation of Kuwait in 1991, UN forces maintained a blockade of Iraq in support of economic sanctions. The restrictions on Iraqi activity included designated 'No Fly Zones' in the northern and southern thirds of Iraq where Iraqi military air operations were forbidden. The USAF maintained a standing CAP of F-15 fighters, controlled by E-3 AWACS, to enforce that prohibition.

While the USAF CAP operation was going on, other Coalition aircraft conducted their own operations in the vicinity. On 14 April 1994, two US Army UH-60 Blackhawk helicopters entered the northern 'No Fly Zone' on a routine transport mission, carrying a total of 26 crew and passengers. Two USAF F-15 fighters on Defensive Counter Air (DCA) patrol detected the helicopters and closed to within visual range. The fighter pilots incorrectly identified the helicopters as Iraqi. Fighter controllers aboard the patrolling USAF AWACS failed to realise that the helicopters were American. The USAF fighters destroyed the US Army helicopters, killing all aboard. In the investigation that followed, a series of errors and omissions was revealed.

[128] *ibid.*, p 308.
[129] *ibid.*, p 174.
[130] *ibid.*, p 292.

Individually, the mistakes would probably not have been fatal, but the cumulative effect was tragic.

US Army helicopter operations in the 'No Fly Zone' were not integrated with other air operations. The ATO was supposed to include all planned flights, but the US Army rarely bothered to announce its helicopter flights in advance. Even when helicopter flights were included on the ATO, the actual flight times and routes often did not follow the plan. Furthermore, helicopter pilots often ignored the instructions from AWACS controllers. On the fateful day, the two helicopters advised the AWACS of their presence by radio on entering the 'No Fly Zone' and then flew on in silence. They soon disappeared off AWACS radar as they flew very low in rugged, hilly terrain.

The helicopters that were shot down did not monitor the AWACS / fighter communications channels. Had someone on the helicopters been listening, they would have realised what was happening in time to prevent the mistake. The helicopters had not even set their electronic IFF transponders to the correct code. A correctly set IFF would have informed the AWACS and the fighters that the helicopters were friendly.

AWACS crews were in the habit of ignoring the helicopters and did not believe it to be their responsibility to control the helicopters, or keep other aircraft in the area informed of the helicopters' movements. The fighter pilots were not adequately trained in helicopter visual recognition, so they were likely to incorrectly identify helicopters, particularly under the difficult conditions of high speed flight close to the ground.[131]

The incident highlighted the fact that, even with all the high technology of the latest AEW&C, air operations can still go tragically wrong without sound procedures and properly trained personnel. It also highlighted the need for regular interservice cooperation and coordination.

The 'shootdown' was the result of a series of human errors and omissions which should not have happened, but did. The human factor remains the principal variable in war.

THE FUTURE OF AEW&C

AEW&C Proliferation

By the year 2005, there will be a proliferation of AEW&C types, with at least 12 fixed wing and three rotary wing AEW types in service. Over 250 AEW&C aircraft will be operational around the world. Annex C lists the types in service, by nation of origin.

By the year 2005, at least 19 nations will be operating AEW&C aircraft. These will include major powers such as the US, Russia, Britain, France, China, India and Japan; and lesser powers such as Australia, Brazil, Chile, Egypt, Greece, Iraq, Israel, Saudi

[131] Report of the Aircraft Accident Investigation Board, *US Army UH-60 Black Hawk Helicopters 87-26000 and 88-26060*, Executive Summary, 27 May 1994.

Arabia, Singapore, South Africa, Sweden and Taiwan. Annex D summarises the national AEW&C fleets.

Several other nations, including Bahrain, India, Indonesia, Italy, Kuwait, Malaysia, Oman, Pakistan, South Korea, Spain, Thailand, Turkey and United Arab Emirates, are likely to acquire AEW&C aircraft early in the next decade.[132] By the Year 2010 as many as 32 nations may be operating AEW&C aircraft.

Future Directions

A small twin-engine business jet such as a Saab 340 or Embraer EMB-145 fitted with ERIEYE can perform the air surveillance AEW&C mission. Another small twin-engine business jet, such as a Gulfstrsam fitted with Astor, can perform the surface surveillance JSTARS mission. Therefore, it should be possible for a medium size aircraft, such as a Boeing 737 or an Airbus 310, to perform both missions - an AWACS/JSTARS.

New technology will probably solve the problems that doomed the AEW Nimrod. The distinction between AEW&C air surveillance and AEW&C surface surveillance, already unclear on some platforms, may disappear completely. One radar may be able to perform satisfactorily in both the air surveillance and surface surveillance modes or the aircraft may be able to carry two different radars. AEW&C may become the surveillance of *all* things moving on or above the earth's surface.

The only limitation on integrating the air and surface surveillance capabilities may be the human factor. In aviation circles, the point has often been made that multi-role platforms are easier to create than multi-role crew. The tasks involved in air and surface surveillance may be sufficiently different to make the workload associated with the dual air/surface mode too intensive.

CONCLUSION

The Utility of AEW&C

Since its inception in 1945, AEW&C has been used in many critical military roles, including air surveillance, early warning, air defence, air intercept control, battle management, maritime and land strike control, combat SAR support, tanker control, airspace control, intelligence collection, reconnaissance support and EW management.

AEW&C has also performed civil support operations including SAR, fisheries and EEZ protection, coastwatch, law enforcement activities (such as interdiction of illegal drugs and immigration) and peacekeeping.

The range of AEW&C platforms has been diverse, both in size and shape. The early, marginally effective, makeshift conversions of small attack aircraft have given way to large, highly capable, purpose-built aircraft. Experience has proven that an effective AEW&C capability can be crammed into an aircraft that can operate off an aircraft

[132] Sengupta, P., 'The Efficacy of AEW&C Systems', *Asian Defence Journal 6/99*, pp 34-35.

carrier. The twin-engine fixed wing E-2 Hawkeye and the AEW Sea King helicopter have been successful. However, those who can afford the 'ideal' AEW&C prefer a larger airframe and AEW&C aircraft based on the four-engine Boeing 707 are popular.

Today, a new range of medium size and small AEW&C aircraft are available. The medium size AEW&C are based on airframes such as the four-engine Lockheed Hercules and Orion and the twin-engine Boeing 737 and Airbus 300 series. The small AEW&C are based on business jet airframes such as the Gulfstream, the Embraer EMB-145 and the Saab 340.

AEW&C capability can now be sized to any budget. The Japanese are using the Boeing 767 airframe as the platform for the world's largest and most expensive AEW&C aircraft because they can afford to.

Many air forces have or plan to soon have AEW&C in their force structures. The edge that can be provided by AEW&C can no longer be seen as a luxury, limited to a small club of major powers. AEW&C is now mainstream and commonplace. It is an essential capability for conducting modern warfare in the information age.

What AEW&C Can Do For Australia

Australian Government Policy

Current defence strategy is encapsulated in the report titled Australia's Strategic Policy which was published in December 1997 and is commonly known as SR97.[133] There are four force structure priorities in SR97, the first and foremost of which is 'the Knowledge Edge'. The three key elements leading to that edge are intelligence, command and control arrangements and surveillance of our maritime approaches.[134] The Wedgetail AEW&C capability will significantly enhance the ADF's ability to contribute to all three key elements leading to the Knowledge Edge.

Intelligence

The Wedgetail will be an important piece of the national intelligence-gathering puzzle. The detailed air and surface pictures generated by the AEW&C will complement the sometimes fuzzy picture produced by the JORN. AEW&C will be able to quickly focus on any area of interest or uncertainty.

Command and Control

The Wedgetail will be a vital link in the rapidly evolving ADF operational level command and control system, centred on HQAST. AEW&C will be a link in a military information revolution. Information and instructions will be passed among platforms in the field and headquarters far more quickly and reliably. Commanders will benefit from the increased situational awareness as much as the crew of a strike

[133] *Australia's Strategic Policy*, Directorate of Publishing & Visual Communications, Canberra, 1997.
[134] SR97, pp 55-66.

aircraft on a mission. AEW&C will be a vital link in creating, improving and exploiting that awareness.

Surveillance of our Maritime Approaches

Without an AEW&C capability, the ADF has been able to maintain only patchy surveillance of the air-sea gap. Beyond the tiny footprints of ground-based radar units at Darwin and a few other coastal sites, the only ADF presence has been a few short range Coastwatch aircraft, the occasional P-3 Orion patrol aircraft and a handful of very slow moving frigates and patrol boats. These platforms have been the only mobile sensor platforms available, but they have very limited fields of view. The most numerous and persistent of these, Coastwatch aircraft, have little more than the human eye for sensors and can only report their findings by voice radio, as they lack datalink.

The Wedgetail will be able to conduct comprehensive surveillance of large areas of the air-sea gap for long periods. Forewarned by good intelligence, the AEW&C capability will provide vastly better surveillance coverage. Australia's northern borders will be far less porous than is currently the case. The large volume and variety of data collected by AEW&C will be available many users, almost instantly.

Overall Capabilities

Over the last 50 years, AEW&C has been successfully used in a range of tactical roles. These have included surveillance, air defence control, strike control, tanker control, search and rescue, special forces support, intelligence collection, reconnaissance support, peacekeeping, peace enforcement, disaster relief and support for civil agencies (including Customs, Quarantine, Immigration, Fisheries and Police).

The ADF plans to use the Wedgetail AEW&C in all of the proven ways. None of the proposed uses for the Wedgetail is unprecedented or even uncommon. The AEW&C capability will enhance the way most ADF elements and many government agencies perform their missions. It will be a force multiplier across the spectrum of security activities.

Annexes:

A. Electronic Warfare Terminology

B. The Electromagnetic Spectrum

C. AEW&C types in service - by Nation of Origin

D. National AEW&C Fleets

ANNEX A

ELECTRONIC WARFARE TERMINOLOGY

Electronic Attack (EA)

- Active EA
  - Jamming
  - Flares
  - Deception
  - Manipulation
  - Imitation
- Passive EA
  - Chaff
  - Signature Reduction

Electronic Support (ESM)

- Electronic Intelligence (ELINT)
- Communications Intelligence (COMINT)
- Signals Intelligence (SIGINT)

Electronic Protection (EP)

- Active EP
- Passive EP

ANNEX B

THE ELECTROMAGNETIC SPECTRUM

Band Range	Abbreviation	Bands
X Rays	--	--
Ultra Violet	UV	--
Visible Light	--	--
Infra Red	IR	--
Extremely High Frequency	EHF	K, L, M
Super High Frequency	SHF	B, C, D, E
Ultra High Frequency	UHF	part of F, G, H, I, J A
Very High Frequency	VHF	part of A
High Frequency	HF	--
Medium Frequency	MF	--
Low Frequency	LF	--
Very Low Frequency	VLF	--
Extremely Low Frequency	ELF	--

ANNEX C

AEW&C TYPES (BY NATION OF ORIGIN)

Brazil

Embraer EMB-145 / ERIEYE

Britain

Westland Sea King AEW Mk 2 helicopter (Searchwater radar)

China

Harbin Z-8 heavy lift helicopter

Israel

Boeing 707 / PHALCON

Russia

Antonov An-71 MADCAP
(based on Antonov An-72, twin jet STOL medium transport)

Ilyushin A-50 MAINSTAY
(based on Ilyushin Il-76, 4 jet heavy transport)

Kamov Ka-31 helicopter

Yakolev Yak-44
(twin turboprop)

Sweden

Saab 340 / ERIEYE

United States

Boeing E-3 Sentry (AWACS)

Boeing E-767 (sole customer : Japan)

Grumman E-2 Hawkeye

Lockheed EC-130V AEW&C Hercules

Lockheed P-3 AEW&C Orion

ANNEX D

NATIONAL AEW&C FLEETS (BY THE YEAR 2005)

NATION	Number	In Service	Type
FIXED WING			
Australia	7	2004	Boeing 737
Brazil	5	2000	Embraer EMB-145
Britain	7	1990	Boeing E-3 Sentry
Chile	1	1995	Boeing 707 Phalcon
China	6	2000	Ilyushin Il-76
Egypt	6	1987	Grumman E-2 Hawkeye
France	4	1990	Boeing E-3 Sentry
	2	1997	Grumman E-2 Hawkeye
Greece	4	2002	Embraer EMB-145
India	?	2003	Ilyushin Il-76 or Airbus
Iraq	2	1989 ?	Ilyushin Il-76
Israel	6	1978	Grumman E-2 Hawkeye
Japan	13	1982	Grumman E-2 Hawkeye
	4	1998	Boeing 767
NATO	18	1982	Boeing E-3 Sentry
Russia	26	1984	Ilyushin A-50 Mainstay
	3	?	Antonov An-74 Madcap
	?	?	Yakolev Yak-44
Saudi Arabia	5	1986	Boeing E-3 Sentry
Singapore	4	1987	Grumman E-2 Hawkeye
South Africa	2	1990 ?	Boeing 707 Phalcon
Sweden	6	1998	Saab 340
Taiwan	4	1995	Grumman E-2 Hawkeye
United States	80	1964	Grumman E-2 Hawkeye
	32	1977	Boeing E-2 Hawkeye
	4	1986	Lockheed P-3 Orion
	8	1989	Grumman E-2 Hawkeye
	1	1991	Lockheed EC-130 Hercules
ROTARY WING			
Britain	9	1982	Westland Sea King
China	?	2003 ?	Harbin Z-8
India	4	2001 ?	Kamov Ka-31

WORLD AEW&C ORBAT (BY THE YEAR 2005)

Nation	Fixed Wing AEW&C	Rotary Wing AEW&C
Australia	7	-
Brazil	4	-
Britain	7	9
Chile	1	-
China	6	4
Egypt	6	-
France	6	-
Greece	4	-
India	6	4
Iraq	2	-
Israel	6	-
Japan	17	-
NATO	18	-
Russia	30	-
Saudi Arabia	4	-
Singapore	4	-
South Africa	2	-
Sweden	6	-
Taiwan	4	-
United States	116	-
TOTALS	**255**	**17**