AIRBORNE EARLY WARNING AND CONTROL:

A PIECE OF THE PUZZLE

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1999 CHIEF OF AIR FORCE AIR POWER FELLOW

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PREFACE

Airborne Early Warning and Control (AEW&C) aircraft have been used by major air forces for decades. In recent years the capability has become more widespread, with several smaller air forces acquiring AEW&C aircraft. Today, AEW&C is widely accepted as a fundamental asset for scenarios ranging from all-out war to peacekeeping.

Australian experience of AEW&C has been limited. American AEW&C aircraft have participated in major exercises in Australia and a few RAAF and RAN officers have had exchange postings as crew on American and British AEW&C aircraft.

By the year 2005, the RAAF will be operating seven AEW&C aircraft, acquired under the Wedgetail Project. AEW&C will be the first completely new capability introduced into RAAF service for many years.

In many ways, the AEW&C Wedgetails will be unlike any other AEW&C aircraft in service. It will take some time to establish the extent of their capabilities and determine how best to use them in Australia's unique environment.

This study is meant to inform and stimulate interest in this important new capability. It avoids technical detail and is based on unclassified sources.

The study of history often helps clarify contemporary ideas on the employment of new capabilities. Chapter One briefly reviews the history of AEW&C, including the reasons for its development, the range of tasks that have been performed by AEW&C and the types of platforms used.

Chapter Two describes the range of AEW&C aircraft in service, and those planned at the turn of the millennium. It shows the surprising range of sensors and platforms and the capabilities of modern AEW&C.

AEW&C aircraft have been used to support many recent operations. Chapter Three includes case studies of some well known operations and shows how AEW&C was the difference between success and failure.

Chapters Four and Five briefly examine the nature of military operations in the third millennium and Australia's unique strategic geo-political situation. The need for the 'force multiplier' effect of AEW&C is demonstrated.

Chapter Six describes the traditional operations conducted by the major force elements of the Australian Defence Force (ADF) and suggests ways that AEW&C may enhance those operations and change the way the ADF does much of its business.

The study concludes with an examination of what AEW&C can do for Australia (Chapter Seven). The Wedgetails can play an important part in scenarios other than all-out war in defence of Australia, including law enforcement, sovereignty enforcement and protection of resources and the environment.

The AEW&C capability will not be a panacea, nor will it be the most important component of the ADF's command and control, air defence or surveillance systems. AEW&C will not obviate the need for RAAF fighters, RAN frigates or Army tanks. It will not be an excuse for further cutbacks in other force elements.

During the first decade of the third millennium, the ADF will upgrade or replace much of its command and control and surveillance organisation and equipment. The Wedgetails will be important members of the new team and they will have a 'force multiplier' effect on many traditional ADF activities. In many cases, the Wedgetails will change the way the ADF does its business; however, the Wedgetails will just be a piece of the puzzle.

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LIST OF ABBREVIATIONS

AAA	Anti Aircraft Artillery
AAR	Air-to-Air Refuelling
ABCCC	Airborne Command and Control Centre
ACP	Airborne Command Post
ADF	Australian Defence Force
ADGE	Air Defence Ground Environment
AEW	Airborne Early Warning
AEW&C	Airborne Early Warning and Control
AFZ	Australian Fishing Zone
ALG	Air Lift Group
AMRAAM	Advanced Medium Range Air-to-Air Missile
AO	Area of Operations
ARDU	Aircraft Research and Development Unit
ARH	Armed Reconnaissance Helicopter
ARM	Anti Radiation Missile
ASEAN	Association of South East Asian Nations
ASM	Air-to-Surface Missile
ASP	Airborne Surveillance Platform
ASW	Anti Submarine Warfare
ASTOR	Airborne Stand-Off Radar
ATC	Air Traffic Control
ATO	Air Tasking Order
AWACS	Airborne Warning and Control System
BAAS	Broad Area Airborne Surveillance
BAI	Battlefield Air Interdiction
BDA	Bomb Damage Assessment
BVR	Beyond Visual Range
CAIRS	Close Air Support
CAP	Combat Air Patrol
CEC	Cooperative Engagement Capability
CIC	Combat Information Centre
COMINT	Communications Intelligence
CONUS	Continental United States
COTS	Commercial off the Shelf
CP	Command Post
CRU	Control and Reporting Unit
CSG	Combat Support Group
CTOL	Conventional Take Off and Landing
DA94	Defending Australia 1994 (White Paper)
DAA	Defeating Attacks Against Australia
DACC	Defence Assistance to the Civil Community
DCA	Defensive Counter Air
DDG	Destroyer Guided missile
DEW	Distant Early Warning
DFACP	Defence Force Aid to the Civil Power
DF	Direction Finding

DGI	Defending Global Interests
DIRCM	Direct Infra-Red Counter Measures
DJFHQ	Deployable Joint Force Head Quarters
DOA87	Defence of Australia 1987 (White Paper)
DRI	Defending Regional Interests
DSTO	Defence Science and Technology Organisation
EASTROC	Eastern Regional Operations Centre
EC	Electronic Combat
EEZ	Exclusive Economic Zone
EHF	Extremely High Frequency
EID	Electronic Identification
ELF	Extremely Low Frequency
ELINT	Electronic Intelligence
EMCON	Emission Control
ESM	Electronic Support Measures
EW	Electronic Warfare
EWSP	Electronic Warfare Self Protection
FAAS	Focal Area Airborne Surveillance
FAC	Forward Air Controller
FEG	Force Element Group
FFG	Fast Frigate Guided Missile
FLIR	Forward Looking Infra-Red
FTI	Fixed Target Indicator
GBAD	Ground Based Air Defence
GSM	Ground Station Module
HF	High Frequency
HFSW	High Frequency Surface Wave
HQAC	Headquarters Air Command
HQAST	Headquarters Australian Theatre
IADS	Integrated Air Defence System
IAF	Israeli Air Force
ICBM	Inter Continental Ballistic Missile
IFF	Identification Friend or Foe
IR	Infra-Red
IIR	Imaging Infra-Red
IRST	Infra-Red Search and Track
JASA	Joint Airborne Sigint Architecture
JOSCC	Joint Offensive Support Coordination Cell
JORN	Jindalee Operational Radar Network
JSEAD	Joint Suppression of Enemy Air Defences
JSTARS	Joint Surveillance and Target Acquisition Radar System
JTIDS	Joint Tactical Information Distribution System
LEO	Low Earth Orbit
LF	Low Frequency
LRMP	Long Range Maritime Patrol (aircraft)
MANPADS	Man Portable Air Defence System
MESA	Multi role Electronically Scanning Array
MEZ	Missile Engagement Zone
MF	Medium Frequency

MPG	Maritime Patrol Group
MR	Maritime Reconnaissance
MTI	Moving Target Indicator
NORAD	North American Air Defence (command)
NORTHROC	Northern Regional Operations Centre
OCA	Offensive Counter Air
OTCIXS	Officer in Tactical Command Information Exchange System
OTHR	Over the Horizon Radar
PGM	Precision Guided Munition
PHALCON	Phased Array L band Conformal
PNI	Protecting National Interests
PRF	Pulse Repetition Frequency
PW	Pulse Width
Radar	Radio Direction and Ranging
RAAF	Royal Australian Air Force
RAF	Royal Air Force
RAN	Royal Australian Navy
RAP	Recognised Air Picture
RCC	Rescue Coordination Centre
RCS	Radar Cross Section
ROE	Rules of Engagement
RSU	Radar Support Unit
RWR	Radar Warning Receiver
RN	Royal Navy
SAM	Surface-to-Air Missile
SAR	Search and Rescue
SAR	Synthetic Aperture Radar
SBR	Space Based Radar
SCG	Surveillance and Control Group
SEAD	Suppression of Enemy Air Defences
SF	Special Forces
SHF	Super High Frequency
SIGINT	Signals Intelligence
SLOC	Sea Lines of Communication
SR97	Strategic Review 1997
SRG	Strike Reconnaissance Group
SSM	Surface-to-Surface Missile
STOL	Short Take Off and Landing
TARS	Tethered Aerostat Radar System
TFG	Tactical Fighter Group
TFR	Terrain Following Radar
UAV	Unmanned Aerial Vehicle (also Uninhabited)
UHF	Ultra High Frequency
UN	United Nations
US	United States
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy
VHF	Very High Frequency

VID	Visual Identification
VLF	Very Low Frequency
V/STOL	Vertical/Short Take Off and Landing
WAS	Wide Area Surveillance
WASP	Wide Area Surveillance Picture
WEZ	Weapons Engagement Zone
WVR	Within Visual Range
XO	Executive Officer

CHAPTER ONE

A SHORT HISTORY OF AIRBORNE EARLY WARNING & CONTROL

All the business of war and indeed all the business of life
is to endeavour to find out what you don't know by what you do;
that's what I call 'guessing what was at the other side of the hill'.

Arthur Wellesley
Duke of Wellington[1]

THE OTHER SIDE OF THE HILL

Military commanders have always wanted to know what the enemy is going to do next — attack or retreat. 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.

[1] Royle, T., *Dictionary of Military Quotations*, Routledge, London, 1990, p. 65.

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.[2] The RAF early warning system could determine the bearing, altitude and range 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 superiority over the English Channel and south-east England. The Germans needed to establish air superiority as a precondition for their 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 10 metres. Intruders often fly behind hills and down valleys, using terrain features to mask their approach. This is the reason why so many air raids since 1940 have been 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. Figure 1.1 illustrates the point.

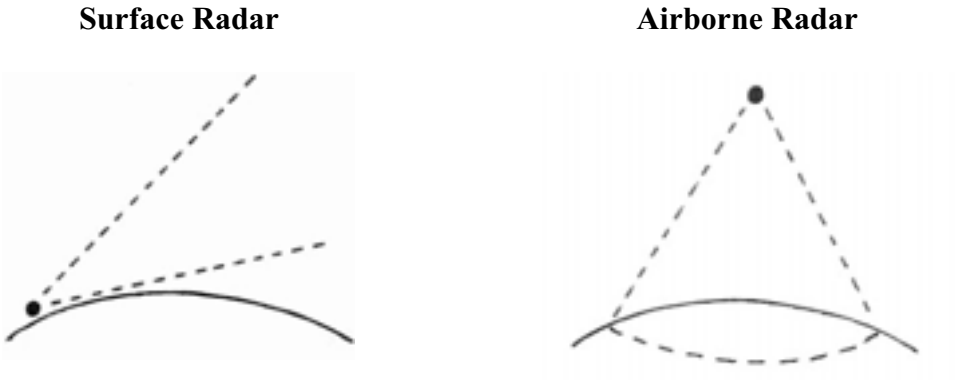

Figure 1.1: Radar Horizons

[2] 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.

Early radar equipment was very large and bulky and required massive amounts of power. In the 1930s, no aircraft could carry such radars. Only the largest ships (battleships and aircraft carriers) had the space and electrical power. Therefore 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 Two 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.[3] 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.

THE AMERICAN WAY

Genesis: World War Two

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 the enemy vessels they were engaging. 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 lengthy affair Japan was at a severe disadvantage. America had vastly superior natural resources, much greater industrial capacity and twice the population. In 1942–43 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.

[3] 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 Malayan coast.

Kamikazes. 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, packed with high explosives. 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 bomb, much like modern 'smart bombs' such as the AGM-142 in service with the Royal Australian Air Force (RAAF) today.[4] 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. Included in the ships lost were three small aircraft carriers and many destroyers.[5] 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 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.[6]

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 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.[7] 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.

[4] The AGM-142 is a 3,000 pound guided missile.
[5] Barker, A.J., *Suicide Weapon*, Ballantine Books Ltd, London, 1971, p. 159.
[6] *Ibid*., p. 90.
[7] Natkiel, R., *Atlas of World War Two*, Bison Books, London, 1985, p. 134.

Cadillacs. In February 1944, the USN initiated Project Cadillac, under which the Radiation Laboratory at Massachusetts Institute of Technology was contracted to develop the world's first operational AEW radar — the APS-4.[8] About 40 single-engine Grumman Avenger torpedo bombers were fitted with the APS-4 radar, in small pods under their wingtips (see Figure 1.2). Delivery of the two-man aircraft began in March 1945 and they were tested operationally in the Okinawa campaign in May/June 1945.

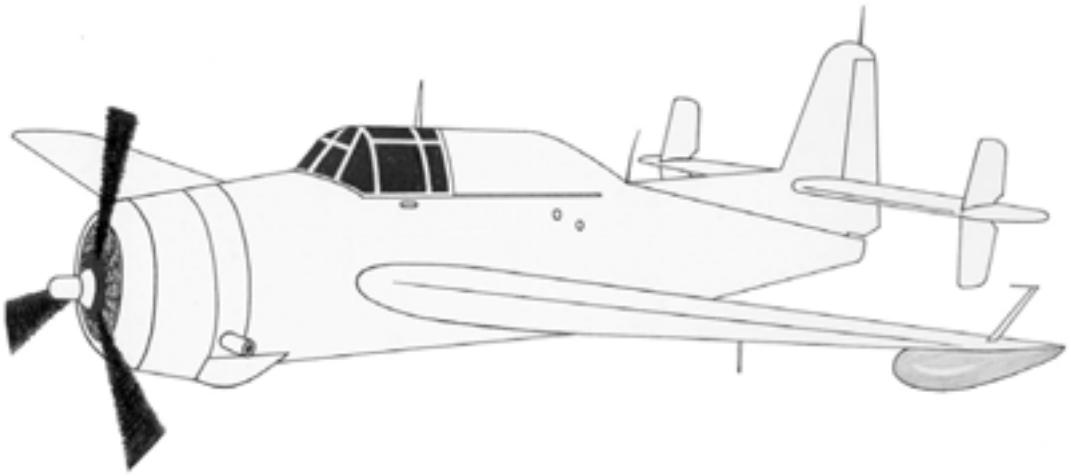

Figure 1.2: Grumman AEW Avenger

The radar 'picture' detected by the AEW Avengers was transmitted back to the Combat Information Centre (CIC), on board a nearby warship, where the interpretation and intercept control were performed.[9] To this day, there is disagreement 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 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. The AEW Avengers provided little more than a morale boost and an opportunity to test a new concept under realistic battle conditions. Development continued after the war.

[8] 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. APS is the US military designation for airborne air search radar.
[9] Allport, D., 'AEW Aircraft Survey', *Air International*, March 1995, p. 169.

Cold War Developments

Soon after the defeat of Japan, the Soviet Union emerged as the new adversary of the Western Alliance. 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.

The German U-Boat threat from World War Two was replaced by the growing Soviet submarine fleet in the early days of the Cold War. 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. The Western alliance (the North Atlantic Treaty Organisation or 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 Two, so ASW aircraft continued to carry radar. These ASW radar equipped aircraft became the basis for later AEW radar equipped aircraft.

Guardians. 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 (see Figure 1.3). 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.[10]

Figure 1.3: Grumman AEW Guardian

[10] *Jane's All the World's Aircraft 1955/56*, Jane's Information Group, Couldson UK, pp. 265-266.

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.[11]

Skyraiders. 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 (see Figure 1.4). 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.[12]

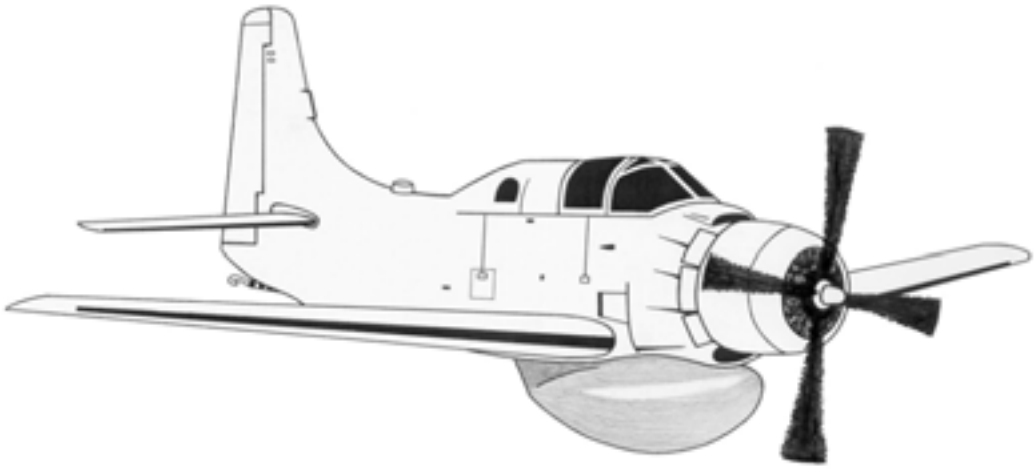

Figure 1.4: Douglas AEW Skyraider

The AEW Skyraider was an advance on its predecessors, but its effectiveness was still limited by the small crew and cramped working space. Like its predecessors, the AEW Skyraider was just a sensor held up high. Experience gained from the first decade of AEW operations had shown that more operators and a better working environment were required to better exploit the radar data. This would require a larger airframe.

Radar Warfare. 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).[13] The USN went so far as to dedicate squadrons of aircraft to the activity. An EW version of the Skyraider

[11] Treadwell, T., *The Ironworks: Grumman's Fighting Aeroplanes*, Airlife Pub Ltd, Shrewsbury, 1986, p. 52.
[12] Yenne, B., *McDonnell Douglas: A Tale of Two Giants*, Bison Books, London, 1985, pp. 52–53.
[13] The common Electronic Warfare terms are listed at Annex A.

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.[14] An EW squadron was assigned to every USN aircraft carrier.

The APS-20 radar was the most powerful airborne radar of the immediate post war period, but its usefulness was quickly overtaken by post war developments in EW. Early radars were inefficient. Much of the power they emitted was not focussed in the main beam, but scattered out in other directions. The excess energy spillage is termed side lobes. Side lobes create several problems.

Side lobes are a waste of energy. If a radar draws more power than necessary, its space and weight requirements will be greater. Space and weight are limited in aircraft.

Side lobes make detection of the radar easier for enemy EW equipment. Ideally, a radar should transmit a narrow focussed beam (a pencil beam) but early radars were more like floodlights. An enemy aircraft or ship fitted with a Radar Warning Receiver (RWR) can intercept radar emissions and determine the direction from which they originated. An RWR will often detect a radar at up to twice the range the radar can detect the RWR platform. An RWR has more chance of detecting a radar with large side lobes and the target can then take evasive action to avoid being detected by the radar.

Side lobes often reflect off clutter and return false signals. The radar's signal processor can be confused by the additional returns.

The APS-20 achieved detection by brute force and its antenna generated side lobes nearly as big as its main beam. It was a good radar in 1945, but by 1955 it was too easily detected by enemy EW. Better radars were available for the AEW role.

Increasing Threat. 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.[15]

The best way of dealing with the increasing air threat was to intercept incoming bombers before they got close enough to launch their missiles. Such interception had to be hundreds of kilometres from the aircraft carrier being defended. AEW aircraft were required to search the huge volumes of airspace and give adequate warning of incoming attacks.

[14] Yenne, *McDonnell Douglas*, p. 52.
[15] Gunston, B., *Rockets & Missiles*, Salamander, London, 1979, pp. 79–80, 134.

Tracers. 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 (see Figure 1.5). The Tracer carried a crew of four, including three mission specialists. The USN acquired 88 Tracers.[16]

For the first time in a carrier based 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 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).

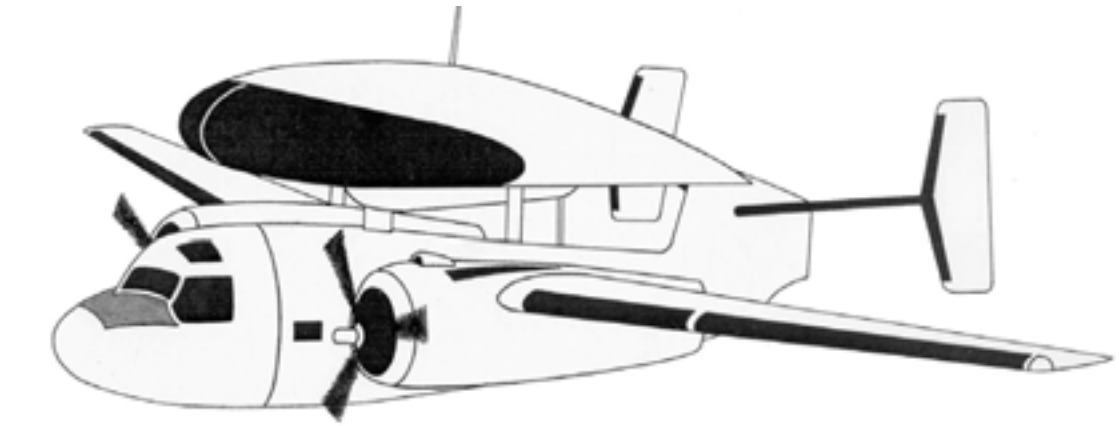

Figure 1.5: Grumman Tracer

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 exact 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 did not perform well over land. The radar could not pick out low flying aircraft from the 'ground clutter' of trees, hills and moving land vehicles. The Tracer's radar equipment had better overland capability, which later AEW radars would improve upon.

Hawkeyes. 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 (see Figure 1.6). The whole radome rotated, hence the term 'rotodome'. The Hawkeye had a crew of five, including three mission specialists.[17] The USN has acquired over 140 Hawkeyes.

[16] *Ibid*., p. 67.
[17] *Jane's Aircraft 1995/6*, pp. 617–618.

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 thousands of targets and tracking hundreds of them simultaneously. The small mission crew manages the mass of data through high levels of automation (common to all modern AEW&C), well-organised data presentation formats (human/machine interface) and well-developed task allocation. The alternative would be to datalink the radar picture to a warship's CIC, where larger numbers of operators could manage the data manually.

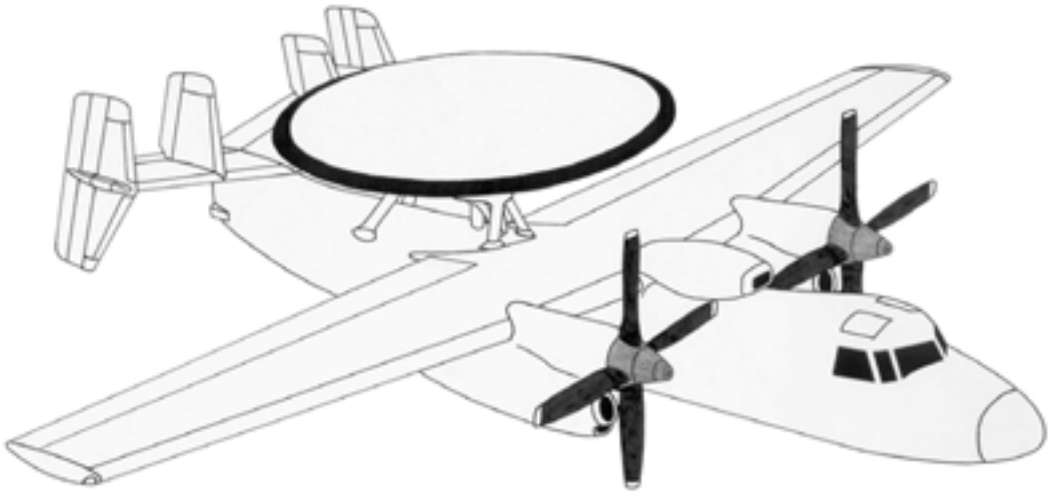

Figure 1.6: Grumman Hawkeye

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.[18]

[18] Treadwell, *The Ironworks*, p. 155. MiG is the common Western colloquialism for Communist Bloc jet fighters. MiG is a contraction of Mikoyan Gurevich, the organisation that designed most Soviet fighters during the Cold War period.

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.

The Hawkeye is the most widely used AEW&C aircraft in the world, with over 200 in service. Hawkeyes are in service in Egypt (six acquired in 1987), France (two in 1997), Israel (six in 1978), Japan (13 in 1982), Singapore (four in 1987) and Taiwan (four in 1995).

Generations. The constant trends over the two decades between the Avenger and the Hawkeye were larger and more powerful radars, greater computer processing power and larger crews to manage the data (see Table 1.1). The first generation AEW aircraft (Avenger, Guardian and Skyraider) carried one or two operators manipulating the radar to optimise its performance, but the radar data was transmitted to a warship's CIC for interpretation and action. The second generation AEW aircraft (Tracer) featured a large operators' compartment and crew which constituted a flying CIC. The third generation AEW aircraft (Hawkeye) introduced digital computers which provided a quantum leap in processing power, enabling the crew to identify and track huge numbers of targets in massive volumes of airspace.

Aircraft	Radar	T/O Weight	Crew	Data Processing	In Service
Avenger	APS-4	18,000 lbs	2	Link to CIC on ship	1944
Guardian	APS-20	25,000 lbs	3	Link to CIC on ship	1950
Skyraider	APS-20	25,000 lbs	3	Link to CIC on ship	1951
Tracer	APS-82	27,000 lbs	4	Onboard aircraft	1958
Hawkeye	APS-96	55,000 lbs	5	Onboard aircraft	1964

Table 1.1: Trends in US Carrier-based AEW&C Capability

Strategic Early Warning and Control

World War Two. The US Army Air Forces had no perceived need for AEW in World War Two. 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 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.

Cold War. 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 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 a surface-based radar can. 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 30,000 feet, 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] Aircraft could also fly above or around bad weather, which could seriously degrade the stability and effectiveness of a ship as a radar platform.

Bigger Cadillacs. Towards the end of World War Two, the USN had modified a few Boeing B-17 Flying Fortress four-engine bombers, under Project Cadillac II. This

[19] Peebles, C., *Guardians : Strategic Reconnaissance Satellites*, Ian Allen Ltd, London, 1987, p. 305.
[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.

involved fitting an APS-20 radar, as fitted to the last few AEW Avengers.[22] 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.

Super Constellations. 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. The Warning Star carried nearly six tonnes of radar and electronic equipment, which was almost the total take-off weight of the original AEW Avenger.

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 fat dorsal fin, two metres high and three metres long (see Figure 1.7).

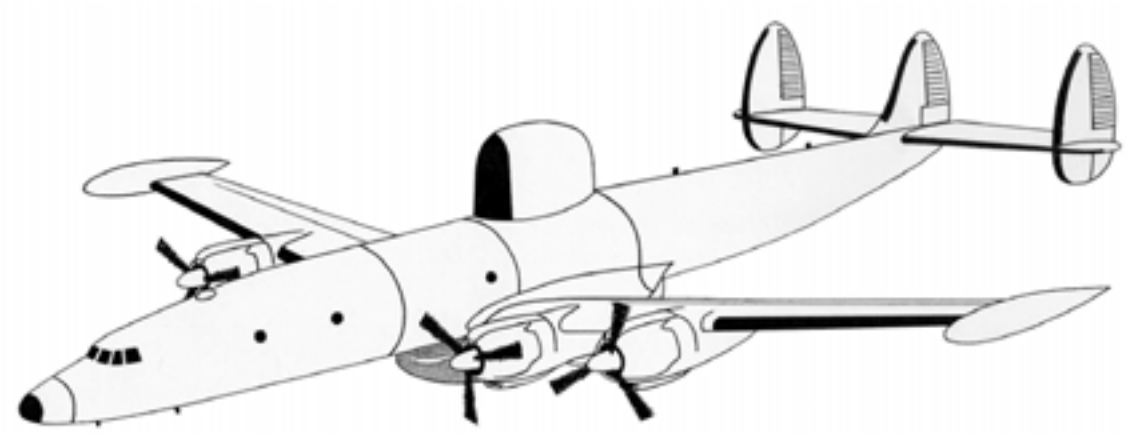

Figure 1.7: Lockheed EC-121 Warning Star

One experimental version of the Warning Star had a large surveillance radar in a rotodome mounted above the rear fuselage. The technology was immature and the first operational application of the rotodome concept was some years later, in the Hawkeye.

The Warning Star was the first AEW aircraft that did not have to transmit its raw radar data to a CIC on the surface. The data could be processed and acted upon by the systems and crew on board the aircraft. The EC-121 was thus the first operational Airborne Early Warning *and Control* aircraft.
In the early 1950s, the USN ordered over 240 Warning Stars.[23] The USAF followed suit and introduced its own AEW version of the Super Constellation, the RC-121.

[22] Hirst, M., *Airborne Early Warning Design, Development and Operations*, Osprey, London, 1983, pp. 60–61.
[23] Yenne, B., *Lockheed*, Bison Books, London, 1987, p. 57.

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.[24] In 1962, all RC-121s were redesignated EC-121s.[25]

Strategic Command and Control

The Cold War. 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.[26] 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.[27]

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.[28]

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 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 dozens of communications systems, including SHF, LF and VLF.[29] A total of 50 antennae festoon each aircraft. An E-4 can remain on station for 72 hours, carrying three times

[24] Grossnick, R., *US Naval Aviation: 1910 – 1995*, US Naval Historical Centre, Washington DC, 1997, p. 202.
[25] Yenne, *Lockheed*, p. 57.
[26] This was the vindication of the pre-World War Two theories of Douhet, who claimed that there could be no defence against air power wielding weapons of mass destruction (WMD).
[27] 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.
[28] Francillon, R.J., 'Messenger of the Gods: The Boeing E-6A Mercury', *Air International*, January 1995, pp. 19–24.
[29] The various radio bands in the electromagnetic spectrum are listed at Annex B.

the payload of the EC-135. Throughout the Cold War, a Kneecap was always on alert at Andrews AFB, near Washington DC.[30]

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. New technology is making electronic systems smaller and more capable, so the strategic ACP function could be performed at a few consoles on a 'tactical' ACP or AEW&C aircraft.

The 21st century will be the age of weapons of mass destruction and ballistic missile proliferation. As warning times get shorter, other nations may yet see the value of a strategic ACP capability to 'back up' conventional land-based systems. The tactical value of an ACP capability is also becoming increasingly attractive to second order powers.

Tactical Command and Control

Vietnam. 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.[31] 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.[32]

Airborne Command and Control Centre. 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 self-contained capsule was fitted with 20 radios (HF, VHF, UHF and FM), two secure teletypes and a 14 channel voice/data recorder. The ABCCC does not have a surveillance radar, so its crew's situational awareness is achieved via voice radio and flight plan data. In addition to the standard cockpit crew of four, the ABCCC carried a

[30] Redding, R. & Yenne, B., *Boeing: Planemaker to the World*, Bison Books, Greenwich Connecticut, 1983, pp. 156–160.
[31] Yenne, *Lockheed*, p.57.
[32] Drendel, L. *TAC : A History of the USAF Tactical Air Forces 1970 –1977*, Squadron/Signal Pub, Inc, Michigan, 1978, p. 59.

'battle staff' of 12.[33] 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.[34]

The ABCCC managed tactical air resources and provided integrated communications support. The ABCCC crew coordinated target assignments and maintained safety margins between aircraft (separation) by assigning them holding locations and altitudes while they waited for tactical control from a Forward Air Controller (FAC).[35]

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 (ABCCCs) to coordinate 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.[36] In the 11 day operation, the North Vietnamese launched 1,242 SAMs at the American bombers, but only 26 B-52s were lost.[37]

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.[38] Hundreds of trucks were destroyed in the campaign. Such a system could be characterised as indirect surface surveillance.

LIGHTER-THAN-AIR SURVEILLANCE SYSTEMS

Strictly speaking, the first airborne surveillance platforms were tethered balloons used by the French Republican Army in 1794. The French balloon observer corps was active in Napoleon's campaigns in Italy and Egypt in the late 1790s. The US Army frequently used balloons in the American Civil War (1861–1865).[39] The balloons were used for visual surface surveillance, to enable soldiers to see what lay on the

[33] Garner, D., 'ABCCC : The Eyes of the Battlespace', *Air Force Magazine*, July 1999, pp. 58–63.
[34] *Jane's Aircraft 1984/85*, p. 435.
[35] Sharer, W., 'Command and Control: The Navy Way Over Kosovo', *Proceedings*, October 1999, p. 28.
[36] Drendel, L., *Air War Over South East Asia*, Squadron/Signal, Carrollton, Texas, 1984, p. 38.
[37] Scott, C., 'Forcing the Peace', *RAF Air Power Review*, Spring 1999, p. 33.
[38] Mersky, B., & Polmar, N., *The Naval Air War in Vietnam*, Nautical & Aviation Pub Co, Annapolis, 1981, pp. 172–177.
[39] Penna, 'The Ascendance of AEW', *Australian Aviation & Defence Review*, March 1981, p. 64.

other side of the hill. Between 1900 and 1914, German rigid airships (Zeppelins) completed 1,600 flights, carrying 35,000 passengers and travelling 160,000 kilometres, without an accident.[40]

World War One. During World War One, 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.[41] 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 76 Zeppelins used by the German Navy, 53 were lost (30 in accidents or storms and 23 to enemy action).[42] Of the 52 Zeppelins used by the German Army, 26 were lost.[43]

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.

World War Two. The Americans and British used unmanned tethered blimps (aerostats) during World War Two. Blimps were used to deter low level air attacks on high value targets, such as the invasion beaches at Normandy. Over 500 blimps were deployed around London as late as September 1944. Blimps were a critical component in the defence of south-eastern Britain against the German V-1 cruise missiles and were credited with destroying about 100 of the missiles. Blimps were also used with some success to assist in ASW in the Atlantic.[44]

Cold War. 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.[45] 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 thrust-vectoring engines, fly-by-wire controls and lighter, stronger carbon fibre structures had solved the historical technical problems of airships. In the late 1980s, airships appeared to be on the verge of a renaissance.[46]

Modern Airships. 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

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[40] Gilbert, M., *First World War Atlas*, Weidenfeld & Nicolson, London, 1970, p. 64.
[41] Hillsdon, R., 'Lighter-than-Air Surveillance Systems', *Air Power: Global Developments & Australian Perspectives*, Pergamon-Brassey's, Sydney, 1988, p. 399.
[42] Gilbert, *First World War Atlas*, p. 68.
[43] Griehl, M. and Dressel J., *Zeppelin! The German Airship Story*, Arms & Armour Press, London 1990, pp. 114–115.
[44] Hillsdon, 'Lighter-than-Air Surveillance Systems', p. 399.
[45] *Ibid.*, p. 399.
[46] *Ibid.*, p. 400.

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, and remain on station for extended periods. A USN study indicated an airship could remain in support of ships for up to 60 days, refuelling from the fleet every four or five days.[47]

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.[48] Israel is also reported to be operating a few airships in the AEW role.

The war 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 patrol, Exclusive Economic Zone (EEZ) protection, law enforcement and search and rescue (SAR).[49]

The disadvantages of airships include relative fragility, very low speed, lack of manoeuvrability and inability to operate in inclement weather. The disadvantages usually outweigh the advantages, and few airships have found their way back into the operational inventories of modern armed forces.[50]

Australian Airships. The ADF considered aerostats for the AEW role in northern Australia and the air sea gap beyond. The RAAF Aircraft Research and Development Unit (ARDU) actually conducted some flight trials, using a borrowed Bond Industries airship.

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.[51] Conventional (heavier-than-air) aircraft are more flexible and capable of operating in worse weather.

[47] Hillsdon, 'Lighter-than-Air Surveillance Systems', p. 408.
[48] Browne & Thurbon, p. 142.
[49] Hillsdon, 'Lighter-than-Air Surveillance Systems', pp. 410–416
[50] Braybrook, R., 'Forward to the Past', *Air International*, August 2000, p. 117. There are currently 15 airships under development in 10 countries.
[51] Duus, A., *Aerostat Availability in Northern Australia*, DSTO Client Report AOD 96/05.

DIFFERENT STROKES FOR DIFFERENT FOLKS: AEW&C AROUND THE WORLD

Rule Britannia: AEW&C on a Shoestring Budget

The British emerged from World War Two 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, and as cheap as possible. They continued their habit, formed during the war, of tapping into the American 'cornucopia' for new capabilities.

Royal Navy — Fixed-Wing AEW

After World War Two, 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 early 1950s, small numbers of AEW Guardians and AEW Skyraiders were acquired from the Americans as interim AEW aircraft.[52]

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 horse power, 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 (see Figure 1.8). The crew consisted of a pilot and two radar operators. The RN operated a fleet of 44 AEW Gannets.[53] 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.[54]

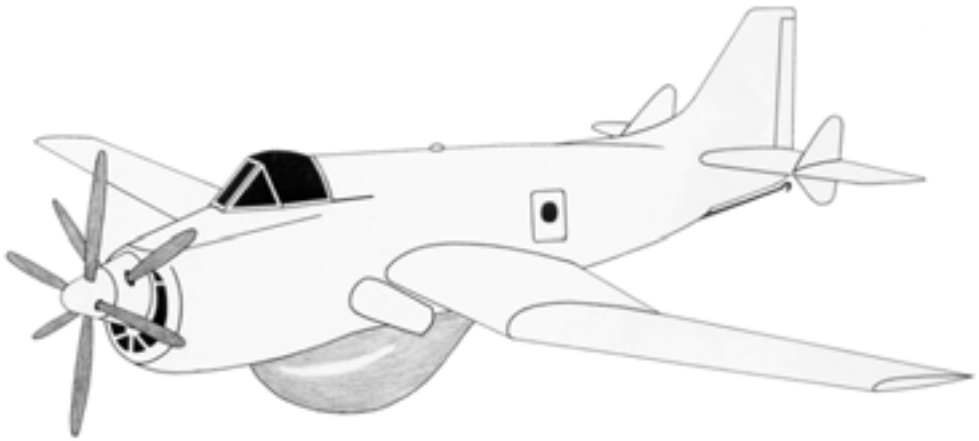


Figure 1.8: Fairey AEW Gannet

[52] *Jane's Aircraft 1956/57*, pp. 270–272.
[53] *Jane's Aircraft 1959/60*, p. 42.
[54] Allport, 'AEW Aircraft Survey', p. 170.

Only four years later, the RN sent the light aircraft carriers 'Hermes' and 'Invincible' to the Falklands war. The ships were not capable of operating CTOL aircraft and were limited to vertical/short take off and landing (V/STOL) aircraft such as Harriers and helicopters. The only British AEW aircraft in service were the large land-based Shackletons of the RAF. The Shackletons could not operate off the carriers.

Royal Navy — Rotary-Wing AEW

During the Falklands War, the RN recognised the operational need for organic AEW and an emergency program was undertaken to fit the Searchwater radar (as carried by 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 (see Figure 1.9). The crew consists of one or two pilots and three mission specialists.

The AEW Sea Kings did not enter service until after the Falklands War had ended. Eventually 13 Sea Kings were converted to the AEW role. The space and electrical power available on the helicopter are limited, so the AEW Sea King lacks on board processing capability. Its radar data must be transmitted back to a warship CIC for further action. The RN retains this rudimentary AEW capability at sea today.[55]

Figure 1.9: Westland AEW Sea King

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 Two vintage, four-engine bomber, which had been converted to the maritime patrol role. The AEW Shackleton carried an APS-20 radar in a circular

[55] Allport, 'AEW Aircraft Survey', pp. 212–213.

radome, conformal to the belly, just ahead of the bomb bay (see Figure 1.10).[56] 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. The AEW Shackleton carried three cockpit crew and eight tactical crew.[57]

Studies conducted in the mid-1970s showed 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.[58]

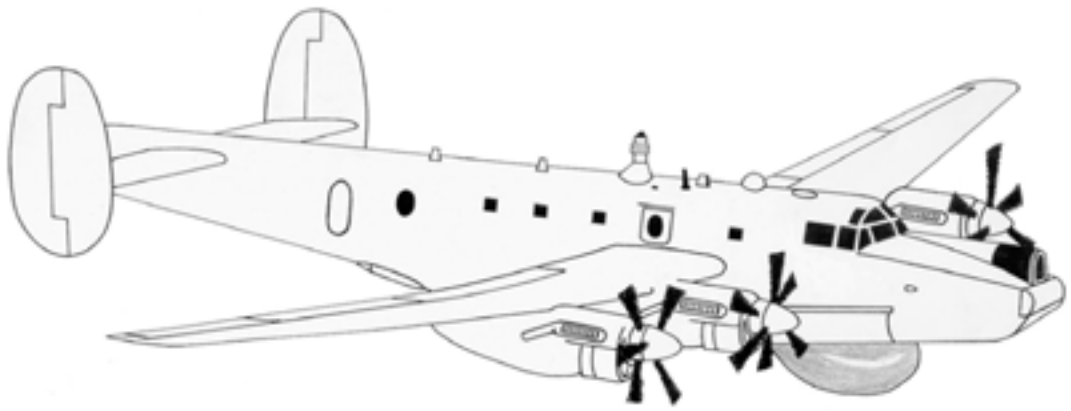


Figure 1.10: Avro AEW Shackleton

Hawker Siddeley Aviation proposed an AEW version of the Nimrod Maritime Reconnaissance (MR) aircraft in 1977. All previous AEW aircraft were fitted with one radar, with coverage ranging from a frontal arc of 90 or 100 degrees up to the full 360 degrees. The AEW Nimrod had a radar in the nose and another in the tail, each with 180 degree coverage. Computer software would integrate the two radar pictures into a single 360 degree picture. 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

[56] *Jane's Aircraft 1972/73*, p. 202.
[57] Penna, D., 'The Ascendance of Airborne Early Warning', *Australian Aviation & Defence Review*, March 1981, p. 65.
[58] Palmer, J., 'AEW Aircraft – The GEC Avionics Proposal', *Air Power: Global Developments and Australian Perspectives*, Pergamon-Brassey's, Sydney, 1988, pp. 265–276.

configuration in June 1977. Large, bulbous radomes were added to the nose and tail to accommodate the radars (see Figure 1.11). The radomes 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.

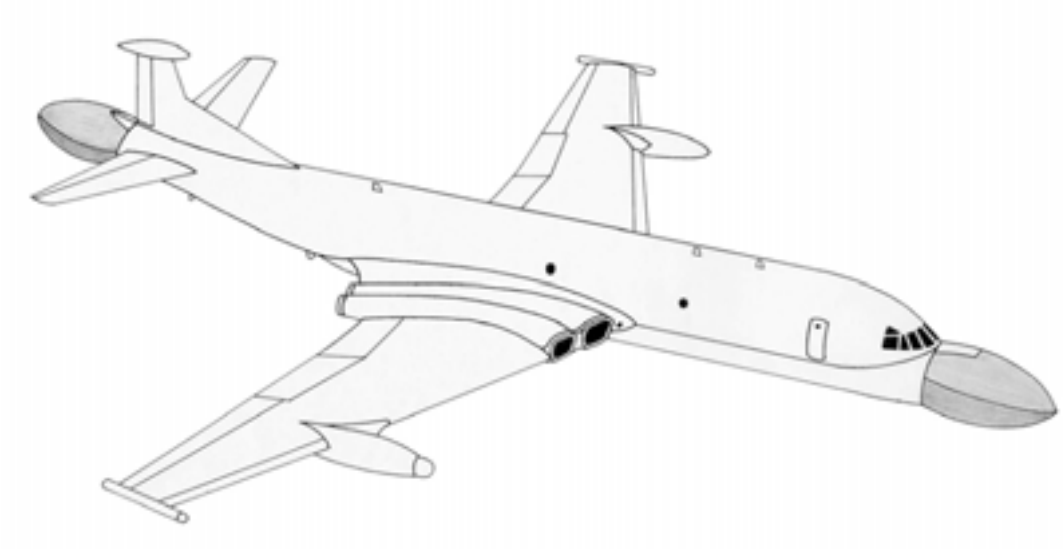


Figure 1.11: Hawker Siddeley AEW Nimrod

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.[59] The radars also failed to meet range requirements and a new radar aerial had to be designed and fitted.[60]

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.[61]

[59] Palmer, 'AEW Aircraft – The GEC Avionics Proposal', pp. 265–268.
[60] *Ibid*., p. 275.
[61] *Ibid*, p. 270.

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.[62]

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.[63]

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 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.[64]

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.

Russian Air Force

The first Soviet AEW&C aircraft was the Tupolev Tu-126 (NATO codename Moss), which entered service in 1970. 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 (see Figure 1.12). The crew numbered about 12. The Soviet Air Force operated a fleet of 12 aircraft.[65]

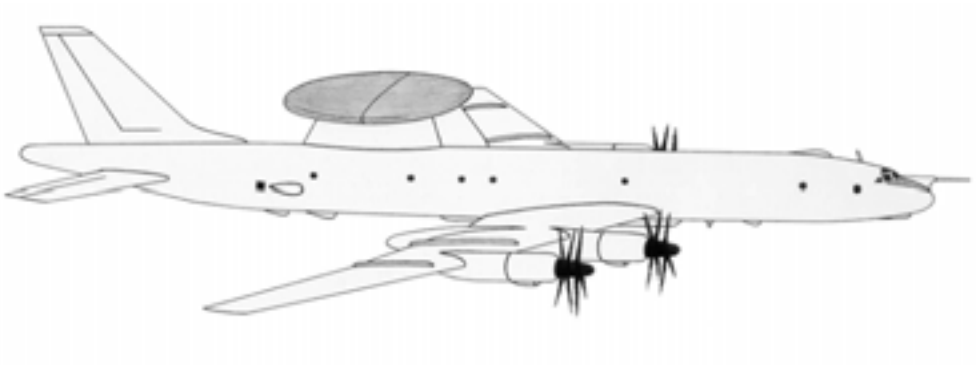


Figure 1.12: Tupolev Tu-126 Moss

The Tu-126 may have been used in combat. After the Indo-Pakistan War of November/December 1971, Pakistani sources reported India had used some type of

[62] Palmer, 'AEW Aircraft – The GEC Avionics Proposal', p. 276.
[63] *Jane's Aircraft 1986/87*, pp. 295–295.
[64] Allport, D., 'AEW Aircraft Survey', *Air International*, March 1995, p. 171.
[65] Nemecek, V., *History of Soviet Aircraft*, Willow Books, London, 1986, pp. 203–204.

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, where they could be protected by Indian SAMs.[66] It has been speculated the Indian AEW&C aircraft must have been Tu-126 aircraft, manned either by Russian crews or mixed Russian/Indian crews.[67] 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.[68]

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 (see Figure 1.13). 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 numbers 12. Of the 25 Mainstays acquired, about 16 aircraft still operate with the Russian Home Defence and Tactical Air Forces.[69]

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, particularly US cruise missile launches, to ensure nothing strayed into Russian airspace.[70] The monitoring would have taught the Russians a great deal about how NATO air forces operate.

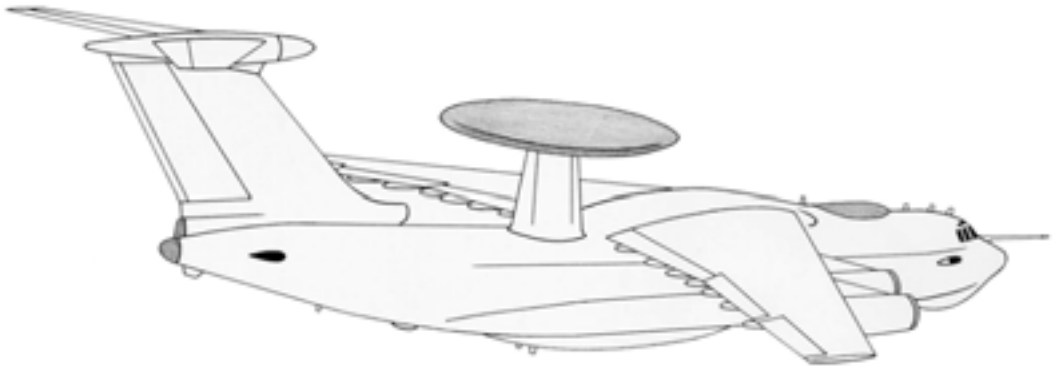


Figure 1.13: Beriev A-50 Mainstay

Russian Navy

[66] Penna, 'The Ascendance of Airborne Early Warning', p. 67.
[67] Nordeen, L., *Air Warfare in the Missile Age*, Smithsonian Institute Press, Washington DC, 1985, p. 109.
[68] *Pacific Defence Reporter*, Annual Reference Edition, 1980/81, Peter Isaacson Publications Pty Ltd, Melbourne, 1980, p. 69.
[69] Browne, J. & Thurbon, M., *Electronic Warfare*, Brassey's London, 1998, p. 152.
[70] *Jane's Aircraft 1997/98*, p. 370.

In the late 1980s, the Soviet Navy built its first 'supercarrier', with a large flight deck and steam catapults, capable of operating fixed-wing CTOL 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.[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 their intended function was exactly the same as their US and NATO counterparts.

We also know 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.

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 China could successfully invade and conquer Taiwan, particularly if the US Pacific Fleet intervened.[73]

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). A viable alternative to replacing or upgrading an entire fleet of combat aircraft is to introduce a few modern force multipliers, which can improve overall force effectiveness at much less cost.

[71] *Jane's Aircraft 1997/98*, pp. 513–514.
[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.
[73] Roos, J., 'The Cutting Edge', *Armed Forces Journal International*, May 2000, p. 13.

In the late 1980s, *Air International* aviation magazine published a photograph of a Chinese Tu-4 Bull bomber fitted with an AWACS-style saucer (see Figure 1.14). 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 aircraft now stands outside the Datangshan Museum near Peking.

Figure 1.14: Chinese AEW Tu-4 Bull

French AEW&C: Buy French or Buy American?

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 they could carry. The small numbers required by French forces drove up unit costs.

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 it had to fold down after take-off and could not be covered by a radome. There was enough space in the helicopter for a few operators who had to datalink their radar picture to a ground station.[74]

The demise of the Soviet Union ended the need for a tactical nuclear capability and the Orchid system was almost cancelled in 1990. The prototype system was deployed to Operation Desert Storm and proved to be useful for surface surveillance. The operational requirement was subsequently redrafted in post Cold War terms, as a battlefield surveillance system. The revised system was renamed 'Horizon'.[75]

[74] Pocock, C., 'The Eyes Have It', *Air International*, April 1997, p. 228.
[75] *Ibid*., p. 228.

French Navy: Air Surveillance

After World War Two, 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 needs 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 Breguet Alize ASW aircraft into rudimentary AEW aircraft. The conversion included a Thomson-CSF 'Iguana' radar. It was mounted in a small, retractable, drum-shaped radome that extended beneath the aircraft's belly after take-off (see Figure 1.15). The crew of three (a pilot and two operators) sat in a cramped cabin. Their radar picture had to be datalinked to the CIC on board a warship.[76]

The AEW Alizes have operated off the French Navy's aircraft carriers 'Foch' and 'Clemenceau' since the early 1980s. The limited capability they provide is not much of an advance on the AEW Skyraiders operated by the USN in the early 1950s. The radar on the AEW Alize is the same as that carried by the twin-engine land-based Dassault-Breguet Atlantique ASW patrol aircraft.

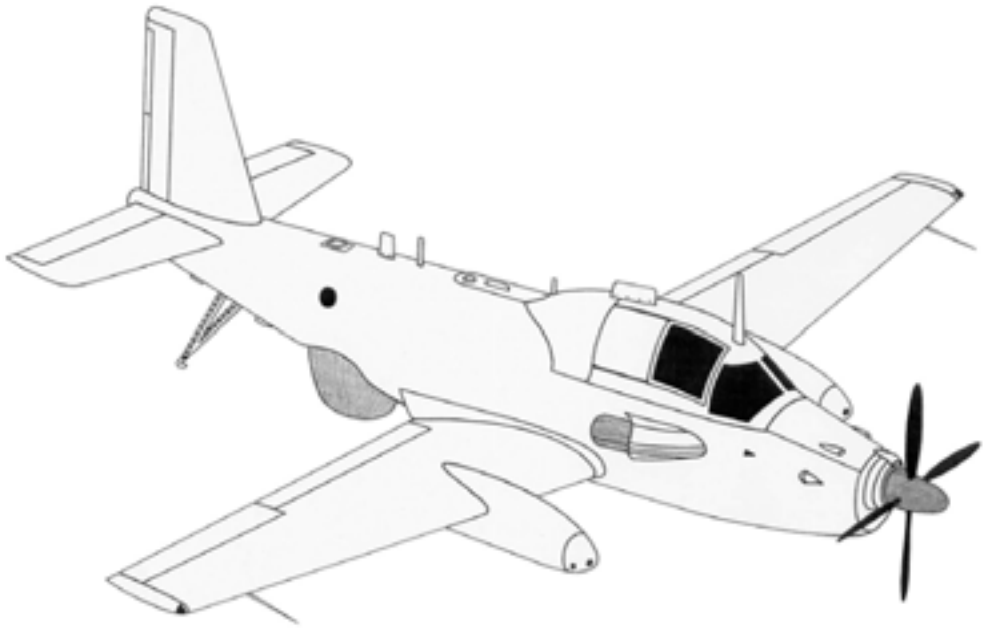


Figure 1.15 Breguet AEW Alize

[76] *Jane's Aircraft 1985/86*, p. 65.

AIRBORNE SURVEILLANCE — THE FIRST 40 YEARS

In 1945, the USN first grafted primitive radars onto small torpedo bombers in a desperate but ineffectual response to the Kamikazes. Since those early experiments, AEW&C has matured to the point where it can provide a reliable 'God's eye' view of the battlespace, distribute that view in 'real time' to many participants and coordinate a range of sensor and striker platforms.

AEW&C is now widely seen as an indispensable component of modern air operations. It is both a force multiplier and a force enabler. A measure of its value is that the major powers have invested many billions of dollars in AEW&C development.

Modern computer technology has made AEW&C capability affordable and many medium powers have each spent hundreds of millions acquiring AEW&C capability. The AEW&C 'club' will soon have at least 20 member nations.

CHAPTER TWO

MODERN AIRBORNE SURVEILLANCE

We shoot no missiles; we carry no cargo; our only product is information and information dominance is the key to success.

Colonel B. Robinson
Commanding Officer
93rd Control Wing, USAF[1]

SURVEILLANCE OF ALL THINGS

As well as being ideal for air surveillance, airborne radar platforms can also be used for surface surveillance. Air surveillance radars have tended to operate in the UHF frequency range, on D, E or F band, whilst surface surveillance radars have tended to be in the higher SHF frequency range, on I or J band.[2] A radar will therefore be optimised for air *or* surface surveillance. It may still be able to perform other tasks, albeit much less effectively.

The air search radar on the Grumman E-1 Tracer was very good at detecting aircraft and fair at detecting ships on calm seas but useless for detecting moving targets on land. Modern surface surveillance radars, coupled with powerful computers, are very good at detecting slow moving vehicles on land but useless for detecting fast aircraft.

Multi-Mode Radars

The APY-2 fitted to the E-3 is a typical modern multi-mode radar. The diagram at Annex G shows the various modes of the radar. In each mode, the radar is optimised to detect a different type of target, ranging from fast moving fighter aircraft to slow moving boats and ships. The common term for the movement detection feature on a radar is Moving Target Indicator (MTI).

Radar systems transmit short bursts of energy (pulses) and listen for the return. The actual duration of each burst of energy is the pulse width (PW). The time interval between pulses is the Pulse Repetition Interval (PRI).[3] The number of pulses per minute is the pulse repetition frequency (PRF). Figure 2.1 represents the operating cycle of a radar.

The PRI/PRF of radar can be varied, depending on the type of target information required. The faster the target is moving, the more often the radar needs to check on its position, in order to keep track of it. High PRF provides accurate data on a moving target's speed but less precise data on its range. Low PRF provides very accurate range data but is susceptible to clutter interference. Medium PRF gives good data on

[1] Saunders, K., 'The Stars Look Down', *USAF Yearbook 1999*, RAF Benevolent Find, London, p. 45.
[2] The bands of the electromagnetic spectrum are shown at Annex B.
[3] The PRI must allow time for the radar energy to travel to the target and back, so it will be twice the range.

speed and range, but requires a high degree of signal processing (computer power). When the target is a slow moving boat or ship, low PRF will be acceptable.

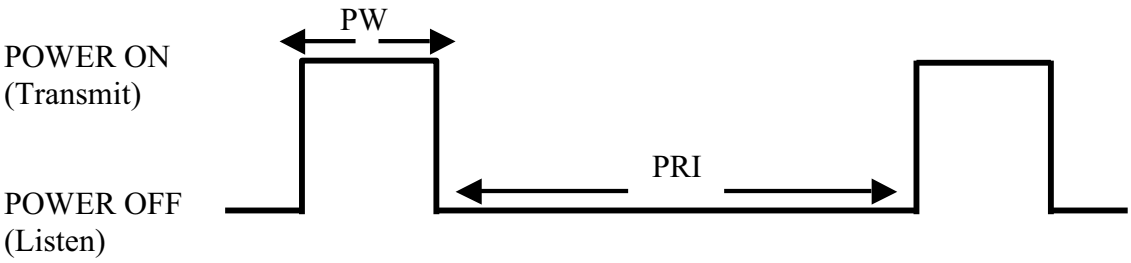


Figure 2.1: Pulse Radar Operating Cycle

The smaller the target, the more power the radar must transmit in order to have any chance of detecting the reflected energy. Aircraft have limited power available. High power transmission may necessitate fewer transmissions per minute (low PRF).

SURFACE SURVEILLANCE

Surface targets are usually either stationary or slow moving and the surrounding area is cluttered. On land the clutter consists of trees, hills and buildings. At sea the clutter consists of waves. Surface surveillance radars tend to operate in two modes — Wide Area Surveillance (WAS) and Synthetic Aperture Radar (SAR).

The SAR process involves illuminating the target from a series of angles as the aircraft moves and then overlaying the set of pictures to build a three dimensional picture. It can take several minutes to build up a SAR picture, so SAR is useless for tracking fast moving aircraft.

In surface surveillance radars, the computer software for the MTI feature is set to automatically ignore fast movers and only track slow movers. The software will also be set to ignore fixed targets, such as trees.

Modern American Surface Surveillance

Joint STARS. The E-8C Joint Surveillance and Target Acquisition Radar System (JSTARS) entered service with the USAF in 1996. 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 (see Figure 2.2). The radar operates in the I band in the middle of the SHF frequency range. The radar antenna alone weighs almost a tonne. There are 18 operator consoles on board. The USAF originally planned to acquire 19 JSTARS, but only 15 have been funded.[4]

[4] *Jane's Aircraft 1998/99*, pp. 694–696 and *Air International*, March 2000, p. 130.

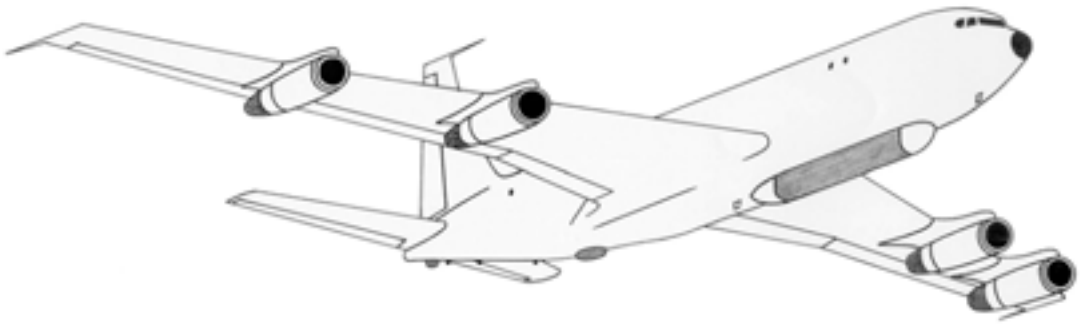


Figure 2.2: E-8 JSTARS

The JSTARS radar has two modes. In Wide Area Surveillance/Moving Target Indicator (WAS/MTI) mode the radar tracks all moving vehicles on a piece of terrain, in the same way that an air surveillance radar can track all aircraft in a volume of airspace. In Synthetic Aperture Radar/Fixed Target Indicator (SAR/FTI) mode, the radar generates a high resolution three dimensional map of the terrain and all the fixed structures on it. The pictures generated by the two modes can be superimposed to give the 'God's eye view' of the battlefield.

Using datalink, JSTARS can receive radar pictures and EW data from other platforms, such as reconnaissance aircraft and unmanned aerial vehicles (UAVs). The JSTARS system includes Ground Station Modules (GSMs) which perform data fusion. The data can be rapidly fused into useable form, thus generating a master 'Recognised Ground Picture', the sum of all the partial views of the battlefield from all the platforms on line. The JSTARS/GSMs then distribute that picture to all participants, giving them greatly enhanced situational awareness. Major 'customers' for the JSTARS picture include army artillery Command Posts at various levels (brigade, division or corps) and air force Tactical Air Operations Centres. General McPeak (former USAF Chief of Staff) has described the JSTARS capability by saying, 'JSTARS can do for ground attack aircraft what AWACS does for interceptors'.[5]

JSTARS in the Gulf War. 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 49 combat missions, totalling 534 flying hours.[6] Though still not fully operational, JSTARS was credited with eliminating much of the 'fog of war' for Coalition forces. The situational awareness that JSTARS gave to Coalition forces significantly reduced confusion and 'nasty surprises'.

The Coalition air offensive began in mid January 1991. On 29 January 1991, the Iraqi Army launched a substantial attack towards the Saudi border town of Khafji. The attacking force included 200 tanks, 300 light armoured vehicles and over 4,000 troops. The small screening force of US Marines in the area was to be taken by surprise. As a result of JSTARS surveillance and 'real time' reporting, the Marines were sufficiently forewarned to ambush and defeat the Iraqis.[7] Iraqi losses included

[5] Saunders, 'The Stars Look Down', pp. 44–46.
[6] Browne, J. & Thurbon, M., *Electronic Warfare*, Brassey's, London, 1998, pp. 159–160.
[7] Friedman, N., *Desert Victory: The War for Kuwait*, US Naval Institute Press, Annapolis, 1992, pp.197–203.

about 40 tanks, 60 light armoured vehicles and 650 troops (200 killed and 450 captured). Coalition losses were two tanks, eight light armoured vehicles and 30 troops.[8]

JSTARS in the Asia-Pacific. 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.[9]

JSTARS Capability. 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 pictures generated by JSTARS. The combination of JSTARS data and EW data can produce more complete target identification and threat assessment.[10]

JSTARS is optimised for operations over land where there are often 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. In recent operations in Yugoslavia, E-8Cs have been able to detect and track low flying helicopters.[11] JSTARS can thus augment AEW&C in the air surveillance role. Working together, JSTARS and AEW&C aircraft can detect and track nearly everything moving on or above the surface of the planet.

JSTARS Proliferation

Several nations have recently stated requirements for an airborne surface surveillance capability similar to JSTARS. Britain and NATO have considered JSTARS, but opted for cheaper alternatives based on small business jets. Japan, Saudi Arabia and South Korea are said to be considering acquiring small batches of JSTARS (four to six aircraft each).[12]

Cold Warrior Soldiering On

[8] Chadwick, F., *Gulf War Fact Book*, GDW, Bloomington Illinois, 1991, pp. 80–81.
[9] Veres, A., 'JSTARS Shines in FOAL EAGLE 97', *Asia Pacific Defence Forum*, Summer 98, p. 35.
[10] Wall, R., 'Army Intelligence Aircraft to Support Ground Forces', *Aviation Week & Space Technology*, 10 May 1999, p. 39.
[11] Wall, R., 'Joint-STARS Changes Operational Scheme', *Aviation Week & Space Technology*, 3 May 1999, p. 26.
[12] Saunders, 'The Stars Look Down', p. 46.

To supplement its JSTARS capability, the USAF recently decided to retain its fleet of U-2 high altitude reconnaissance aircraft. The original U-2s entered service with the CIA in the 1950s and flew high altitude spy missions over the Soviet Union. The current version is the U-2R, which is operated by the USAF. The first batch of U-2Rs was built in the 1960s and another batch was built in the 1980s.

The U-2 is a small, single seat aircraft, best described as a glider with a jet engine (see Figure 2.3). It is capable of cruising at 75,000 feet and has a mission endurance of over ten hours and range of 12,000 kilometres.[13] The U-2R sensor suite includes a SAR (for generating high resolution radar maps), an MTI feature, a dual band electro-optical camera (visible light and infra-red), panoramic cameras and a SIGNIT system.[14]

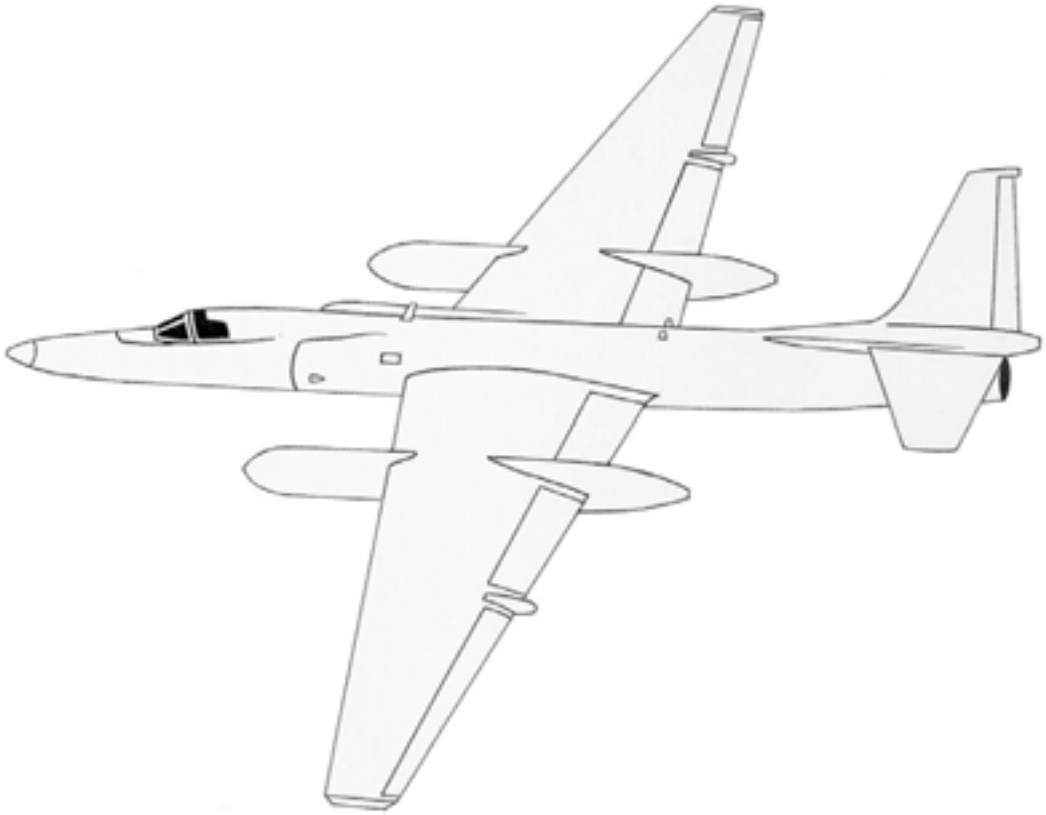


Figure 2.3: Lockheed U-2R

The radar data is partially processed on board the aircraft to reduce its bandwidth requirements and is then transferred to a ground station, via satellite datalink. The other imagery is transmitted directly to the ground station. The data can then be fused with inputs from other platforms, in 'real time'.[15]

[13] Pocock, C., 'U-2000 and a Long Way Beyond', *USAF Yearbook 1999*, RAF Benevolent Society, London, 1999, p. 16.
[14] *Ibid*., p. 16.
[15] Pocock, 'U-2000 and a Long Way Beyond', p. 16.

The USAF has a fleet of about 30 U-2Rs. They have proven to be very useful in operations in the Balkans and Iraq, and there are four permanent overseas detachments. The USAF plans to keep the U-2 in service until 2020 and may even acquire an additional 16 new aircraft.

ELECTRONIC 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 a fighter jet, 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.

Modern American Electronic Surveillance

Since the 1960s, the four American armed services (Army, Navy, Air Force and Marines) have all fielded large numbers of airborne SIGINT platforms. In the 1990s there has been significant rationalisation of the SIGINT fleets, in line with the policy of Joint Airborne SIGINT Architecture (JASA). JASA requires that all American SIGINT aircraft have the ability to interconnect by datalink.[16]

The Americans plan to standardise on a common platform — the Aerial Common Sensor. Platforms under consideration include the Fokker Friendship 50 twin turboprop airliner and the Lockheed Martin Alenia C-27J twin turboprop military transport.[17]

US Army. Over the period 1967 to 1975, the US Army used about 90 Beech King Air twin engine 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 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 andto 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 Vietnam.[18]
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

[16] 'The US Navy Today', *Air International*, August 1999, p. 103.
[17] Paris Report, *Air Pictorial*, August 1999, p. 456.
[18] Harding, S., *US Army Aircraft Since 1947*, Airlife Pub Ltd, Shrewsbury UK, 1990, pp. 21–23.

North Korean radars, monitor the shaky truce and provide early warning of any North Korean attack.[19]

Today, the US Army operates a fleet of 50 Guardrails. The National Security Agency has another 12, operating in Central America. The Israelis operate a fleet of nine Guardrails. A replacement for the Guardrail is to be acquired over the period 2000–2006, under the US$2 billion Aerial Common Sensor project.[20]

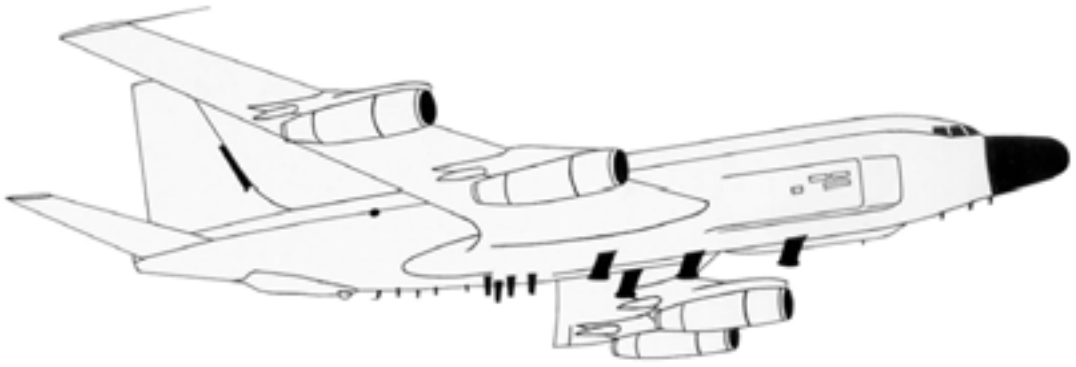
In the early 1990s, the US army developed the RC-7 Airborne Reconnaissance Low — Multi Purpose (ARL-M) aircraft. The ARL-M is a SIGINT/imagery intelligence system, based on the De Haviland Canada Dash 7 turboprop commuter airliner. The US Army is in the process of acquiring 18 RC-7s to replace a fleet of smaller aircraft with colourful code names such as Grisly Hunter and Crazy Panther.[21]

RC-7s have been deployed to regional 'hot spots' in Korea, Haiti and Bosnia. Eight RC-7s have been deployed to Central America and South America to assist in the 'War on Drugs'. As recently as July 1999, an RC-7 was lost in Colombia.[22]

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 long range EW role (see Figure 2.4).[23]

Since entering service in the 1960s, RC-135s have mapped the location and capabilities 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. The data is also used to develop 'threat libraries' for ESM systems.



[19] Harding, *US Army Aircraft Since 1947,* pp. 24–26.
[20] *Air International*, April 1999, p. 198.
[21] Kaminski, T., 'US Army Airborne Reconnaissance', *Combat Aircraft*, AIRtime Publishing, Narwalk CT, USA, pp. 52–55.
[22] Air News, *Air Pictorial*, September 1999, p. 515.
[23] Fulghum, D., 'Electronic Intelligence', *Aviation Week & Space Technology*, 5 May 1997, pp. 48–50.

Figure 2.4: RC-135 Rivet Joint

The USN operates a fleet of 12 EP-3 Aries SIGINT aircraft, based on the smaller Lockheed Orion airframe. The Orion is a four engine land-based ASW aircraft (see Figure 2.5). The EP-3 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, by specialising in naval targets including warships and coastal facilities.[24]

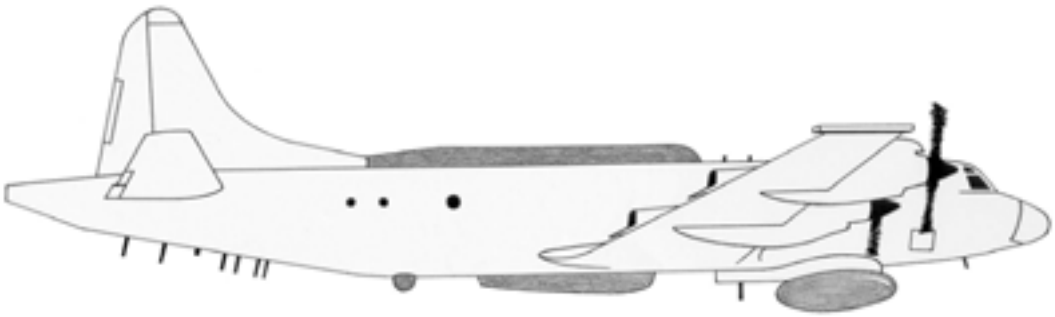


Figure 2.5: Lockheed EP-3 Aries

The USN also operated a carrier-based SIGINT aircraft. In the early 1990s, 16 S-3 Viking ASW aircraft were converted into SIGINT aircraft. The ES-3 Shadow Vikings performed well in Operation Desert Storm and a detachment of two ES-3s was deployed aboard each aircraft carrier throughout the 1990s. The ES-3s gave the fleet the flexibility of an organic SIGINT capability. The ES-3s were retired from service in mid 1999, as the cost of upgrading them to JASA standard was considered less cost-effective than simply acquiring new aircraft.

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.

AIR SURVEILLANCE

Modern American Air Surveillance

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. The increase in capability was due mainly to the significant increase in the processing power of digital computers.

USAF Sentry

[24] Fulghum, 'Electronic Intelligence', pp. 51–57.

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 (see Figure 2.6).

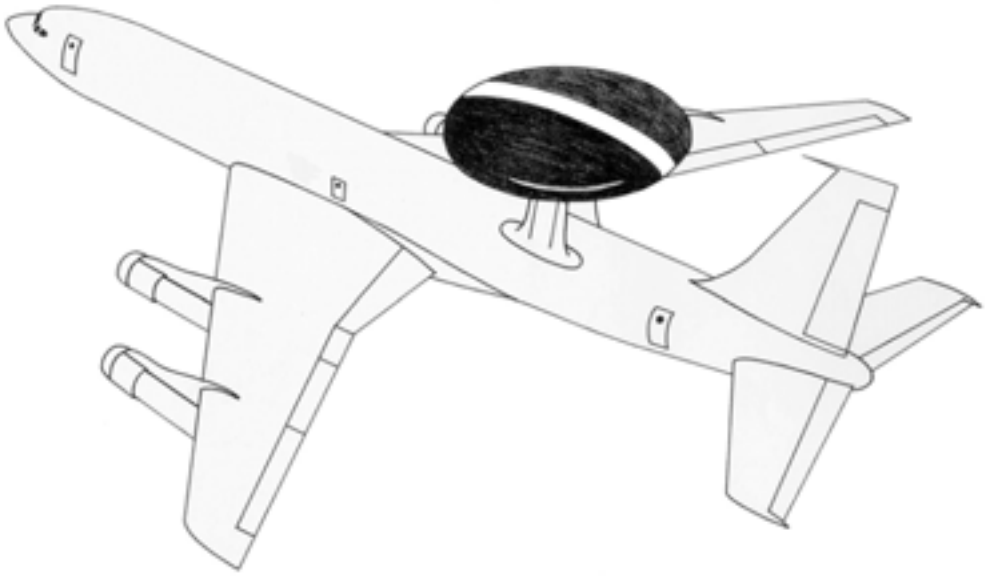


Figure 2.6: Boeing E-3 AWACS

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. A communications operator manages 19 radios, including two VHF, three HF and 14 UHF. There is also

a small team of technicians, consisting of a communications maintainer, a software specialist and a radar maintainer. More specialists can be carried, including an entire reserve crew.[25]

The AWACS has great endurance. In Operation Desert Storm, the average AWACS sortie was of 16 hours and 40 minutes duration.[26]

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.

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).[27] The AWACS is the most widely used large AEW&C aircraft in the world today. Production has totalled 66 aircraft.

USN Hawkeye

The USN planned to develop a new aircraft to replace its carrier-based support aircraft, including the E-2 Hawkeye AEW&C aircraft, the Lockheed S-3 Viking ASW aircraft and the ES-3 ELINT aircraft. The project was cancelled because of the excessive cost. Instead, the USN is developing improved versions of the E-2, the Hawkeye 2000 and 2005.[28] They will be externally similar to the basic Hawkeye.

The Hawkeye 2000 will have an improved mission computer with much greater processing power. In the Hawkeye 2005, 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.[29] The radar will be mounted in a circular radome.

An Infra-Red Search and Track (IRST) system can be fitted, for the detection, tracking and targeting of theatre ballistic missiles. This capability would complement the anti-ballistic missile capability of USN Aegis cruisers and destroyers.[30]

There will also be improvements to the EW systems, enabling better detection and identification of enemy radar emissions. The ESM system will have a wider frequency range and better emitter classification. There will also be a limited COMINT capability. The three multi function display consoles will be upgraded with enhancements to their colour displays.[31]
The communications suite will be integrated and upgraded, allowing the Hawkeye to participate in 'cooperative engagements'. In a cooperative engagement, one aircraft or

[25] O'Dell, R., 'Boeing E-3 Sentry Variants and Capabilities', *RAF Air Power Review*, Summer 1999, London, 1999, pp. 91-105.
[26] Waters, G., *Gulf Lesson One: The Value of Air Power,* RAAF Air Power Studies Centre, Canberra, 1992, p. 102.
[27] Simpson, R., 'Boeing E-3 Sentry', *Air Pictorial*, March 1987. p. 97.
[28] Wall, R., 'Enhanced E-2C', Aviation *Week &Space Technology*, 26 April 1999, p. 82.
[29] *Ibid*., p. 82.
[30] *Ibid*., p. 82.
[31] *Ibid*., p. 82.

ship may launch a weapon at a target that its sensors have not detected, because another aircraft or ship in the battle group has detected the target and can transfer the target track data to the 'shooter' by datalink. The shooter can then guide the weapon to an intercept. The Hawkeye is expected to remain in service until the year 2020.[32]

WHAT NEXT?

The Final Frontier

The US military plans to migrate the AWACS and JSTARS missions into space using space based radar (SBR).[33] There are several significant technical problems to overcome, but the solutions are just a matter of time and money.

The earth's atmosphere distorts the electromagnetic radiation that sensors emit and detect. Over short distances this atmospheric distortion is insignificant but over long ranges it can degrade sensor resolution to the point that the data is useless. The sensors mounted on satellites in orbit must penetrate hundreds of kilometres of atmosphere to scan the surface and the lower altitudes where aircraft can operate.

Using current technology, surveillance satellites need to be in low earth orbit (LEO), to get an undistorted, high resolution picture of a target area. A LEO satellite has a limited field of view and is in position to conduct surveillance of a given target area for only a few minutes at a time, a few times a day, as its orbit brings it over the target area. For most of the day it will be passing over areas of little or no interest. Current satellites are therefore inflexible. An enemy aware of surveillance satellite orbital timings can exploit their limitations by scheduling activities to occur when the satellites are not overhead.[34]

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.

A constellation of SBR satellites could give continuous global coverage and obviate the need for AEW&C aircraft deployments.[35] SBR could offer much quicker response times. Complex AEW&C aircraft take days to deploy to remote areas and require expensive support, but satellites can put a remote area under close scrutiny in a matter of minutes.

Small satellites orbiting at speeds of over 20,000 kph and altitudes of hundreds of kilometres are much more difficult to target and destroy than large, slow transport aircraft flying at speeds around 500 kph and altitudes of 20,000 or 30,000 feet.

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[32] Wall, 'Enhanced E-2C', p. 82.
[33] Moorman, T., 'The Explosion of Commercial Space and the Implications for National Security', *Airpower Journal*, Spring 1999, p. 19.
[34] Low Earth Orbit is defined as any orbit at an altitude of less than 1,000 kilometres.
[35] MacLean, M., 'The Militarisation of Space', *RAF Air Power Review*, London, Spring 1999, p. 23.

Furthermore, there are no geographic or political limitations on where satellites may overfly.

Mini AWACS and Mini JSTARS

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.

In its own national security interest, the US rarely exports fighter aircraft or missiles with the latest capabilities, preferring to release platforms fitted for older weapons (eg: Sparrow missiles, rather than the latest AMRAAM[36]) and 'second rate' or 'downrated' sensors and other systems. The policy maintains the US capability edge, without the need for constant reinvestment to develop greater capabilities and 'leap frog' ahead of allies who have just acquired the current state-of-the-art. The policy also generates economies of scale and revenue for the US aerospace industry.

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 proposed 'standard' AEW&C Hercules on offer appears to be less capable than the version proposed for Australia's Project Wedgetail.

SURVEILLANCE PROLIFERATION

British Surveillance: A Quart from a Pint Pot

The British aerospace industry has suffered the same financial problems as its international competitors. Modern aircraft and avionics are very expensive to develop. Development costs must be factored into unit production costs. When only a small number of aircraft are produced, the cost per aircraft is prohibitive. Sometimes the British have resorted to buying American aircraft such as the F-4 Phantom fighter-bomber and the C-130 Hercules transport, without having had any involvement in their development.

British AEW aircraft have been a mixed bag of indigenous and foreign aircraft. Britain can no longer afford to develop and field indigenous designs and is progressively resorting to joint ventures with other nations. Such joint ventures have included the Harrier (with the US), the Tornado (with Germany and Italy) the Future Large Aircraft (with France, Germany, Italy, Spain, Turkey and Belgium) and the Joint Strike Fighter (with the US).

[36] Braybrook, R., 'All Singing from the Same Hymn Sheet', *Air International*, May 2000, p. 309.

Royal Navy Air Surveillance. The RN currently operates a fleet of three small (20,000 ton) Invincible class aircraft carriers, which are limited to operating V/STOL aircraft, such as Harriers and helicopters. The only AEW&C aircraft that can operate from such small platforms is the AEW Sea King helicopter.

The RN plans to replace the V/STOL aircraft carriers with a pair of much larger (40,000 ton) CTOL aircraft carriers. At about the same time, the AEW Sea Kings will be replaced by a new aircraft. Possible platforms include the Anglo-Italian EH-101 Merlin helicopter, the American V-22 Osprey V/STOL aircraft and a range of as yet unspecified UAVs.[37]

Royal Air Force Air Surveillance. The story of indigenous British land-based AEW did not end with the Nimrod fiasco. Since the cancellation of the AEW Nimrod in 1986, BAe have tried to recycle the GEC radar and avionics package on a wide variety of 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 has entered service with any nation. The RAF will continue to rely on the Boeing AWACS.

Royal Air Force Surface Surveillance. The British are currently developing an airborne surface surveillance radar system, designated Airborne Stand-Off Radar (Astor). The ASTOR will carry a dual mode (MTI/SAR) Raytheon radar in a long canoe-shaped radome under the forward fuselage, in the same manner as JSTARS. The platform is the Bombadier Global Express twin-engine, long range business jet (see Figure 2.7).[38] 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.[39]

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. Astor will rely on datalinking to ground stations, where much of the data processing and command and control of functions will be performed.[40] ASTOR will be able to provide real-time targeting information to strike aircraft via datalink (Link 16).[41]

The RAF plans to acquire at least five Astor aircraft. There is already another potential customer. NATO has a requirement for up to 12 such aircraft.[42] ASTOR may become the benchmark affordable 'mini-JSTARS' for second order powers.

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[37] Hoyle, C., 'High Flying Assets', *Jane's Defence Weekly*, 21 July 1999, p. 27.
[38] *Ibid*., p. 27. Note: The Global Express is a derivative of the Canadair CL-600.
[39] 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.
[40] Pocock, C., 'ASTOR', *RAF Yearbook 1999*, RAF Benevolent Fund Enterprises, UK, 1999, pp. 56–58.
[41] 'Airscene', *Air International*, June 1999, p. 323.
[42] Morrocco, J., 'UK's Astor Eyed as NATO Springboard', *AW&ST*, 8 March 1999, pp. 33–34.

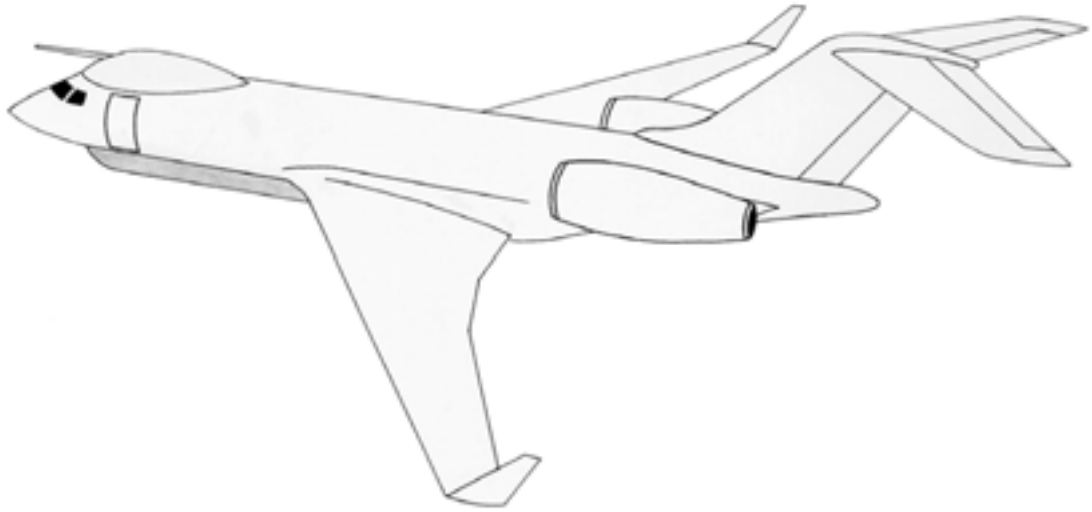

Figure 2.7: ASTOR mounted on a Bombadier Global Express

Russian Surveillance: Remnants of Empire

Russian Air Force. The Russian Air Force inherited the 16 surviving Beriev A-50 Mainstay AEW&C aircraft from the Soviet Air Force. These continue in operation as the only Russian land-based AEW&C aircraft. There is no evidence of a replacement aircraft being developed.

Russian Navy. 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.[43]

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 Navy's aircraft carrier 'Kuznetsov'.[44]

Chinese Surveillance: Playing Catch-Up

Taiwan's acquisition of four Hawkeyes in 1995 appears to have sparked an AEW 'arms race' reaction from China.[45] The Chinese clearly perceive themselves to be at a disadvantage against the air forces of Taiwan, Russia and the United States and believe that AEW&C is an essential part of their force modernisation program.

[43] *Jane's Aircraft 1998/99*, p. 363.
[44] Lake, J., 'The Hawkeye Abroad', *Air International*, December 1997, p. 347.
[45] Stokes, M., *China's Strategic Modernisation*, US Army War College, 1999, p.32.

Chinese Air Force. The Chinese Air Force recently acquired a Russian A-50 Mainstay aircraft, which was fitted with Israeli AEW&C radars and mission systems.[46] The plan was to fit Israeli AEW&C systems to five A-50s, at a cost of $250 million per copy. Intense pressure from the Americans forced the Israelis to cancel the deal in July 2000.[47]

Chinese Navy. In the late 1990s, the Chinese Navy acquired a small number of Racal Skymaster radars. The Skymaster is a derivative of the Searchwater radar fitted to the Royal Navy's AEW Sea King helicopters. The Chinese have installed the Skymaster radars in the noses of a few Shaanxi Y-8 transport aircraft. The Y-8 is a four engine turboprop similar to the American C-130 Hercules. The AEW Y-8s are believed to be in service.[48]

The Chinese are also believed to be developing a rotary-wing AEW aircraft, based on a license built Super Frelon (French) heavy lift helicopter. 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 soon and may be intended to operate off the projected Chinese aircraft carrier.[49]

In response to Communist modernisation efforts, the Taiwanese have ordered two state-of-the-art Hawkeye 2000s. Their new acquisitions will be fitted with the latest APS-145 air surveillance radar and more powerful systems. The four Hawkeyes currently in Taiwanese service are fitted with the old APS-138 radars.[50]

Indian Surveillance: Non-Aligned AEW&C

The Indians view AEW&C as a vital force multiplier for their air defence interceptor force. In keeping with the Indian version of defence self-reliance, they have been developing an indigenous Airborne Surveillance Platform (ASP) for several years.

Hindustan Aeronautics Limited built an ASP testbed, consisting of an indigenous radar and mission system on a Hawker Siddeley HS 748 turboprop platform. The development program was interrupted by the loss of the testbed. During a test flight in 1998 the rotodome fell off the aircraft, which then crashed.

In November 1999, the Indians announced that two or three Beriev A-50 Mainstays would be leased from Russia. The first aircraft began a period of evaluation at an Indian Air Force base in April 2000.[51]

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[46] Young, P.L., 'Asian Aviation Programs', *Armed Forces Journal International*, February 2000, p. 59.
[47] 'Headline News', *Air Forces Monthly*, September 2000, p. 4.
[48] *Ibid*., p. 14.
[49] *Jane's Aircraft 1998/99*, pp. 57–58.
[50] 'Airscene', *Air International*, September 1999, p. 134.
[51] Reade, D., 'US Customs Service P-3 Air Force', *Air International*, May 2000, p. 261.

French Surveillance: Buy American

Like the British, the French have struggled to maintain an indigenous aerospace industry. The French have persevered in their support for indigenous designs, but the financial penalty of spreading expensive research costs over small production runs has made the French aircraft very expensive.

French Air Force. The French Air Force was the first service to abandon the local industry. They acquired four Boeing E-3 AWACS in 1990 (see Figure 2.8).

The French Air Force AWACS are different to the standard USAF model. Whereas USAF AWACS are fitted with receptacles for refuelling from boom tankers, the French AWACS are fitted with refuelling probes for refuelling from hose tankers. The French also have different communications suites in their AWACS.

Figure 2.8: French Air Force Boeing E-3 AWACS

French Navy. The AEW Alizes have operated off the French Navy's aircraft carriers 'Foch' and 'Clemenceau' since the early 1980s. By modern standards the AEW capability of the Alize is marginal. The Alizes are being replaced by the vastly more capable American Hawkeye. The first of four on order was delivered in 1998. The French Hawkeyes will operate off the new aircraft carrier 'Charles De Gaulle'.

The French Navy has thus followed the lead of the French Air Force and bought American. The Army is the only French service persevering with surveillance aircraft of indigenous design.

French Army. The Orchid radar/Puma helicopter combination that was under development during the Cold War has evolved into the Horizon battlefield surveillance system mounted on the Aerospatiale Cougar helicopter, a derivative of the Puma. The radar is a large slab, mounted on a swing arm. It folds up under the tail of the helicopter for landing and folds down under the fuselage in flight. There is no radome (see Figure 2.9).

The prototype of the Horizon system was successfully tested in Operation Desert Storm. The first operational Horizon/Cougar helicopter was delivered to the French Army in 1994. The data collected by the airborne part of the system is transmitted by datalink to a ground station. The ground station processes the information and disseminates it to users. The French Army now operates four Horizon/Cougar helicopters and two ground stations.[52]

Figure 2.9: Aerospatiale Cougar/Horizon

Japanese Surveillance: Spare No Expense

For nearly two decades, the Japanese have operated the largest AEW&C force outside the United States, a fleet of 13 Hawkeyes. The Japanese have not operated aircraft carriers since 1945, so their AEW&C fleet has always been land-based. They could have simply upgraded their Hawkeyes to the new Hawkeye 2000 standard, but instead the Japanese decided to move to a larger aircraft.

The Japanese are acquiring at least four AEW&C Boeing 767 aircraft, which is the largest and most expensive AEW&C aircraft ever built. The radar and mission equipment fitted to the 767 will be basically similar to that on the current USAF E-3 AWACS, hence the Japanese aircraft is often called a 767 AWACS.[53]

In their 767 AWACS program, the Japanese have continued their post war habit of acquiring the latest American systems. Aegis destroyers are being built for the Japanese Navy and the Japanese operate many American aircraft types (F-4 Phantom, F-15 Eagle, P-3 Orion, CH-47 Chinook, UH-60 Blackhawk, etc). It remains to be seen

[52] Pocock, C., 'The Eyes Have It', *Air International*, April 1997, p. 228.
[53] *Jane's Aircraft 1999/2000*, p. 583.

whether the Japanese will improve the capability of their AWACS with indigenous electronics, as they did their version of the F-16 fighter.

Israeli Surveillance: Kosher AEW&C

The Hawkeyes that Israel acquired in 1978 are no longer in service. They are in storage awaiting disposal.[54] The Israelis operate in a land environment and found that ground clutter degraded the radar's performance. They now operate AEW airships similar to those used by the Americans along the Mexican border.

The Israeli-developed Phalcon system 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 each side of the fuselage, extending from the nose to the wing leading edge and a large bulbous radome in the nose (see Figure 2.10). An advantage of conformal radar is that it avoids the aerodynamic drag and weight penalties associated with large protruding antennas. The radar does not rotate mechanically — it points its beam electronically. The coverage provided is through an arc of about 240 degrees.[55]

The roles of the Phalcon 707 include AEW&C and SIGINT. Inside the cabin are 13 operator consoles. There are many blade antennae protruding from the aircraft's belly.

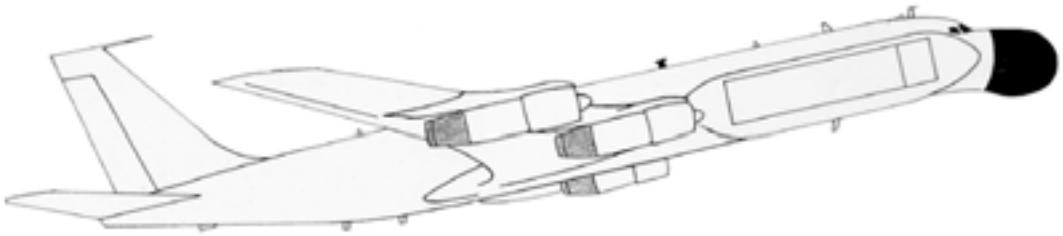

Figure 2.10: Israeli PHALCON 707

The Phalcon employs a relatively new concept in AEW&C. A traditional AEW&C aircraft carries a mechanically rotating radar, to give 360 degree coverage. The Phalcon has a fixed electronically scanning array (ESA), which has only 240 degree coverage. The aircraft must physically turn to point the radar elsewhere.

Those who prefer the fixed array 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 longer than a 240 degree scan, so the interval between illuminations of a target is shorter with the fixed system. The Hawkeye's mechanically scanning radar rotates every 10 seconds, while the Phalcon's ESA usually scans a given point every five seconds, but the rate can be varied. The Israelis argue that the extra few

[54] 'Headline News', *Air Forces Monthly*, September 2000, p. 12.
[55] Chamish, B., 'Phalcon: Israel's AWACS', *Air International,* April 1994 p. 218.

seconds could be crucial in 'close quarters' engagements with supersonic aircraft and missiles.[56]

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 240 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 few seconds difference in revisit rates will not often be significant.

The Israelis sold the one and only Phalcon AEW B707 to Chile in 1995. There have been no further sales. Chile and Brazil are the only nations in South America with operational AEW&C aircraft. The Israelis do not operate a Phalcon of their own. It appears to have been a product for export only.

Scandinavian Surveillance: Smaller, Cheaper, Less is More

In the early 1990s, the Ericsson company developed the PS-890 ERIEYE air surveillance radar system for the Swedish Air Force. The radar consists of two fixed, back-to-back, electronically scanning radars, in an eight metre long bar, mounted above the spine of the aircraft (see Figure 2.11). The radar alone weighs 1,300 kilograms and each array scans a 120 degree arc. The system therefore covers only 240 degrees.[57]

The platform can be any twin engine business jet. The mission crew consists of at least three (a Tactical Coordinator, an EW operator and an intercept operator) but up to five mission crew can be carried.[58]

The Swedish Air Force requirement was originally conceived as a 'gap filler'. Sweden is a small, compact country with a totally defensive posture and an extensive Integrated Air Defence System (IADS), based on a network of land-based radars. The AEW aircraft were to be launched to cover any 'holes' in the system caused by enemy attacks on radar sites. The Swedes have since realised the benefits of the greater detection range and flexibility of airborne radar as opposed to surface based radar. AEW is coming to be seen as a useful complement to surface radar.[59]

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. The ground station does all data processing and fighter controlling. This version is just an AEW platform and it suited the Swedish requirement for a substitute radar to cover gaps in the national Air Defence Ground Environment (ADGE).[60] In the Air Surveillance/Airborne Control (ASAC) version, the aircraft performs the full

[56] *Ibid*., p. 218.
[57] Nicholls, M., 'Embraer's New Stars', *Air Forces Monthly*, July 1999, p. 48.
[58] *Ibid*., p. 49.
[59] Interview with Colonel Anders Silwer, Royal Swedish Air Force, 23 September 1999.
[60] *Jane's Radar & EW Systems 1996/97*, Jane's Information Group, Couldson UK, pp. 231–232.

AEW&C role, acting as a flying Control and Reporting Unit (CRU). This version suits foreign customers looking for a more autonomous system.[61]

Figure 2.11: Swedish Air Force Saab 340

The ERIEYE system has been purchased by three air forces. It has been fitted to six Swedish Air Force Saab 340 aircraft, five Brazilian Air Force Embraer EMB-145 aircraft (see Figure 28) and four Greek Air Force Embraer EMB-145 aircraft.[62] The Brazilians and Greeks have opted for the ASAC version.[63] Another prospective customer is Mexico. In mid 2000 the Mexicans were said to be negotiating for the acquisition of four Embraer EMB-145 aircraft, with an option for up to four more.

The Swedish version (nicknamed the Argus) is fitted with a unique Swedish datalink system which is not compatible with US/NATO Link 16. As a neutral country, Sweden saw no need for interoperability with any other nation or alliance. The unique datalink has also been fitted to many Swedish naval and air combat platforms.[64]

The most interesting aspect of this development is that an 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 onto a relatively small platform. The adoption of commercial off the shelf

[61] *Ibid.*, pp. 231–232.
[62] Browne & Thurbon, *Electronic Warfare,* pp. 151–152.
[63] Nicholls, 'Embraer's New Stars', p. 48.
[64] Interview with Colonel Anders Silwer, Swedish Air Force, 23 September 1999.

(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.[65]

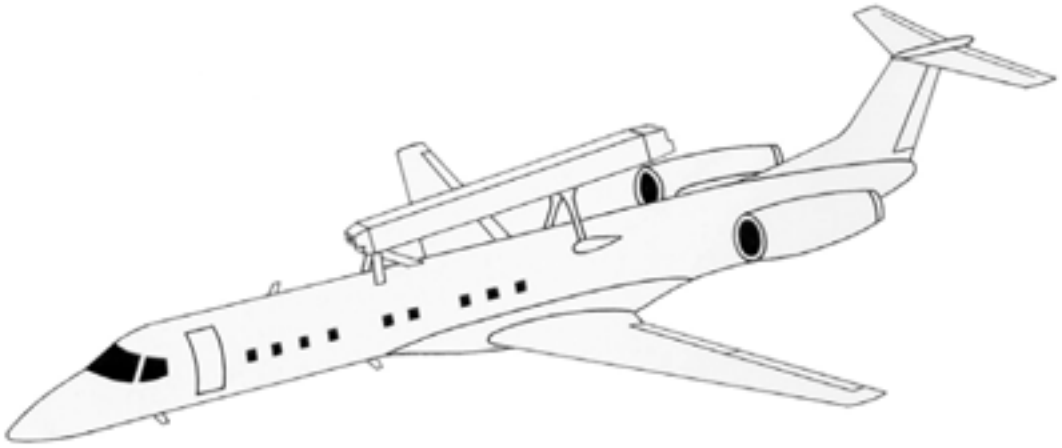

Figure 2.12: Brazilian Air Force EMB-145 AEW&C

Brazilian Surveillance: Policing the Amazon

Over the period January 2001 to May 2002, the Brazilian Air Force will acquire three examples of the surface surveillance version of the EMB-145, designated the EMB-145RS (Remote Sensing). The primary sensor fitted to the EMB-145RS will be a Synthetic Aperture Radar (SAR) mounted in a canoe-shaper radome under the forward fuselage, in the same manner as on the American JSTARS. There will also be a Forward Looking Infra-Red (FLIR) sensor, a combined UV/visible light/IR scanner and COMINT/ELINT suites.

The role of the Brazilian EMB-145RS fleet will be resource protection in the Amazon basin. The sensor suite is designed to detect illegal river traffic and unauthorised defoliation and construction activities in inaccessible rainforest areas.[66] Therefore, they are the first 'military standard' surface surveillance aircraft to be acquired for a purely civilian policing role. In the past, such aircraft have been acquired primarily for military purposes and used only occasionally to support civil police operations.

Spanish Surveillance: Guiding the Matador

The Spanish Navy operates a 17,000 ton light aircraft carrier (CVL). The CVL's air wing consists of eight Harriers (which the Spanish call Matadors), eight ASW helicopters and two AEW Sea Kings.[67] Spain has been the only export customer for the AEW Sea King

[65] Hewish, M., 'Lords of the Skies', *Jane's International Defense Review*, July 1999, p. 18.
[66] 'Embraer rolls-out its SIVAM aircraft', *Air International*, July 1999, p. 2.
[67] Kaplan, G., 'Maritime Air Power for Australia', *The Navy*, July 2000, p. 27.

THE AUSTRALIAN WAY

First Contact

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.[68]

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 CRU on the ground at Darwin, which then arranged a response. Detection was possible only while the target aircraft were over water. The APS-20 could not detect aircraft over land, nor could it determine the altitude of the targets.[69]

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 and planned by the US. However, the ADF is catching up, with many new surveillance capabilities entering service.

LAND-BASED RADAR: STATE-OF-THE-ART OTHR

Unlike conventional microwave radar, over-the-horizon-radar (OTHR) *can* see around corners. By bouncing its beams off the upper atmosphere, OTHR can detect targets over the horizon. The Americans and others experimented with OTHR in the 1970s. The Jindalee Operational Radar Network (JORN) is an OTHR system that has been under development in Australia for decades and is expected to be operational soon.

JORN will monitor activity out into the archipelagoes to the north of Australia. The operational sites will be in Western Australia and Queensland. The development site near Alice Springs will be retained for ongoing development work and will be

[68] Reminiscences and Log Book entries of WGCDR K. Brent, CSC, former 10 SQN Navigator, interview conducted on 8 June 1999.
[69] *Ibid.*

available as a back-up for the operational sites. The radar data from the JORN sites will be transmitted by datalink to a central point for fusion with data from other sources.

JORN will facilitate the generation of a 'recognised picture' of air and surface activity to the north, throughout the year. Once the normal patterns of activity are known, any unusual activity can be recognised and assessed to determine whether it is a threat. JORN will also provide early warning of the approach of specific aircraft and ships in the air sea gap.

OTHR is more dependent on environmental conditions than most radar systems. When atmospheric conditions are not supportive, OTHR detection capabilities are minimal. Even under ideal conditions, the information provided by JORN was never expected to 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 other projects underway that will provide a spectrum of air and surface surveillance capabilities to complement JORN.

AIRBORNE RADAR: STATE-OF-THE-ART AEW&C

The ADF plans to acquire six or seven AEW&C aircraft, with the first to be delivered in the year 2004. Under Project Air 5077 (Project Wedgetail), the AEW&C design offered by Boeing was selected (see Figure 2.13).

Wedgetail Platform

The Wedgetail platform combines the Boeing 737-700 fuselage with 737-800 wings (more fuel for greater endurance) and 737-800 undercarriage (greater strength for the heavier weight). The aircraft will be new build rather than 'second hand'.

The Wedgetail flight deck will be virtually identical to the standard airline configuration, except for a cockpit tactical display, which will give the pilots a level of situational awareness similar to that which Link 16 can give the crew of other platforms. The main cabin will be divided into three functional areas. A diagram of the Wedgetail's interior layout is at Annex E.

Just aft of the flight deck will be the surveillance and control operators' consoles. The Wedgetail will enter service with ten consoles, which are planned to be identical multi-function stations. However, one of the consoles may be dedicated to the highly specialised and complex ESM function.

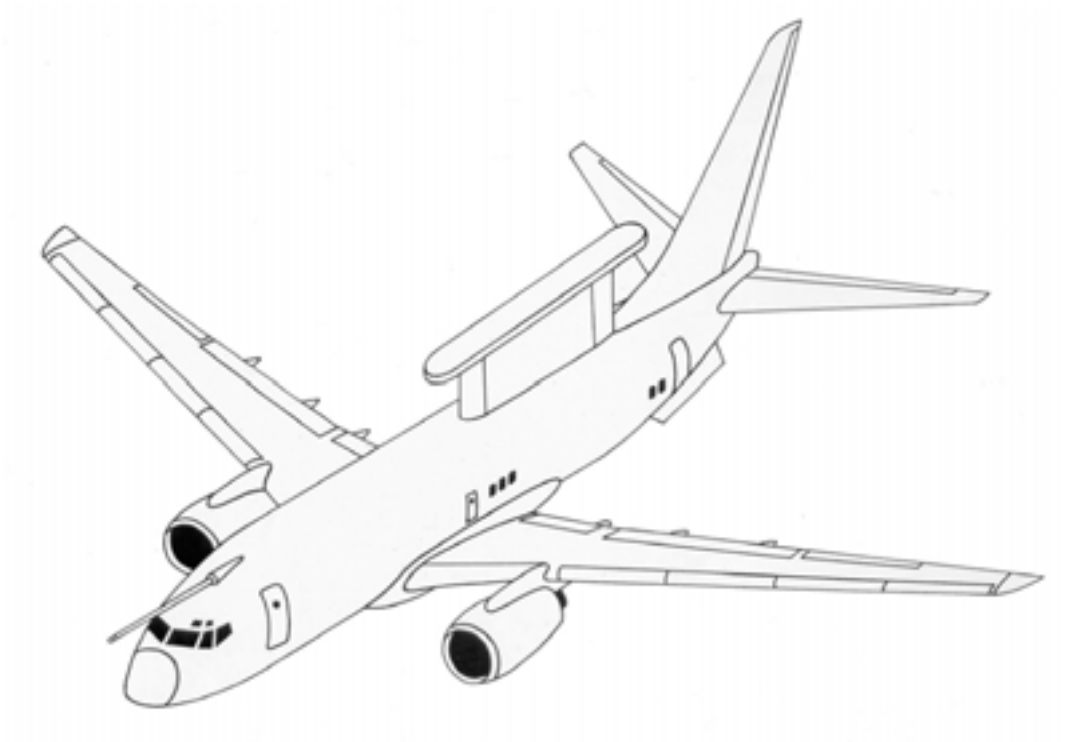

Figure 2.13: Australian Boeing 737 Wedgetail

At the middle of the fuselage will be the crew rest area and the avionics racks and computers associated with the mission sensors. The Wedgetail will have far more computer 'power' than any other RAAF aircraft. The crew rest area will include a small galley with refrigerator and oven, a toilet and lounge chairs. Such 'luxuries' will be essential on long missions and are usually fitted to long range/endurance platforms such as maritime patrol, transport and AEW aircraft.

At the rear of the fuselage will be an open area. The Wedgetails will be based at RAAF Williamtown (near Newcastle) but will often deploy away for extended periods. Rather than rely on scarce airlift resources, the Wedgetails will 'self-deploy'. The rear cargo area will provide space for the required spares and maintenance equipment to support the aircraft on deployment.

Wedgetail's Active Sensors: Radar and IFF

Primary Sensor. The Wedgetail's primary sensor consists of two fixed back-to-back Multi-role Electronically Scanned Arrays (MESA), in a bar-shaped radome along the aircraft's back. Each of these gives 120 degree coverage. Small curved arrays at each end of the bar complete the 360 coverage. The Northrop Grumman radar operates in the upper UHF band and above, as do many AEW radars.[70]

The radar is primarily an air search radar but it will have some surface search capability, over water. It will be virtually useless for tracking targets on land, as it will lack the specialised (JSTARS style) software. The performance of the Wedgetail's

[70] Bostock, I., 'Australia Opts for Boeing AEW&C', *Jane's Defence Weekly*, 28 July 1999, p.4.

radar is classified, but it will have a capability similar to the latest Hawkeye radar, the publicly stated capabilities of which are as summarised at Table 2.1.[71]

Target Type	Detection Range (in nautical miles)
Fighter aircraft (fast/high)	200 +
Fishing boat (very slow/on surface)	120 +
Cruise missile (slow/low)	75 +

Table 2.1: Indicative Hawkeye Radar Detection Ranges

Helicopters will be detectable at ranges of up to 200 kilometres. However, helicopters that fly low and at slow speed amongst trees and valleys may be harder to detect.

Secondary Sensor. The Wedgetail's secondary sensor is Identification Friend or Foe (IFF). All military aircraft and commercial aircraft (airliners) have IFF systems but most small general aviation aircraft (private light aircraft) do not. IFF is an active system that transmits an identification code and interrogates the IFF systems of other aircraft. There are four modes of IFF. Modes 1, 2 and 3 are for civilian use and Mode 4 is an encripted military mode.

An IFF system can determine whether a particular aircraft is civilian or military and whether it is friendly or hostile. However, the civilian IFF modes are not foolproof. An enemy combat aircraft could pretend to be an airliner by transmitting a civilian code. While transmitting the correct Mode 4 code is a reliable means of identifying friendly military aircraft, failure to transmit the correct Mode 4 code does not necessarily prove that an aircraft is hostile. The IFF may be malfunctioning or just turned off.

In a hostile environment, if all ADF and other friendly military aircraft use their IFF (Mode 4) systems, the Wedgetail controlling the operation can ensure that friendly forces do not attack each other. There should be no fratricide.

Wedgetail's Passive Sensors: ESM

The Wedgetail will be fitted with the ALR-2001 Electronic Support Measures (ESM) system, similar to the system fitted to the RAAF AP-3 Orions. The ALR-2001 is a passive system that detects all radar emissions, out to a range greater than the primary radar. ESM is a means of detecting all the emitting platforms in a huge volume of airspace and over a wide surface area, without those platforms being aware of the ESM platform's presence.

An important peacetime activity for the military aircraft of all nations is the collection of ELINT data on emitters in the region. The data is fused with intelligence from other sources to compile a 'threat library'. By comparing a detected emission with the library of known radar 'signatures', an ESM operator can identify the emitter.

[71] Braybrook, R., 'Enhancing Hawkeye', *Air Pictorial*, July 1999, p. 406, also *Jane's Defence Weekly*, 21 July 1999, p. 23.

Intelligence data will usually permit an ESM operator to identify the specific platform type, such as an F-16 fighter or an ANZAC class frigate. The nationality of the platform can be deduced from knowledge of the regional order of battle.

Wedgetail's Defensive Systems

The Wedgetail will have a limited self defence capability, in the form of Electronic Warfare Self Protection (EWSP). The EWSP system can be set to automatically respond when sensors detect an imminent threat or it can be set to merely warn the operator of threats and be operated manually.

A major threat to the Wedgetail will come from small shoulder-fired SAMs which may be fired at the aircraft when it is flying close to the ground (during take-off and landing) or on the ground, while it is taxiing. Such missiles are usually heat seeking and their infra-red (IR) guidance systems can be deceived by flares.

The Wedgetails will also be fitted with a new type of active defensive system. The Direct Infra Red Counter Measures (DIRCM) system will detect the hot exhaust plume of the incoming missile and fire a laser beam at the missile. The laser beam will overstimulate the missile's IR guidance system and the missile should wander out of control and miss the Wedgetail.

A less likely threat will be from radar-guided SAMs and AAMs. Radar-guided missiles can be deceived by chaff plumes or electromagnetic emissions (jamming). The Wedgetails will be fitted with chaff dispensers. There are no plans to fit electronic jammers to the Wedgetails.

Wedgetail's Communications

The Wedgetail will have an extensive communications suite to enable the crew to communicate with most ADF headquarters, ships and aircraft and to enable the aircraft to act as a communications and data relay station. The Wedgetail must also be capable of communicating with a wide range of foreign forces, including the US military and the militaries of regional neighbours, such as New Zealand, ASEAN nations and other regional neighbours beyond ASEAN. In UN operations, the Wedgetail may have to deal with air force, navy and army units from all over the world.

This wide variety of likely and potential 'customers' uses a bewildering array of communications systems. The systems are often incompatible so the Wedgetail communications suite will need more communications systems than any other ADF platform. In coalition or UN operations, the Wedgetails may act as translators, shuffling data between platforms which otherwise could not communicate with each other and would be unable to even participate in an operation. The Wedgetail's communications suite will include all the commonly used datalinks, voice radios, satellite communications and tactical intelligence systems.

Datalink

Datalink transfers large volumes of data quickly and can transmit complex tactical pictures, such as the Recognised Air Picture. A limitation of datalink is that it can only transmit along direct 'line-of-site', which is rarely more than 300 kilometres. The Wedgetails will be fitted with the two standard NATO datalink systems (Link 11 and Link 16). Link 11 gives interoperability with most navies. Link 16 (JTIDS) is the preferred datalink of the future for air forces and navies. Some aircraft currently in service are fitted with old Link 4 system, which is capable of much lower data transmission rates than the new systems. By the time that the Wedgetails enter service, most modern military aircraft will use Link 16.

Link 16 will be compatible with RAAF Hornets and F-111s and leading American aircraft, such as the E-3 AWACS, the E-8 JSTARS, the F-15 fighter, the F-22 stealth fighter and the Joint Strike Fighter. The RAN's Adelaide and ANZAC class frigates, the Collins class submarines, and the Huon class mine warfare vessels may also be fitted with Link 16. The Army's Rapier SAM replacement may also be Link 16 capable.

Most NATO nations now see Link 16 as essential for most platforms. Even humble transport aircraft and utility helicopters are being fitted with Link 16. The German and Italian armies intend to fit Link 16 to the hundreds of new NH90 tactical transport helicopters that will enter service over the next decade.[72]

Data Forwarding

When an aircraft is fitted with Link 16 and must coordinate its activities with a warship that is fitted with Link 11, they cannot exchange data and are limited to the far slower and less precise alternative of voice radio communications. Such communications were adequate in the age of propeller aircraft, but are hopelessly inadequate in the jet age.

The Wedgetail will be able to facilitate effective communication between otherwise incompatible platforms by receiving, reformatting and retransmitting the data. The interpreter service will be fast enough to be useful in fast moving air combat situations.

Satellite Communications

Satellites have revolutionised long range communications and we have come to take it for granted that we can have instant communications with anyone on the planet, for a price. Unlike the US military, the ADF does not own any communications satellites. For communications within Australia, the ADF rents space on commercial satellites, such as the Telstra system, which has coverage over the continent. For communications outside Australia, the ADF has arranged access foreign commercial systems and the American military satellite communications (MILSATCOM) system.

Access to global commercial systems is cash-driven and Australia is a small customer. In a future offshore operation the ADF might not be able to buy adequate satellite communications, as the available capacity may be contracted to other

[72] 'Aviation News', *Air Forces Monthly*, August 2000, p. 18.

customers or may be temporarily dedicated to some other major world event, such as the Olympics. Access to the US MILSATCOM system is not guaranteed. In wartime, the US might be forced to keep all its communications capability for use by its own forces. There are plans for an ADF satellite, but funding and in-service date are unsure. The ADF may not have its own MILSATCOM system for many years.

The Wedgetail will have a 'state-of-the-art' satellite communications suite and will be able to exploit any available satellite systems that are available. In situations where satellite communications are not available, the Wedgetail can act as a high flying relay station and link widely scattered surface units and low flying aircraft in a secure and effective manner.

Tactical Intelligence Systems

A significant benefit of membership in the American-led Western community is free access to much of the tactical intelligence data gathered by the huge American intelligence organisation. Australia could not afford to replicate even a fraction of the American capability.

The 'offboard intelligence inputs' available from the Americans will often add greatly to our overall situational awareness and certainty levels. The Wedgetails will be fitted with the equipment necessary to tap into several American tactical intelligence systems. The data derived can then be added to the Wedgetail's 'picture'.

Voice Radio

One of the simplest but most important roles of an AEW platform is providing voice communications to and between 'customers'. Each Wedgetail will be fitted with many radios. Most will be used for the purposes of air traffic control, tactical control of aircraft, coordination and command and control. A few will be dedicated to datalink. Each Wedgetail will be fitted with three HF radios, four UHF radios and ten VHF/UHF radios.

Communications Relay

When two platforms are out of radio range of each other or lack the equipment to talk to each other a third party can act as a relay station. Communications relay can be performed by satellite, but Australian access to American MILSATCOM is not guaranteed in wartime. The Wedgetail will have the capability to relay computer data and communications automatically.

Wedgetail's Tasks

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 broader early warning and battle management functions.

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 a friendly 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 have to rely totally on the anti-air warfare ships for protection.

Force Coordination

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' 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.

International Interest in Wedgetail

The defence force hierarchies and political leaderships of many small nations take note of ADF equipment choices and appear to consider Australian selection of a weapon system to be a good recommendation. Several nations considering an AEW&C purchase early in the next decade can be expected to show interest in the Wedgetail.

The cost of developing complex new AEW&C system and getting it fully operational is so high that few small nations are willing to take the technical/financial risk. The fact that the Wedgetail will be in production early in the next decade and in RAAF service for several decades, reduces the technical risk and financial exposure to other buyers.

The US military/industrial complex has been the 'Arsenal of Democracy' for over 60 years. American designed and built weapon systems are the preferred choice of most nations. The Wedgetail will mount a Northrop radar on a standard Boeing airliner and will therefore be seen as a mostly American product. This will add further to its attractiveness to foreign customers.

American Interest in Wedgetail

There are indications that even the Americans are interested in the Wedgetail. The Pentagon's ultimate aim of migrating the AWACS and JSTARS missions into space will be a long term program. The AWACS/JSTARS platform, the Boeing 707, is out of production and the cost of supporting such an old platform can only increase. In the medium term, the USAF may need an AWACS/JSTARS replacement aircraft.

The USAF has an ambitious modernisation program and will be lucky to get adequate budget allocations for its F-22 Raptor air superiority fighter and the Joint Strike Fighter. The Americans cannot afford to develop a new AEW&C aircraft and may elect to acquire an existing type, as they acquired the Canberra bomber and the Harrier attack aircraft from the British. The best existing options will be the Japanese Boeing 767 AWACS and the Australian Boeing 737 Wedgetail. The Australian option will be affordable in larger numbers.

The USAF AWACS and JSTARS fleets are in constant demand for operations all over the world. There are not enough aircraft to meet the demand and not every scenario requires the full AWACS/JSTARS capability. The USAF may consider acquiring a small fleet of small, relatively cheap AEW&C aircraft to supplement the large, relatively expensive 707-based fleet. Again, the Australian Boeing 737 Wedgetail will be the most cost-effective existing option.

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. About 280 AEW&C aircraft will be operational around the world. Annex C lists the types in service, by nation of origin.

At least 21 nations will be operating AEW&C aircraft by 2005. 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, Mexico, Saudi Arabia, Singapore, South Africa, Spain, Sweden and Taiwan. Annex D summarises the national AEW&C fleets.

At least 12 other nations are believed to be considering the acquisition of AEW&C aircraft in the next decade. These nations include Bahrain, India, Indonesia, Italy, Kuwait, Malaysia, Oman, Pakistan, South Korea, Thailand, Turkey and United Arab Emirates.[73] By 2010 as many as 33 nations may be operating AEW&C aircraft.

Future Directions

A small twin-engine business jet, such as an Embraer EMB-145 fitted with ERIEYE, can provide modest air surveillance (AWACS) capability. Another small twin-engine business jet, such as a Gulfstream V fitted with Astor, can provide a modest surface surveillance (JSTARS) capability. Therefore, it might be possible for a medium size aircraft, such as a Boeing 737 or an Airbus 320, to perform both missions — an AWACS/JSTARS.

New technology has solved 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 vehicle for surveillance of *all* things moving on or above the earth's surface.

A 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. Perhaps an AWACS/JSTARS will just need to be big enough to carry separate air and surface surveillance teams.

[73] Sengupta, P., 'The Efficacy of AEW&C Systems', *Asian Defence Journal 6/99*, pp. 34–35 Hewish, p. 19.

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 surveillance, SAR, fisheries and EEZ protection, coastwatch, law enforcement activities (such as interdiction of smugglers and illegal immigrants) and peacekeeping.

Horses for Courses

Over the last 55 years the range of AEW&C platforms has been diverse, both in size and shape. The marginally effective, hasty 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 from the deck of an aircraft carrier. The fixed-wing Hawkeye and the rotary-wing AEW Sea King 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 jet Boeing 707 are popular.

Prior to the 1990s, the fixed-wing AEW&C market was dominated by the Americans. The choice was limited to the large, expensive AWACS and the small, more economical Hawkeye. Today, a wide range of large, medium size and small AEW&C aircraft are available from several American and European suppliers. The large AEW&C are still based on the Boeing 707 airframe and, more recently, the Boeing 767. The medium size AEW&C are based on airframes such as the twin jet Boeing 737 and the propeller driven four-engine Lockheed C-130 Hercules and P-3 Orion. The small AEW&C are based on business jet airframes such as the Gulfstream V and the Embraer EMB-145.

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 — simply because they can afford it.

Dozens of 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 among middle order and minor powers. AEW&C is widely accepted as an essential capability for conducting warfare in the information age.

Albert Einstein could have been talking about the future of AEW&C when he said: 'Imagination is more important than knowledge, for while knowledge points to all there is, imagination points to all that will be.' The processing power of modern computers gives the AEW&C customer unprecedented knowledge of the battlespace. The only limit on what AEW&C can do may be the imagination of users as to how they use the knowledge and the organisational structures they adopt.

CHAPTER THREE

THE IMPACT OF AEW&C ON RECENT OPERATIONS

The secret of war lies in the communications.
Sun Tzu[1]

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 OPERATIONS

In the late 1970s, the Israelis acquired four E-2 Hawkeyes to monitor Arab airspace and control Israeli air operations.[2] Israel is a tiny nation, surrounded by enemies, and Israeli air bases are 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.[3] Unfortunately, in overland operations, the effectiveness of the systems on the Israelis' early model Hawkeyes was somewhat degraded by the mass of surface traffic, hills and other ground clutter.

The Israelis have usually been outnumbered, have a very low tolerance for casualties and cannot afford to lose many aircraft. They are understandably secretive about their combat operations, but the Hawkeyes are generally believed to have been instrumental in most of Israel's 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 was nearly complete in June 1981.[4]

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 SAMs and AAA fighters available. There was the further complication of the Iran-Iraq War and the Saudis had their AWACS aircraft on station in northern Saudi Arabia

[1] Clavell, J., *The Art of War*, Hodder & Stoughton, London, 1986, p. 62.
[2] Ripley, T., 'Israeli Air Power into the 1990s', *Air International*, September 1993, p. 131.
[3] Chamish, B., 'Phalcon – Israel's AWACS', *Air International*, April 1994, p. 218.
[4] Drew, D., 'Air Power in Peripheral Conflict', *The War in the Air: 1914–1994*, RAAF Air Power Studies Centre, 1994, pp. 249–251.

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 the Arabs.[5]

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 (RAP) 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.[6] 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 and escaped undetected. The Iraqis did not even know the identity of the attackers until the Israeli Prime Minister announced what the Israeli Air Force had done.

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.

The Iraqi Air Force no longer operates AEW&C aircraft. The Adnans were among the aircraft flown to 'safety' in Iran during the Gulf War. The Iranians never returned the aircraft, so Iran may now possess a limited AEW&C capability.

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 Palestine Liberation Organisation (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 counter

[5] Drew, 'Air Power in Peripheral Conflict', pp. 251–252.
[6] Ripley, 'Israeli Air Power into the 1990s', p. 131.

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 to give 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). The Israelis electronically disguised UAVs to appear as fighters on Syrian radar. As the decoys flew towards Syrian airspace, Israeli Hawkeyes orbited off the coast of Lebanon, out of harm's way. When Syrian air defence surveillance and fire control radars illuminated the decoys, the Hawkeyes used their ESM systems to detect, identify and locate the Syrian radars and then directed Israeli fighters in to destroy the radar sites with ARMs.[7]

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.[8] 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.[9]

Israel versus the PLO

In 1985 the IAF attacked the headquarters of the 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.[10]

AIR DEFENCE: OPERATION DESERT SHIELD

[7] Hirst, M., *Airborne Early Warning*, Osprey, London, 1983, p. 176.
[8] Anglim, S., 'Boyd Loops, Ace Factors and Fighter Combat', *RAF Air Power Review*, Summer 1999, p. 62.
[9] Lake, J., 'The Hawkeye Abroad', *Air International*, December 1997, p. 346.
[10] *Ibid*., p. 346.

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 (Operation Desert Shield). The first US forces sent 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.[11]

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 Component Commander, assured General Schwarzkopf, the overall Commander in Chief, that: 'Not one airplane will get through.'[12] 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 were 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 Wedgetails and about 70 Hornet fighters. Such a force should be able to defend Australia from any foreseeable regional air threat.

During Operation Desert Storm, Coalition AWACS aircraft maintained four continuous orbits and controlled about 3,000 Coalition sorties per day. A measure of the effectiveness of the AWACS support is the number of Coalition aircraft accidentally shot down by friendly aircraft or SAMs (fratricide). There were none.[13]

[11] Mann, E.C., *Thunder and Lightning: Desert Storm and the Airpower Debates*, Air University Press, Maxwell Alabama, 1995, pp. 130–131.
[12] *Ibid*., p. 131.
[13] Waters, G., *Gulf Lesson One: The Value of Air Power*, RAAF Air Power Studies Centre, Canberra, 1992, p. 102.

SUPPRESSION OF ENEMY AIR DEFENCES: OPERATION DESERT STORM

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).[14]

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-16 Wild Weasels in physical attacks with ARMs. USAF E-3 AWACS and EC-130E ABCCC coordinate all of the aircraft involved, while juggling responses to the dynamic airborne and surface-based threats. Navy E-2 Hawkeyes can supplement the AWACS. Above it all, satellites are performing more detection and location tasks and may ultimately replace AWACS with Space Based Radar.[15]

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 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: DRUGS, IMMIGRATION AND DISASTERS

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

[14] Brungess, J., *Setting the Context : SEAD and Joint War Fighting in an Uncertain World*, Air University Press, Maxwell AFB, Alabama, 1994, p. 104.
[15] *Ibid*., p.104.

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.[16]

AEW&C and the Coast Guard

The US Coast Guard has experimented with several types of AEW&C. These have included USAF AWACS, USN Hawkeyes, the one and only Lockheed AEW Hercules and radar-equipped tethered aerostats.[17]

In January 1987, the USN dedicated two Hawkeyes (with USN crews) to Coast Guard operations. Two more Hawkeyes (with USN crews) that had been supporting the US Customs Service were redirected to support Coast Guard operations in August 1989. The Hawkeyes, based first in Virginia and later in Florida, were used in drug interdiction operations in the Caribbean.

The AEW&C support was very effective, but the Coast Guard could not afford to operate such expensive platforms permanently. Since 1991, USN Hawkeyes and USAF AWACS squadrons have been rotated through the task of supporting joint operations in the Caribbean. These operations involve the Coast Guard, the Drug Enforcement Agency and other US Government agencies. AEW&C support is now considered essential for these operations.[18]

In November 1991, the Coast Guard began operating the one and only AEW Hercules (with a USAF crew). The AEW Hercules is a C-130H fitted with a Hawkeye APS-138 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 returned to the USAF in April 1993. It was too expensive for the Coast Guard.[19]

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 five AEW Orions. At least one more AEW Orion is to be acquired.

The first 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 rotodome above the rear fuselage, and a standard Hawkeye avionics suite, including IFF and passive EW.[20]

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[16] Lake, 'The Hawkeye Abroad', p. 345.
[17] *Ibid.*, p. 345.
[18] *Ibid*., p. 345.
[19] Reade, D., 'Frisbee Hercules', *Air International*, November 1993, pp. 279–280.
[20] Reade, D., 'US Customs Service P-3 Air Force', *Air International*, May 1993, p. 225.

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.[21]

PEACE ENFORCEMENT: BOSNIA AND KOSOVO

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 visible 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 and cavalry. 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.[22]

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.

NATO governments felt compelled to act, but remained conscious of their constituents' sensitivity to 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

[21] Reade, D., 'US Customs', pp. 226–227.
[22] Scott, C., 'Forcing the Peace', *RAF Air Power Review*, Spring 1999, pp. 27–38.

bombing campaigns, NATO deployed large numbers and many types of aircraft. Coordination 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.[23] In the first month of the campaign, over 10,000 sorties were flown, of which about 30 per cent were strike missions.[24] The Serbian air defence system was modern and active. The Serbs fired over 700 SAMs at NATO aircraft, but only two aircraft were shot down (an F-117 and an F-16).[25] Both pilots were rescued by NATO Combat SAR.

USAF and NATO's AWACS and USAF's ABCCC aircraft provided the critical coordination. At least one AWACS and one ABCCC were always airborne while air operations were underway. The AWACS and ABCCC were the first aircraft to take off each day and they were the last to land each night.[26]

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. A total of 27 E-3 AWACS participated in the operation, including 17 NATO, five British, three US and two French. They flew over 800 AEW&C missions totalling 7,800 hours.[27]

The ABCCC was an extension of the Joint Force Air Component Commander and acted as the direct link between the Combined Air Operations Centre in Italy and the aircraft on task. Each 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).[28] The ABCCC and AWACS used the Joint Tactical Information Distribution System (JTIDS) and Situational Awareness Datalink (SADL) data sharing networks to ensure that all platforms involved had access to 'the big picture'.[29]

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

[23] *Aviation Week & Space Technology*, 3 May 1999, p. 25.
[24] Mann, P., 'Belgrade called Victor in War's First Phase', *Aviation Week & Space Technology*, 26 April 1999, p. 28.
[25] Goodman, G., 'Aerospace Force', *Armed Forces Journal International*, September 2000, p. 51.
[26] Wall, R., 'New ABCCC Tactics used in NATO Air Strikes', *Aviation Week & Space Technology*, 26 April 1999, p. 32.
[27] Hoyle, 'High Flying Assets', *Jane's Defence Weekly*, 21 July 1999, p. 24.
[28] 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.
[29] Wall, 'New ABCCC Tactics', p. 32.

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 USAF-preferred Link 16. The Hawkeyes were 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 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.[30]

OPERATIONS WITHOUT AEW&C

British Operations in the Falklands: Okinawa Redux

On 2 April 1982, Argentine troops seized the Falkland Islands, 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 Army 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. The destroyers gave sufficient warning to the carriers, but were themselves very vulnerable and many were sunk or damaged. In the Falklands in 1982, the RN found itself in the same situation.

[30] Wall, R., 'E-2Cs become Battle Managers', *Aviation Week & Space Technology*, 10 May 1999, p. 38.

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.'*[31] His response was that: '*… 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.'*[32]

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*'.[33] The Argentine strike aircraft that sank HMS Sheffield had approached at low level, to postpone 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*'.[34]

The British campaign was ultimately successful, if a surprisingly 'near run thing'. Many observers had expected it to be a British 'walkover'. 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). Argentina was a backward Third World country, while Britain was a leading 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 that: '*Surface ships must have AEW ... for survival in open water*'.[35] A few British AEW aircraft would have transformed the campaign.

OPERATIONS WITHOUT EFFECTIVE AEW&C

The Accidental Shootdown of US Army Blackhawks 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. The USAF maintained a

[31] Woodward, J., *Memoirs of the Falklands Battle Group Commander*, Book Club Associates, London, 1992, p. 3
[32] *Ibid*., p. 174.
[33] *Ibid.*, p. 308.
[34] *Ibid.*, p. 174.
[35] *Ibid.*, p. 292.

continuous 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 were revealed. 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 helicopter crews did not monitor the AWACS/fighter communications channels. Had someone on the helicopters been listening, they may 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.[36]

The incident highlighted an old truism. 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 inter-service cooperation and coordination.

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

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.

CHAPTER FOUR

THE NATURE OF MILITARY OPERATIONS IN THE THIRD MILLENNIUM

Our foes have extended the fields of battle from physical space to cyber space; from the world's vast bodies of water to the complex workings of our human bodies. Rather than invading our beaches or launching bombers, our adversaries may attempt cyber attacks against our critical military systems and our economic base.

William Jefferson Clinton
President of the United States[1]

FUTURE WAR

Australia's squadron of Wedgetail AEW&C aircraft will be operational by the middle of the first decade of the new millennium. The Wedgetails can be expected to serve until at least the year 2020.

This chapter will briefly examine the likely nature of military operations in the period 2000 to 2020. It will not address broad issues, such as grand strategy, why nations go to war, what keeps them at war and what their war aims might be? The focus will be on the nature of operations at the operational and tactical levels.

Nobody can predict the exact nature of warfare and military operations in the future, but current trends can be identified. Educated guesswork indicates which trends are likely to continue for a few decades. The significant trends that are likely to continue will include the following:

a. Operations will be Joint (not single Service).

b. Situations will deteriorate to the point of hostilities, with little or no warning.

c. Wars will be short but intense.

d. The tempo of operations will be very high.

e. There will be few conventional wars and many 'Military Support Operations'.

f. Technology will be more widespread, thus negating it as a force multiplier.

g. Knowledge will be the key force multiplier.

h. Personnel and logistics will be important force multipliers.

i. There will be more non-state entities and more intra-state conflicts.

[1] Clinton, W., from a speech delivered on 22 May 1998.

j. Faced with Western conventional preponderance, our opponents will employ asymmetric warfare.

k. Public opinion will impact decisively on Western military operations.

JOINT WARFARE

Inter-Service Cooperation

Joint Warfare can be defined as operations conducted by elements of two or more Services in concert. There should be a seamless continuum. There should be no friction caused by inter-Service rivalry. There should be no confusion caused by misunderstandings. Joint warfare became the norm in World War Two. The successful D-Day landings at Normandy in 1944 were a classic example of armies, navies and air forces working together effectively.

Prior to World War One, nations had only armies and navies. The two Services operated independently of each other, rarely interacted and evolved very different cultures, languages and operational concepts. Army and navy officers often treated each other with levels of misunderstanding, suspicion and hostility usually reserved for the enemy. There was rarely any overlap between the army's continental strategy and the navy's maritime strategy.

The rare exception was amphibious operations, where the army relied on the navy for transport, fire support and logistics support. Army/navy cooperation was difficult and amphibious operations almost never ran smoothly. The debacle at Gallipoli in 1915 was a classic example of the failure of the army and the navy to work together.

Joint Command Structures

The Germans adopted a joint command structure in the 1930s. The High Commands of the Army (Heer), the Navy (Kriegsmarine) and Air Force (Luftwaffe) were subordinate to the High Command of the Armed Forces (Whermacht). The High Command was theoretically subordinate to the political leadership, in the form of the democratically elected Government. During World War Two, the German military was clearly subservient to the civilian head of state (Adolf Hitler).

At the same time, Britain and the United States formed Chiefs of Staff committees to coordinate joint operations, but the various Services remained largely independent. By the end of the war, the US Army's organic air corps was the largest air force in the world and the US Navy's organic air arm was the second largest air force. Since the re-organisation of 1947, the US Army, US Navy, US Marines and US Coast Guard have each maintained air arms larger than most nations' air forces. The US Air Force operates less than half of America's military aircraft. For small nations such duplication is not affordable.

Since the war, the armed forces of most nations have been moving closer to true joint operations. Traditionalists have resisted the process and slowed its progress, while visionaries have demanded a faster pace of reform. The champions of joint structures

have often been politicians, who narrowly viewed it as an opportunity to save money. There are economies of scale in joint maintenance, logistics and personnel. 'Jointness' is an appropriate goal, as it maximises operational effectiveness by achieving synergies and achieves success in the minimum time, with the minimum waste of blood and treasure.

In the 1970s, the Canadians went so far as to merge their army, navy and air force into one force, with the same rank structure and uniforms. They have since backtracked a little and most defence experts believe that separate Services, with separate structures, traditions and ethos are still appropriate, as long as they are trained and equipped to operate jointly. This can include issues as simple as compatible standard operating procedures, compatible communications equipment and regular joint exercises.

The ADF has adopted a joint command structure. Army Headquarters (AHQ), Navy Headquarters (NHQ) and Air Force Headquarters (AFHQ) are subordinate to Australian Defence Headquarters (ADHQ). The Chief of the Defence Force (CDF) commands the ADF. When a joint operation is to be conducted, CDF delegates command of selected elements of the ADF to a Joint Force Commander (JFC). The headquarters available to support the JFC include Maritime Headquarters (MHQ) at the RAN base in Sydney, Headquarters Northern Command (NORCOM) in Darwin and the Deployable Joint Force Headquarters (DJFHQ) built on the foundation of the Army's divisional headquarters in Brisbane.

The process of jointness continues in Britain and the United States. To ensure the efficient employment of scarce helicopter resources in their three Services, the British formed the UK Joint Helicopter Command in 1999. In April 2000 the Harrier squadrons of the Royal Air Force and Royal Navy were amalgamated to form Joint Force Harrier.[2] To force the pace of reform, the Americans formed US Joint Forces Command (JFCOM), under the command of a 'four star' admiral. JFCOM's mission is to integrate combat training in the US and conduct joint operations overseas.[3]

Joint Operations and Joint Support

Modern operations are nearly always joint. In 1999, the Australian government decided to deploy peacekeeping forces to Timor. Elements of two Australian Army brigades were transported to Timor by RAAF aircraft and RAN ships. Though Army troops (predominantly infantry) did most of the peacekeeping out in the countryside, the RAAF and RAN continued to provide essential fire support, logistics support and communications support. Joint intelligence capabilities kept the JFC informed and aware. Timor was a typical 21st century operation.

As funding shortages continue to force rationalisation of ADF assets, the individual Services will rely on each other even more. Future activities will be more joint. The Australian defence budget is too small to support duplication, so each Service manages some activities on behalf of the other Services. The Australian Army manages small arms and the ammunition. The RAN manages explosive ordnance (bombs and missiles).

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[2] *Air International*, May 2000, p. 262.
[3] Goodman, G., 'Chief Advocate for Jointness', *Armed Forces Journal International*, December 1999, pp 32–36.

The American JSTARS provide vital targeting data to air force strike aircraft and to army and marine corps artillery units. JSTARS aircraft are operated by the USAF, but the mission crews usually include US Army personnel. It would be more expensive, but no more efficient, if each service operated its own small JSTARS fleet.

The Wedgetail AEW&C will be a system operated by one Service (RAAF) to support operations involving all the Services. AEW&C will add value to air, land and maritime operations. The alternative to AEW&C might be additional reconnaissance and surveillance platforms and communications equipment, tailored to each Service's environment. Though this would be more expensive and less flexible

SHORT WARNING CONFLICT

In the future, situations will deteriorate to the point of hostilities with little or no warning. Short Warning Conflicts (SWC) are a nightmare for military planners. There is no time to structure, equip and train force tailored for the conflict, so existing military forces must be adapted. Such wars are sometimes called 'Come-as-You-Are' wars.

Australian planners do not have a good track record for predicting the location or nature of the next war. The Australian Army emerged from World War Two with a mastery of jungle warfare and amphibious operations in the littoral areas of South East Asia. They continued to prepare for such conflict. Only five years later they were fighting in the snow-covered mountains of northern Asia (in Korea). In the 1980s, the ADF responded to Government guidance that nominated South East Asia and the South West Pacific as our area of interest. It was a low threat, maritime environment. In 1990, ADF elements were sent to the Persian Gulf and there was a prospect of fighting in a high threat, continental environment. In the 1990s, the ADF was involved in many UN peacekeeping operations, outside the (still extant) area of interest.

The ADF must be flexible enough to respond to a wide range of contingencies. The ADF could maintain a large number of contingents, each one specialising in a different type of operation, covering the full spectrum of conceivable contingencies. Such a force would resemble the US armed forces in all but scale and would be very expensive. The alternative is a small force, with as many multi-purpose systems as possible. The hope is that a force with multi-purpose systems can adapt quickly to a wide range of credible contingencies.

The ADF therefore needs multi-purpose systems and multi-purpose force multipliers. AEW&C is just such a system. AEW&C can add great value to any ADF operation where air support is involved. In modern warfare, air support is essential to nearly every scenario.

SHORT INTENSE WARS

Future wars will be short but intense. Operation Desert Storm included a 40 day air campaign. In just six weeks, the USAF dropped nearly the same tonnage of bombs as it had dropped in the four years during World War Two.

In the first week of the Arab-Israeli War of 1973, the Israeli Air Force flew such intensive operations that its aircraft wore out and needed major overhauls. Without a massive emergency resupply from their US allies, the Israelis would have run out of air power in the second week of the war. Such wear and tear would take years of normal peacetime use.

In 1982, British amphibious operations to recover control of the Falkland Islands lasted only a few weeks. In World War Two, such campaigns took much longer to prepare and conduct. The British commanders were under intense political pressure from their government, who were demanding quick resolution. A long, slow campaign of methodical, cautious operations was out of the question.

The cost of modern weapon systems is so high that even superpowers cannot afford to maintain large numbers of platforms or large stockpiles of ordnance. After a short period of intense violence, most forces will need to perform extensive repair and maintenance on their platforms, and will have exhausted their stocks of precision guided munitions. The cost of trained military personnel is so high that most Western military organisations have severely constrained staffing structures. After short periods of intense activity their personnel will be exhausted.

Force multipliers such as AEW&C can help coordinate and maximise the impact of combat forces during intense operations. AEW&C can help maximise the shock effect and minimise the opportunity for the enemy to inflict losses on friendly forces, as was the case during Operation Linebacker over North Vietnam in 1972 and Operation Desert Storm over Iraq in 1991.

HIGH TEMPO OPERATIONS

The tempo of future operations will be very high. Modern technology will enable properly equipped and trained forces to operate continuously, without pause. Such capabilities have already driven operations and campaigns at rates much faster than was the norm in World War Two.

During the German invasion of France in 1940, the German Panzer divisions stopped each night to rest, re-organise and resupply. In 1991, during Operation Desert Storm, Coalition forces conducted true 24 hour operations. Neither darkness nor adverse weather slowed their advance. Coalition armoured divisions advanced through Iraq at more than twice the rate achieved by the Germans in France 50 years earlier.[4]

[4] 1940: Germans advanced 300 kilometres from the Meuse River to the English Channel in 10 days. 1991: Coalition forces covered a similar distance in only three days.

In 1991 electronic sensors gave Coalition forces the ability to perform accurate navigation and targeting anywhere, anytime. Most air activity was at night. Coalition air and ground platforms were able to move around the battlefield and successfully engage in combat at night and in foul weather. There was no rest for the enemy or for friendly forces.

When Australian troops were deployed to East Timor the conservative approach would have been to establish and secure a beach head and air head, then develop a logistics base and then gradually expand the area of control by careful incremental operations. However, the Australians troops were expected to begin aggressive patrolling immediately and establish control over the entire AO as soon as possible. Instead of sequenced or serial operations (one step at a time) everything had to be done simultaneously.

MILITARY SUPPORT OPERATIONS

High intensity wars involving the regular combat forces of nation-states (such as the Gulf War of 1991) will be very rare events. Military Support Operations (MSOs) will be increasingly common. MSOs are typically UN or US led peace operations. They are usually long, drawn out operations.

ADF Military Support Operations

Australia's last major involvement in a conventional high intensity war ended with our withdrawal from Vietnam in early 1972. ADF forces have not been in high intensity combat since. Current defence policy recognises the benefits of American global hegemony and identifies high intensity conflict and direct threats to Australian sovereignty as unlikely contingencies in the foreseeable future. The most likely tasking for the ADF has been and will be operations other than war — MSOs.

In the 1990s the ADF has been heavily committed to a series of MSOs. ADF commitments have included peace monitoring in Bougainville, mine clearance in Cambodia, drought relief in Indonesia, arms inspections in the Middle East, mine clearance in Mozambique, disaster relief in Papua New Guinea, humanitarian aid in Rwanda, peacekeeping in Somalia, EEZ patrols in the South West Pacific and peace enforcement and stabilisation in East Timor. Most of our MSO commitments have been under UN auspices. Many have been under US leadership. In East Timor, Australia was the leader.

AEW&C may not appear to have an obvious role in infantry-dominated peacekeeping operations, but air power remains useful in low intensity MSOs. Even if there is no threat of an opponent employing air power directly against the peacekeeping force, the *control* capability of AEW&C is very useful for maximising the effectiveness of friendly air power. AEW&C can coordinate air surveillance, search and rescue, air supply, and the air transport of personnel within the AO and into or out of the AO. The *communications* capability of AEW&C can be very useful when establishing a point of entry in a devastated or undeveloped area and may provide the only reliable communication services in remote and rugged areas.

Blockades

The UN has maintained many long-term campaigns, including blockades. Blockades can prevent movement by land, sea or air

Land Blockades. Land blockade is one of the oldest forms of warfare. A land blockade can be maintained by committing ground forces to physically block movement by road, rail or overland. Such a physical presence requires large numbers of troops and carries with it the risk of casualties inherent to all land operations.

A modern alternative is an airborne surveillance and response. Surface surveillance aircraft (such as JSTARS) provide the most effective sensor to detect vehicles attempting to violate the blockade. Surveillance aircraft also provide the command, control and communications capability to arrange a timely response, usually by strike aircraft. The blockading force can operate from safe bases, remote from the area under blockade.

The most famous large scale attempt to impose an airborne land blockade was the USAF operation to interdict the Ho Chi Minh trail during the Vietnam War. Since that unsuccessful operation the technology of airborne surface surveillance and ground attack aircraft have greatly improved.

Naval Blockades. The naval blockade of Iraq during and after the war in the 1990s was maintained by a combination of aircraft and warships. In modern naval blockades, the area of ocean to be kept under surveillance is often huge and the number of ships available is usually limited, so there are never enough ships to physically cover it. AEW&C aircraft provide the most effective sensor coverage of large surface areas. AEW&C aircraft can also provide the command control and communications capability to arrange a timely response, usually by ships.

Blockades can be employed to prevent ships from leaving a place or to prevent them from entering or both. One of the most famous naval blockades was the successful US response to the Cuban Missile Crisis in 1962. US drug interdiction operations in the Caribbean are analogous to a selective naval blockade. Efforts to prevent illegal entry by boat to Australia is a form of blockade, where surveillance aircraft are essential to maintain situational awareness over a huge area and a few RAN patrol boats provide the response.

Air Blockades. The No Fly Zones imposed in Iraq and Yugoslavia involved the creation and enforcement of an Air Defence Identification Zone (ADIZ). AEW&C aircraft are essential for such air blockades. AEW&C aircraft provide the most

effective sensor to detect aircraft attempting to violate the blockade. AEW&C aircraft also provide the command, control and communications capability to arrange a timely response, usually by fighter aircraft.

The British have enforced an ADIZ around the Falklands since their naval task force arrived in 1982. In periods of tension and during hostilities the ADF may have to enforce an ADIZ in the northern approaches. US drug interdiction operations in the Caribbean are analogous to a selective air blockade.

TECHNOLOGY EVERYWHERE

Many smaller nations are now operating or acquiring state-of-the-art weapon systems. The RAAF Hornets no longer enjoy a significant performance edge over aircraft in the region. There is a proliferation of MiG-29s, Su-27s and F-16s, which compare favourably with the Hornet.[5] Advanced air-to-air missiles and precision guided munitions are also becoming more widespread. Short term economic problems will only delay capability increases for a few years.

Military technology will be more widespread, thus negating it as a force multiplier. Commercial-off-the-shelf (COTS) computer systems are often as capable as military systems, much cheaper and easier to acquire, maintain and upgrade. Illegal arms dealers can provide virtually any system required, for a price. Even Weapons of Mass Destruction (WMD) are available.[6]

Technology is freely available, even to terrorists and criminals, and it is getting cheaper. The force multiplier effect of technology is no longer monopolised by the major powers and the industrialised nations. The West can no longer assume that it will be able to match Third World mass with high technology 'gunboat diplomacy'.

In an environment awash with technology, the force that selects the right technologies, and best harnesses them will prevail.

THE KNOWLEDGE EDGE

The capacity to gather information and exploit knowledge has always been important in war, but in the 1990s it came to be regarded as a capability in its own right.[7] The proliferation of powerful digital computers has made it possible to collect huge volumes of information, process that information into useful knowledge, understand the situation and act decisively, all in a timely manner. The current term for the cluster of activities involved in creating the knowledge edge is C4ISR, which stands for Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance.

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[5]India and Malaysia operate MiG-29s, China operates SU-27s, Indonesia and Thailand operate F-16s. *Aviation Week & Space Technology*, 11 January 1999, pp. 248–259.

[6] WMD includes Nuclear, Biological and Chemical (NBC) weapons.

[7] Stephens, A., 'The Knowledge Edge', *Asia Pacific Defence Reporter*, April 1999, p. 56.

In war, the commander with superior knowledge has an enormous edge. This is the knowledge edge. The knowledge edge is particularly important to the ADF.[8] We lack the mass to provide defence in depth over the whole continent, let alone the even larger EEZ and the broader area of strategic interest. The small ADF forces must be in the right place at the right time to have any chance of success. This requires adequate warning of enemy intentions and actions. Therefore, current Australian defence policy nominates the knowledge edge as the ADF's highest priority for force structure development.[9]

This policy led to the formation of a force element group dedicated to achieving the knowledge edge — the RAAF's Surveillance and Control Group (SCG). The Group fuses Australia's major fixed and mobile surveillance capabilities with an integrated command, control and communication system. The overall effect will be a better coordinated intelligence and surveillance effort, which should significantly improve situational awareness.

PERSONNEL

Trained, motivated personnel will be an important force multiplier. Typical of modern Western military forces, the ADF is a small professional force. Lacking mass force, the ADF relies on creating mass effect.

In the air war over Korea in the 1950s, the American F-86 Sabre jet fighter and the Communist MiG-15 battled for air superiority. The Sabre and MiG-15 had similar performance, but the MiG was superior in some important aspects. To make matters worse, the MiGs usually outnumbered the Sabres.

In spite of rough qualitative parity and significant numerical inferiority, the Sabres achieved an impressive record in air-to-air combat. Almost 800 MiGs were shot down, for the loss of only 79 Sabres (a kill ratio of ten to one).[10] The key to American success was the superior skill of their pilots and tacticians.

In the Falklands War, a small British ground force faced a much larger Argentine force. Both sides had similar weapons and the British had inadequate air support and naval gunfire support to counter balance the Argentine numerical superiority. The Argentines had the additional advantage of defending. The key British advantage was morale and esprit de corps. The young Argentine conscripts lacked commitment and motivation. The British won the war, largely because their personnel were better motivated and more committed.

As the technological edge that Australia once enjoyed slips away, the ADF will rely increasingly on the quality of its personnel. Many nations will operate AEW&C and

[8] Hawke, A., *Address to the Royal United Services Institute (Victoria)*, 27 April 2000, p. 9.
[9] SR 97, pp. 56–60.
[10] Davis, L., *MiG Alley: Air to Air Combat in Korea*, Squadron/Signal Publications, Carrollton Texas, 1978, p. 71.

other high technology force multipliers. The ADF will need to get more value out of the platform, to maximise the effectiveness of its small forces.

In the 21st century, a very important aspect of qualitative superiority will be the capability to maintain and update computer software. The ADF has 'world class' software development units embedded in its force element groups and elsewhere in the Defence organisation.[11] These development units give the ADF the capability to operate software without the support of the original supplier and even improve software beyond the original suppliers' specifications. Such capability has two benefits. First, if the original supplier withdraws support, operations can continue. Second, if two air forces operate the same type of aircraft in similar numbers, an indigenous software development capability may be the decisive difference. The key element of the software development capability is highly trained personnel.

LOGISTICS

Modern military systems are very expensive to acquire and operate and often require complex, specialised logistical support. Precision Guided Munitions (PGMs) are so expensive that even the US cannot afford to expend them in large numbers or maintain stockpiles.

Middle order powers, such as Australia, rely on logistics support from major power allies. The supply of expensive PGMs will be limited and replenishment stocks may not be waiting on the shelf. A customer may have to wait for a dormant production line to be reactivated and PGMs to be produced and shipped; this process can take many months.

Improving the chances of a successful first strike will obviate the need to revisit targets. The result will be reductions in rate of effort and attrition. A given number of platforms and weapons will achieve more if sorties are not wasted. AEW&C and associated surveillance systems will help reduce aircraft attrition and PGM wastage rates.

NON-STATE PLAYERS

Since the formation of the United Nations in 1945, war between nation-states (inter state conflict) has become a rare event.[12] Most of the death and destruction since 1945 has been inflicted in civil wars, wars of 'liberation' and the chaos that followed the collapse of failed states.[13] There will be more intra-state conflicts and more non-state entities.

The traditional non-state entities include drug cartels, illegal immigration operations and other organised crime groups, terrorist groups (such as the IRA and PLO) and ethnic secessionist groups (such as in Bougainville). More novel non-state entities include radical environmentalists (including eco-terrorists) and parochial Luddite

[11] Stephens, 'The Knowledge Edge', p. 57.
[12] The notable exceptions are the Arab-Israeli wars, the Indo-Pakistani wars and wars fuelled by Cold War rivalry between the power blocs, such as the Korean War.
[13] Typical 'failed states' include Yugoslavia and Somalia.

groups (such as those opposed to the World Trade Organisation or the United Nations)

Surveillance has often proven to be crucial in dealing with non-state entities. American Hawkeyes and AWACS have been very successful in anti-drug operations in the Gulf of Mexico and Central America. AEW&C can give the operator an 'unfair advantage' over non-state entities. High technology airborne surveillance is one of the few capabilities still beyond the means of non-state entities. AEW&C can be crucial in keeping track of non-state entities and their activities.

ASYMMETRIC WARFARE

Conventional warfare is epitomised by Operation Desert Storm. It involves the use of uniformed professional troops, operating tanks, warships and fast jet aircraft as platforms for high tech sensors and 'smart' weapons. It involves sophisticated C4I and is employed primarily by wealthy nation-states.

Asymmetric warfare is unconventional warfare that seeks to drive the military dimension into the civil dimension to offset Western superiority in high technology and financial resources. The weapons of choice in asymmetric warfare are terrorism and WMD, particularly cheap 'home made' chemical and biological agents with primitive yet effective delivery mechanisms. In some scenarios, a truck loaded with 44 gallon drums of home made nerve agent can be just as effective as a stealth bomber loaded with smart weapons. Cyber warfare is another emerging form of asymmetric warfare.

Regular forces engaged in conventional warfare tend to observe the Laws of Armed Conflict (LOAC). Irregular forces engaged in unconventional asymmetric warfare tend to ignore the LOAC or even seek to abuse or exploit them on the battlefield and use them for propaganda purposes in the world media. Western forces are expected to scrupulously follow LOAC and can lose public support if they are not seen to do so.

PUBLIC OPINION

Public opinion will impact decisively on military operations. Operations will have to be planned and conducted with domestic and world opinion in mind.

It is clear from the Vietnam experience that broad domestic political support is essential for the prosecution of successful military operations, by a democratic nation. The British Government was able to mobilise domestic support for the Falklands War. The US Government was able to mobilise domestic support for Operation Desert Storm. The Australian Government was able to mobilise public support for the MSO in East Timor.

Unfortunately, public opinion is fickle. In the mid-1960s there was broad domestic American and Australian support for the Vietnam War, but it waned after a few years. Since Vietnam, the attention span of the electorate has become much shorter. Support

for operations against Iraq dwindled rapidly. Western voters take it for granted that our technological superiority is overwhelming and expect quick, clean results.

Public support can be destroyed by one isolated incident. The accidental destruction of a commercial airliner, or a train on a bridge can generate bad publicity. An enemy can be expected to use any error for propaganda purposes. A perceived error can be blown out of proportion and will quickly lead to a general perception of overall failure. This in turn leads to loss of support and demands for an immediate cessation of hostilities.

The impressive situational awareness and data recording capabilities of AEW&C aircraft can provide compelling evidence to prove operations to be legally and morally valid. The timely broadcast of video footage on the six o'clock news can stifle a negative reaction or at least lessen the criticism.

FACTORS AFFECTING AIR OPERATIONS

Political Constraints

Recent history has shown that air power is the force of choice in many situations. Air power has been used either as the sole force (as in the Balkans) or the means of achieving the essential preconditions for successful land operations (as in Kuwait).

Politicians see the deployment of land forces as a commitment that can be both bloody and difficult to discontinue. Over 50,000 American troops were killed in the Vietnam War. The quagmire of Vietnam haunts Western politicians. Approximately 250 British and 650 Argentine personnel died in the Falklands War. The majority of the casualties in both wars were ground troops.

Sea power usually has little or no immediate effect on situations ashore. Naval forces are slow to deploy and expensive to maintain. Land forces must deploy much of their heavy equipment and logistical support by sea.

Air power is perceived to be very quick to deploy. Air power can be just as easily withdrawn, without the appearance of a major retreat. The withdrawal of the US Marines from Lebanon in the 1980s was seen as a defeat. The cessation of a bombing campaign or a no fly zone is easier to portray as a successful conclusion.

Air power is widely perceived to be clean and flexible. The Western obsession with technology leads most people to expect that precision weapons will always hit the target, with no errors.

Collateral Damage

The international media often have better communications than the military forces on which they are reporting. The media can be expected to detect and publicise every error. Public opinion is very intolerant of errors, particularly casualties. The most unacceptable casualties are those sustained by friendly forces, but even enemy casualties can engender sympathy and calls for cessation.

Precision engagement will be used increasingly, to minimise collateral casualties. However, the increased lethality of modern air-delivered weapons is a double-edged sword. A single incident of fratricide can generate significant casualties and undermine public confidence. The majority of Coalition battle casualties in Operation Desert Storm were fratricides.

Air operations against Iraq in the 1990s produced embarrassing cases of collateral damage. American aircraft bombed a large civilian air raid shelter (mistaken for a military command bunker) and the Chinese Embassy in Baghdad. Another target was alleged by Iraqi propaganda to be a baby milk factory. In such cases, the data records of surveillance aircraft (including AEW&C) are useful in operations 'post mortems'. They can help prove that we were acting in good faith and also clarify what went wrong.

Cost Effectiveness versus Counter Measures

A feature of modern air power is very high technology. However, high technology aircraft can still be surprisingly vulnerable to relatively low technology countermeasures. In some scenarios, air power may not be as cost effective a means of delivering high explosive as army artillery or naval gunfire support. Manned aircraft may not be as cost effective a means of reconnaissance and surveillance as UAVs.

In Vietnam, state-of-the-art American helicopters were sometimes brought down by very primitive mechanisms. One improvised device consisted of a five metre long wooden log loaded into a hole in the ground, with a tractor tyre inner tube acting as a spring and a simple trigger mechanism attached to a sheet of corrugated iron. When a helicopter passed low overhead, the rotor downdraft put sufficient pressure on the sheet of corrugated iron to trigger the release of the pole. The inner tube launched the pole into the air, where it fouled the main rotor and brought down the helicopter. A few hundred dollars worth of items available at any Hardware store could destroy a million dollars worth of air power! In every war cheap small arms fire has brought down many low flying aircraft (especially helicopters).

Air defence systems based on radar-guided SAMs are far more expensive than infra-red (IR) guided man-portable systems, such as the shoulder fired Stinger. Paradoxically, sophisticated radar-guided SAMs are easier to deal with.

The only Israeli Air Force aircraft lost in the Beeka Valley campaign in 1982 was probably shot down by a shoulder fired IR-guided SAM. Such weapons are readily available to any Third World infantryman or well-bankrolled terrorist. American and

NATO SEAD was very effective in shutting down Iraqi and Serbian radar-guided SAM networks in the 1990s. Small, mobile IR-guided SAMs remained a threat.

Economics

Competition for Funds. A common trend in Western democracies over the last few decades has been a sharp increase in spending on health, education and welfare and a consequent decrease in the percentage of the government budget available for defence spending. Large fleets of aircraft, warships and tanks are no longer affordable. Therefore modern military hardware must be as cheap as possible to acquire and operate.

At the same time, the cost of personnel has increased, as conscription has been phased out and the cost of labour in the civilian market has skyrocketed. Therefore, technology and equipment has been substituted for manpower, wherever possible.

Longevity. The expense of new combat platforms will be prohibitive, so old platforms will be retained for longer periods and upgraded with new systems and weapons more often. The USAF intends to keep some of its B-52 bombers in service until 2040, by which time it will be 80 years since the aircraft were built.[14] Closer to home, the RAAF intends to keep its F-111 bombers in service until 2020, by which time it will be over 50 years since the aircraft were built.

Adaptability. Over time, circumstances change. Over long periods, circumstances can change radically. Combat platforms built for specific scenarios but retained in service for many decades must adapt to radical change.

The B-52 bomber was designed in the 1950s as a high altitude, intercontinental *strategic* bomber armed with a few nuclear gravity bombs. In the 1960s it was adapted to the *tactical* close air support role armed with dozens of high explosive gravity bombs. In the 1970s it was adapted to the low level penetration role as a *strategic* bomber armed with a few precision-guided stand-off nuclear weapons. In the 1990s, some were adapted to the *tactical* maritime strike role armed with a few anti-ship missiles. The B-52 will remain in service for another 40 years. Further adaptations may include using them as stand-off jamming platforms.[15]

Force Multipliers. Force multipliers help keep ageing systems effective in a changing environment. Platforms are now less important than the weapons and avionics systems that they carry, and the total force of which they are a part. The B-52 bomber is still considered effective, over 40 years after it was designed. The addition of modern sensors and other on board systems have been part of the reason for its longevity. However, the panoply of supporting capabilities now available greatly enhances the survivability, flexibility and lethality of the B-52. Those capabilities include AEW&C.

[14] *Air International*, April 2000, p. 247.
[15] *Ibid.*, p. 247.

The cost of the B-2 'stealth' bomber was so high that the USAF could not afford the originally envisaged fleet of 130. The retention of about 90 B-52s and about 90 B-1s has enabled the USAF to 'get by' with only 20 B-2s. The billions of dollars saved are available for other requirements, such as airlifters or fighters.

Computer simulations and exercises in the field have proven that the acquisition of a force multiplier is often a more cost effective means of increasing overall combat power than an incremental increase in force numbers. Depending on the scenario, a force of 50 fighter aircraft with AEW&C support may be more effective than a force of 100 fighters without AEW&C support. The extra 50 fighter aircraft would probably cost much more to acquire and operate than the few AEW&C aircraft. A future Churchill, paying tribute to the decisive factor in a future Battle of Britain, may talk of so many owing so much to so few AEW&C aircraft.

CONCLUSION

The end of the Cold War did not signal the end of international or intra-national conflict. Despite the best efforts of the UN and the best intentions of most nations, there has been no golden age of peace and there is no universal rule of law. The world is unstable and nations must retain the capability to protect their national interests by force.

Western democracies can no longer afford to maintain large standing forces. Their traditional technological edge can no longer be taken for granted either. In the new global economy, state-of-the-art technology is within the reach of many potential adversaries and awesome firepower is available to most nations and many non-state entities.

Only the United States can afford the financial burden of maintaining great mass and a significant qualitative edge across the spectrum of military capabilities. Other nations must carefully choose a few decisive areas in which to have the edge.

Australia is among the Western nations that have chosen to maintain the knowledge edge. AEW&C is an essential enabler for the knowledge edge in most credible scenarios in information age warfare. If the intention is to get the maximum effect out of small forces, then force multipliers are essential. AEW&C is a very effective force multiplier. The command and control power of AEW&C helps small combat forces to maintain a high tempo of operations and maximise the effectiveness of those operations.

AEW&C is a flexible capability. It can be very useful in the full range of conventional military operations, assymetric conflicts, military support operations and law enforcement operations. AEW&C enhances air, land and sea operations.

Public opinion can be decisive, both on the home front and around the world. The public expects quick results, low casualties and no mistakes. AEW&C can facilitate all that and will often help provide convincing electronic evidence of when, where and how an incident happened.

Like air power generally, AEW&C does not guarantee victory and will not eliminate errors or casualties. However, the conduct of any kind of air operation, in isolation or in support of land or sea operations, will be much more difficult without AEW&C. A force operating without AEW&C will be at a severe disadvantage, particularly in operations against an adversary who employs AEW&C.

CHAPTER FIVE

AUSTRALIA'S UNIQUE CIRCUMSTANCES

The AWACS is at the centre of coalition air warfare.
It is the glue cementing interoperability

Group Captain Ron Cook
Royal Air Force[1]

AUSTRALIA'S UNIQUE GEOGRAPHIC SITUATION

Smallest Continent: Largest Island

Australia has almost the same land mass as the continental United States but twice the coastline. Australia's Exclusive Economic Zone (EEZ) is the largest in the world. Other large countries such as China, Russia and the United States each have populations of hundreds of millions from whom to draw manpower for their defence. Australia has less than 20 million.

The popular perception is that strategic geography dictates that any threat is likely to approach Australia through the northern arc. That assumption is the basis for the ADF force structure and provides the scenarios for most major ADF exercises. The defence of Australia is complicated because most of the population and infrastructure are concentrated in the south-eastern corner of the continent. Many important resource exploitation activities are thousands of kilometres away from the main bases from which ADF protection operations would be launched.

Lines of Communication

Australia has been characterised as an archipelago. There are tiny islands of population scattered across a vast area of desert linked by few sealed roads and very few railways. Being the driest continent, Australia lacks the network of internal waterways that have substituted for roads and railways in other countries. Australia has very poor internal lines of communication and transit times for coastal shipping are very long.

Since European settlement the 'tyranny of distance' has made operations in the northern and western parts of the continent very difficult. The transport, communications and logistics challenges are significant. In the absence of alternatives, Australians embraced air travel relatively early and enthusiastically. Aviation pioneers established regular air lines of communication in the 1920s and organisations like the Royal Flying Doctor Service and QANTAS made an essential contribution to the nation's development.

Parochial Army and Navy officers are fond of comparing the RAAF to other small air forces, such as those of Israel or Sweden. They claim that the RAAF has too many

[1] *Flight International*, 13 October 1999, p. 40.

support personnel or a disproportionately large transport and training force and not enough combat capability to justify its share of the Defence budget. Israel and Sweden are small, compact nations. Australia is hundreds of times larger.

Given the range of modern fighter aircraft, the RAAF needs the existing chain of bases across the northern arc of the continent (Learmonth, Curtin, Darwin, Tindal and Sherger). Given that the centres of gravity of Australia's industry and population are in the south-east (3,000 kilometres away), the northern bases are too far forward for economical logistics support. The RAAF therefore needs some main bases in the south east for maintenance and training. This all generates a need for many bases and many personnel to operate them.

Conventional land-based systems will not solve the problem of the air defence of Australia. Australia cannot afford a coastal chain of conventional microwave radar stations — there would need to be hundreds of them. Even if such a chain was affordable, most of the valuable assets to be protected are on or near the coastline — oil and gas fields, mines, fishing villages, tourist spots and coastal settlements. Land-based radar would not give adequate warning time to organise defensive measures. Australia needs AEW for the same reasons the Americans and British decided that AEW was essential to their defences.

All organisations have 'overheads' of management and specialist functions that are necessary to run their business. An air force half the size of another may have the same sized 'overheads'. The RAAF will soon have as many AEW&C aircraft as the much larger RAF. Six or seven AEW&C aircraft give an air force a minimal AEW&C capability, whether that air force has 100 fighters and bombers or 500.

Vulnerable Sea Lines of Communication

In the 21st century Australia will continue to be heavily reliant on international trade for its economic prosperity. The security of the sea lines of communication (SLOCs) will be essential to national security. The most important of these SLOCs pass through Indonesia and the South China Sea, past the Philippines, China and Taiwan, to lucrative markets in Japan and Korea. Australia has a vested interest in the political stability of the region.

Regional flashpoints abound along Australia' northern SLOCs. The flashpoints include the Korean peninsula, Taiwan, the South China Sea and several points in Indonesia. A flare up of the suppressed hostility at any of these points could disrupt Australia's trade flow and impact on the economy.

Korean Peninsula. The North Korean government is one of the most isolated, xenophobic and paranoid regimes on the planet. North Korea has the dangerous combination of a reclusive dictator, a moribund economy, the constant threat of famine, an aggressive foreign policy and a disproportionately large military. The

Communist government has fed the people a steady diet of anti-Western propaganda for over 50 years. As far as most North Koreans are concerned, the Korean War (1950 to 1953) never ended.

Every year, there are incidents such as commando raids on coastal areas and gunfights between naval vessels. Aggressive espionage operations have been conducted by both sides. High level South Korean officials have been killed by bombs that were allegedly planted by North Korean agents. The South Koreans and their American allies maintain a tense watch along a heavily fortified border.[2] The Korean peninsula is often cited as the most unstable flashpoint on Earth.

China. There are two Chinas: the Republic of China (Taiwan) and the Peoples' Republic of China (Red China). Each China claims sovereignty over the other. The Chinese Civil War, which began in the 1930s, was put on hold for the war with Japan, resumed in 1945 and never formally ended. There are plausible scenarios where Red China would attempt to conquer Taiwan. A regular, high priority mission for the US Pacific Fleet is to deploy significant forces to the vicinity of the Straits of Formosa, to keep the two Chinas apart.

South China Sea. The Spratley islands in the South China Sea are in a strategically important position and may contain valuable oilfields. The islands are claimed by Brunei, Red China, Malaysia, the Philippines, Thailand and Vietnam.[3] There have been military incidents between Chinese and Vietnamese forces that occupy tiny outposts in the islands. China and Vietnam fought a short war in 1979 and have not normalised relations since.

Defending Australia

Defending a large empty continent and distant, vulnerable SLOCs by means of a conventional continental strategy ('Fortress Australia') is impossible. The Australian army would need hundreds of thousands of soldiers to adopt such a defensive posture. Even a huge army could do little to protect offshore resources and distant SLOCs.

To defend the homeland and its more distant economic interests, Australia has been forced to adopt a maritime strategy of forward defence and reliance on alliances and the United Nations. Rather than wait for an enemy to land a force on the continent, the ADF will be pro-active and defeat threats in the air sea gap to the north.

AUSTRALIAN DEFENCE POLICY: HISTORY AND EVOLUTION

[2] The US maintains a US Army Infantry Division and a few USAF fighter squadrons in South Korea. A USN Carrier Battle Group, a US Marine Infantry Division and more USAF fighter squadrons are stationed nearby in Japan.

[3] Huerto, D., *Command & Control of Philippine Maritime Air Surveillance*, RAAF Air Power Studies Centre, Canberra, pp. 8–9.

Imperial Connection

Australia has always relied on collective security and the protection of a powerful ally. Prior to World War Two we relied on the British imperial system. Australia deployed small contingents to British colonial wars all over the world on the assumption that if Australia was threatened by a major power (France, Russia or Japan) the empire would come to our assistance.

The Royal Navy (RN) dominated the oceans and could concentrate overwhelming imperial land power at any point in the empire. The doctrine, organisation and equipment of Australian armed forces were closely modelled on those of the British. The RAN was effectively a squadron of the RN. The Australian Army was a niche force, providing a predominantly infantry force for imperial contingencies.

Australians fought alongside Imperial forces in New Zealand in the 1840s (the Maori Wars), the Sudan in the 1880s, China in 1900 (the Boxer Rebellion), South Africa 1899–1901(the Boer War) and both World Wars.

World War Two

In 1941–42 the British proved to be unable to protect Australia from Japan and the Australian government turned to the United States. After the sinking of the HMS Repulse and the HMS Prince of Wales in December 1941,[4] the British deployed no significant maritime force to the Asia-Pacific region until the arrival of a small fleet (a handful of battleships and aircraft carriers) in late 1944. The Pacific war was an overwhelmingly American affair.

World War Two was thus a watershed in Australian defence. In the absence of British equipment, Australian forces were equipped with large quantities of American weapons. In the absence of British forces, Australian forces fought alongside Americans forces. In the absence of an effective British imperial strategy, Australia accepted a role in the American global strategy.

Cold War

During the Cold War, Australia saw itself as a member of the Western alliance, locked in a struggle against the Soviet Union (with its Warsaw Pact allies) and Communist China. The Western alliance favoured the status quo. The industrialised nations of the 'First World' needed access to cheap raw materials and markets in the 'Third World' and the free flow of international trade was essential to their economic stability. The Soviet bloc and the Chinese were seen as forces for change and instability, fomenting

[4] Repulse and Prince of Wales were sunk a few days after the US Pacific Fleet base at Pearl Harbor was attacked.

revolution and 'wars of liberation' to overthrow the European colonial presence in Africa and Asia and pro-Western military dictatorships in Central America and South America.

In any dispute involving the major powers' direct interests or the interests of core members of their alliance blocs, the UN proved to be ineffectual. It was usually hamstrung by the veto of the major powers in the Security Council. The UN was a useful propaganda forum and its support for an operation was a bonus, but wars to maintain the status quo had to be fought by the armed forces of the core allies.

Australia contributed to the British war of containment in Malaya (1948–60) and to the American wars of containment in Korea (1950–53) and Vietnam (1965–73). Again the assumption was that our powerful allies would repay the debt and come to our assistance if we ever needed them.

In the late 1960s, the reliability of our powerful allies was put in doubt by policy changes. As part of their global military cutbacks, the British announced a policy of withdrawal from virtually all points 'east of Suez'. Henceforth, the British would concentrate on their commitments in Europe (military commitments to NATO and economic commitments to the EEC). In 1969, US President Richard Nixon, reacting to the debacle in Vietnam, articulated the so-called 'Guam Doctrine'. Henceforth, the US would assist allies if they were threatened by a major power (the USSR or China) but expected allies to deal with regional problems with their own resources.[5]

Vietnam

After the Vietnam War, defence policy gradually shifted from forward defence (participation in major allies' distant wars) to continental defence; and from reliance on the protection of a major ally to 'self reliance', without abandoning alliances.

In the 1972 Defence White Paper, the McMahon government stated that Australia:

> *… should not allow its expectation of external support for its defence … to overshadow its obligations to assume, within the limits of it resources, the primary responsibility for its own conventional defence and to accept an even greater share, if not indeed the entire burden, in circumstances of lesser challenge*[6].

The new policy placed greater emphasis on improving the capabilities of the RAAF and RAN.[7]

1976 White Paper

In the 1976 Defence White Paper titled 'Australian Defence', the Fraser government signalled that Australia's armed forces would no longer be developed and trained primarily to fight abroad as part of a major ally's force. Future operations would most likely be in our own region and would be joint in nature. The force-in-being was to be

[5] Cheeseman, G., *The Search for Self-Reliance*, Longman Cheshire, Melbourne, 1993, p. xv.
[6] *Ibid*., p. 4.
[7] *Ibid.*, p. 5.

capable of performing current and foreseeable tasks (including UN peacekeeping) and dealing with short term contingencies. There was to be the capacity (skills and structure) for timely expansion against a range of higher contingencies.[8]

The 1976 White Paper also established the assumption that there would be considerable warning time (many years) before any threat of high level intense conflict would emerge. If short warning conflicts (SWC) were likely to be low level, the ADF could structure its 'ready' forces accordingly. Low level contingencies were defined as such things as harassment of coastal shipping, terrorism and spoiling raids on coastal assets.[9]

The need for improved surveillance of the northern approaches to Australia was also highlighted. As a consequence of the policy, the Fraser government expanded Defence infrastructure in the north. Patrol boat bases were built at Darwin and Cairns, and the RAAF Bases at Amberley and Learmonth were upgraded.[10]

1987 White Paper

In the 1987 Defence White Paper titled 'Defence of Australia' (DOA87), the Hawke government formalised the concept of '*self-reliance within a framework of alliances*'. The 'allies' mentioned included the US (the most important), New Zealand, Papua New Guinea, Britain, Malaysia and Singapore. Australia was described as a member of the 'Western strategic community'.[11]

DOA87 focussed on *defence in depth* and defensive operations in the *air sea gap* to the north.[12] There was an emphasis on the need for maritime and air surveillance. DOA87 addressed the of broad area surveillance capabilities, including the Jindalee over-the-horizon-radar (OTHR) system.[13] DOA87 was a vehicle for the government to announce that it had instructed the Department of Defence to evaluate proposals from industry for AEW&C systems to complement OTHR.[14]

Collapse of the Soviet Union

The implosion of the Soviet Union in the early 1990s did not lead to a golden age of peace and stability. The clamour for a Peace Dividend (the transfer of resources from defence to welfare) flew in the face of the increasing instability around the world. The relatively stable global tension between the two superpowers and their alliance blocks was replaced by the chaotic resurgence of long-suppressed regional pressures.[15]

1994 White paper

[8] Cheeseman, *The Search for Self-Reliance,* p. 8.
[9] *Ibid.*, p. 8.
[10] *Ibid.*, p. 9.
[11] *The Defence of Australia 1987*, Department of Defence, AGPS, Canberra, 1987, p. 1.
[12] *Ibid.*, p. 31.
[13] *Ibid.*, pp. 34-36.
[14] *Ibid.*, p. 37.
[15] Hawke, A., *Address to the Royal United Services Institute (Victoria)*, 27 April 2000, p. 5.

In the Defence White Paper titled 'Defending Australia' (DA94), the Government refined the policy laid out in DOA87. In DA94 the emphasis was on the defence of Australia's geography, but there was also mention of the growing importance of commitments to '*regional engagement*' and *UN peacekeeping.*

1997 Ministerial Statements

In a speech to the Royal United Services Institute of Australia in Canberra in May 1997, the Minister for Defence stated the belief of the Howard Government that national defence strategy should aim at '*preventing attacks from reaching our shores ... rather than a narrow approach to the defence of Australia*'. The Minister stated that:

> *… the ability to operate our forces beyond our shoreline, if necessary, is an essential objective of our national defence policy. We are seeking security in and with Asia, not against the countries in our region*[16].

The Minister also emphasised:

> *… the importance of Australia being able to make a contribution to an expanded range of peacekeeping or enforcement actions by international coalitions*[17].

Less than three years later, Australia led an international coalition force into East Timor on a peace enforcement mission.

1997 Strategic Review

The 'Strategic Review' published in 1997 (SR97) formalised the Howard Government's new policy of more active defence and robust regional engagement. Australian defence policy could be characterised as having come full circle from the forward defence era of the 1950s and 1960s, through the continental defence era of the 1970s and 1980s, and back to a more outward looking policy.

There are essential differences between the old and new policies. The policy of the 1950s and 1960s was a Cold War strategy aimed at defeating the Communist menace, with Australia as a small player in the global Western alliance. The current policy charts a more independent course for Australia in the New World Order (some call it the New World *Dis*order). The policy sees Australia as a major partner in regional coalitions — even a coalition leader (as in East Timor).

Focus on the North

[16] Shine, C., 'Restructuring the Australian Army', *ADF Journal*, July / August 1998, p. 6.
[17] *Ibid*., p. 6.

In the 1970s, the bulk of the Australian Army, RAN and RAF were concentrated in the south-eastern corner of the continent, particularly in the Brisbane, Sydney and Melbourne regions. In keeping with current policy, the ADF has developed a chain of bases across the northern arc of the continent and moved much of its combat power to the north.

The Australian Army has deployed its only mechanised brigade from Sydney to the Darwin area. The bulk of the Regular Army's tanks (1st Armoured Regiment), Armoured Reconnaissance (2nd Cavalry Regiment) and Mechanised Infantry (5th/7th Battalion) with considerable artillery, aviation and support assets have moved north to establish Army's Presence In the North (APIN).

The RAN has deployed most of its patrol boats and heavy landing craft to the north (Cairns and Darwin) and has established a major fleet base near Perth, arguably closer to the likely AO. Fleet Base West (FBW) is now the homeport for half of the RAN's destroyers and frigates and all of its submarines.

The RAAF has built major bases in the north-west (RAAF Curtin), the Darwin region (RAAF Tindal) and Cape York (RAAF Scherger). A Hornet fighter squadron is now permanently based at Tindal.

The scenario for major ADF exercises is the deployment of most of the combat forces to the northern AO. Defence of the air sea gap is the usual mission.

In 1941, the US Pacific Fleet redeployed from its traditional home base on the US west coast (San Diego) to its forward base in Hawaii (Pear Harbour). The redeployment put the fleet within reach of a Japanese naval strike force. In spite of having an operational land-based early warning radar system, the Americans were caught by surprise when the Japanese launched a massive air attack. The rest is history.

A danger of deploying much of the ADF combat forces so far forward is that they are more vulnerable to attack than they would be in the south-east. The situational awareness provided by an AEW&C capability and associated systems should prevent a replay of Pearl Harbour.

CURRENT AUSTRALIAN DEFENCE POLICY

The Government has detailed Australia's current strategic policy in a 1997 document titled *Australia's Strategic Policy*, commonly referred to as ASP97. The policy defines three strategies for ensuring national security. These are Defeating Attacks on Australia, Defending Regional Interests and Defending Global Interests.

Defeating Attacks on Australia

The requirement to Defeat Attacks on Australia (DAA) is the least likely but most important and demanding contingency that the ADF could be expected to deal with. Government policy states: 'Australia must have the military capability to prevent an enemy from attacking us successfully in our maritime approaches, gaining a foothold on our territory or extracting political concessions from us through the use of military force'.[18]

The sensors, communications, and command and control capabilities of AEW&C would be essential in some DAA scenarios and very useful in most DAA scenarios. Most ADF air, land and maritime DAA operations would be enhanced by AEW&C. The DAA is a major justification for an ADF AEW&C capability.

If the need should ever arise to defeat attacks on Australia there should be sufficient warning to allow some expansion of the ADF to meet the threat. Understaffed units can be 'topped up' to full strength by quick recruit/train/qualify programs and accelerated promotion of serving personnel. Amongst the ADF's combat elements, this applies particularly to the bulk of the Army's infantry units, which will be tasked with static defensive roles such as Vital Asset Protection. The support services (clerical, catering, supply and maintenance) can be quickly expanded with personnel drawn from similar civilian employment areas.

However, AEW&C is a particularly complex capability. Many of the operator and maintainer skills associated with AEW&C take years to develop. These skills are perishable — they require constant practice or they are quickly lost. The ADF will take years to develop a mature AEW&C capability and to train other force elements to operate effectively with AEW&C support.

An operational AEW&C capability must be maintained in the peacetime ADF. There may not be enough time to hurriedly acquire an AEW&C capability after a specific DAA threat emerges.

Defending Regional Interests

Australia can not afford to act in isolation. Even the US relies on allies to share the defence burden. Any attack on Australia must either pass through, or originate from, the territory of our regional neighbours. Australia aims to maintain, 'a network of regional defence partnerships, wherein countries develop a shared sense of strategic perceptions and objectives and working levels of interoperability'.[19] This requires regular liaison and combined training to develop familiarity and teamwork.

The requirement to Defend Regional Interests (DRI) has generated more ADF effort and activity than the other strategies. In recent years it has led to ADF commitments in Cambodia, Bougainville, Papua New Guinea and East Timor. It has led to the forging

[18] *Australia's Strategic Policy*, Department of Defence, Canberra, 1997, p. 29.
[19] *Ibid.*, p. 32.

of links between the ADF and the defence forces of most of the nations in the region, including information exchanges, exchange postings, overseas training and combined exercises.

The nations in our region operate a wide variety of American, British, French, Russian and Chinese platforms and weapons. There is a wide variety of communications systems and different levels of technological sophistication. For example, a mixed force of Australian, Indonesian, Malaysian and Singaporean fighter or strike aircraft would have to overcome incompatible datalinks and voice radios, language barriers and doctrinal and procedural mismatches.

AEW&C would be a significant aid to interoperability in coalition operations. Australian AEW&C aircraft could coordinate the activities of aircraft and ships from many nations in the region. The resultant coordinated force would be far more effective than the otherwise disjointed ad hoc groupings.

Defending Global Interests

Global peace and stability create an environment beneficial to Australia. The United Nations (UN) is seen as an important focus of international efforts to preserve the peace. Australia has therefore supported the UN in many operations. The requirement to Defend Global Interests (DGI) has generated significant ADF commitments, including the large deployment to Somalia and smaller commitments in many other distant places, including Africa and the Middle East.

Since the collapse of the Soviet Union, the US is the world's sole remaining superpower. Australia has a strong strategic interest in 'the US accepting and being accepted in the global role that it has evolved over the past few years as the predominant support to an orderly international community, especially via the UN'.[20]

AEW&C can enhance interoperability in multinational DGI operations. American and NATO AEW&C aircraft have been essential participants in many recent UN operations and in many US-led coalition operations.

AUSTRALIA'S SOCIAL POSITION IN THE REGION

By many measures, Australia is the most powerful nation in the South-East Asia/South-West Pacific region. Australia is the richest nation in the region, with a GDP equivalent to the GDPs of all the ASEAN and South West Pacific nations combined. Australia has the largest and highest quality defence force in the region and has a wider range of capabilities than any other nation in the region.[21]

[20] *Australia's Strategic Policy*, p. 32.
[21] If the boundaries of the region are set to exclude India and Communist China.

In the same sense that the US is the natural leader of any Western coalition, Australia is the natural leader of any regional coalition. Unfortunately our leadership is not always politically acceptable. Like the Americans, we must be careful to avoid offending the cultural, religious, racial and historical sensitivities of our neighbours. Australia is predominantly Western in outlook, Christian and Anglo-Saxon. As a Dominion, Australia had privileged partner status within the British Empire. Australia has been a core member of the American-led Western alliance for over 50 years.

Our South-East Asian neighbours are predominantly Eastern in outlook, Islamic or Buddhist and Asian. Many people in Asia harbour a lingering resentment over their former status as colonies. ASEAN maintained a non-aligned stance during the Cold War.

Our South-West Pacific neighbours are often tribal in outlook. They have a diverse mixture of Christian and non-Christian religions. They are Melanesian, Micronesian or Polynesian. They have a history of economic and political dependence on the European colonial powers but many are anti-colonial and have perhaps unrealistic ambitions of total economic and political self-sufficiency.

Many people in the region see Australia more as a Western colonial power than a regional partner. We must therefore be careful to avoid being perceived as paternalistic and interventionist, which the Americans have been accused of being in Latin America.

AUSTRALIA'S POSITION IN REGIONAL COALITIONS

Most of the coalition operations since 1945 have been technically under UN auspices, but they have been effectively American-led operations. The Americans usually provide the bulk of the combat power, logistics and command and control. They also usually provide the overall strategy. Other nations contribute contingents that are often either niche forces or mere token forces. Since the collapse of the Soviet Union, the Americans have pressured allies to take a larger share of the burden.

Recent political debate in Australia has raised the issue of Australia assuming the leading role in regional security activities. There have been media references to Australia as a regional 'Sheriff' or a 'Deputy Sheriff' to the Americans. To many Australians and many people elsewhere in the region such a role is uncomfortably reminiscent of America' historical policy towards Latin America or of British, French and Dutch activities in the Asia/Pacific region during the colonial period. To some, it smacks of paternalism or even imperialism.

The Americans and Europeans have interests in the region and they will usually participate in regional coalition operations, but for many reasons they would prefer that regional powers take much of the burden. Often this will mean that Australia will be expected to perform the role previously performed by major global powers such as the US, Britain or France.

Whilst recognising regional and domestic concerns and sensitivities, Australia must by virtue of its wealth and power, be willing to assume a leadership role when

appropriate. Such was the case in the Timor crisis. Such will probably be the case again.

Coalition Operations under American Leadership

In 1990, the Australian government decided that it was in the national interest for the ADF to participate in the American-led coalition to contain Iraqi aggression to Kuwait (Operation Desert Shield) and later to free Kuwait from Iraqi occupation (Operation Desert Storm). The ADF leadership had to advise that the ADF's most potent force elements, the RAAF F-111 bomber and Hornet fighter forces, were incapable of participating. They lacked the EW Self Protection (EWSP) and even the communications links (datalink) to operate effectively or even safely with US/NATO forces in a 'world class' intensive threat environment.

The government was not impressed. Many politicians and some influential commentators wondered what Australia was getting for its annual $11 billion defence budget. The Australian contribution of two small destroyers (with organic afloat support) was little more than a token. The main coalition strike force for most of the campaign was an *air* armada of 2,000 aircraft.

In 1998, the Americans organised another coalition operation to punish the Iraqis for their refusal to cooperate with UN arms inspectors. The Australian government decided that ADF participation in the coalition operation was in the national interest. The Australian contribution to the coalition was limited to a pair of Boeing 707 AAR tankers and a small contingent of SAS soldiers. The tankers were of limited use to the Americans, and the SAS was apparently never called upon.

Desert Storm had clearly proven that western coalitions prefer to deploy predominantly *aerospace* forces, yet the RAAF's fighter and bomber forces were still incapable of participating in a 'real' war.

Australian AEW&C in Coalition Operations

Interoperability. Interoperability can be seen as simply operating the same equipment. New Zealand has acquired many weapons of the same type as Australia, including the Steyr rifle, the M-113 APC, the ANZAC class frigate, the C-130 Hercules transport and the P-3 Orion maritime patrol aircraft. However, the RNZAF fighter aircraft is the antique 1950s technology A-4 Skyhawk, which has little in common with the 1980s technology F-18 Hornet. The New Zealand Army operates the tiny British Scorpion light tank, which is in a totally different class to the formidable German Leopard medium tank.

Yet the Kiwi fighter and armoured forces manage a high degree of interoperability with the ADF. To be interoperable the forces of different nations do not have to acquire the same equipment.

The real key to interoperability is commonality of procedures and the familiarity that comes from working together regularly. Since 1914 Australian and New Zealand forces have operated together in war and peace. Ongoing combined exercises and exchanges of information and personnel keep the forces of both countries familiar

with each other. The adoption of similar doctrine and procedures enhances interoperability.

It would be impractical to train every pilot in every air element in the region to operate effectively with every other air force, army and navy in the region. The cost of the exercises would be orders of magnitude beyond current levels.

If Australian AEW&C aircraft are integrated into the current exercise program, over time the majority of regional pilots can become accustomed to operating with AEW&C assistance. Only the AEW&C community need be fully conversant with each air arm's idiosyncracies.

It would be prohibitively expensive to equip every aircraft in every air force, army and navy air arm for full communications interoperability. The cost of upgrading of many older aircraft types in service in the region would be far beyond the residual value of the platforms.

Many nations are finding it too demanding and expensive to keep up with the rate of modernisation being set by the Americans. Many of Australia's regional partners cannot afford to upgrade their older platforms with the latest communications systems, including Link 16 and the tactical intelligence datalinks. The Wedgetails will be equipped to be fully interoperable with most other regional aircraft, so they will be able to act as a link between regional forces and American forces. Often, the ADF will be more familiar with regional forces than the Americans can be. The Wedgetails can be the glue that cements regional coalition air operations.

There is no guarantee that the Americans will be available for every regional operation. The Americans may be overcommitted elsewhere and unable to assume a leadership role. In pursuit of their own national security objectives, the Americans may be unwilling to get involved in a particular situation. In such cases, Australia may have to assume a more prominent role. The Wedgetails will be capable of performing the same role that American AWACS would.

Political Considerations. A major reason for Australia's participation in coalition and UN operations is to establish our credentials as global good citizens, and thus accumulate 'credit points' to increase the likelihood that other nations will assist Australia. As a minimum, coalition leaders seek token commitments to increase the legitimacy of their operations by including as many nations as possible — sometimes referred to as 'more flags on the pole'.

Politics is often more a matter of perceptions than objective reality. Middle powers like Australia usually seek to contribute to coalition operations in a way that minimises the costs and maximises the benefits. The political costs of coalition participation go beyond financial matters and include casualties, domestic political opposition and social unrest.
In Operation Desert Storm, an Australian Hornet squadron would have been just one of dozens of coalition fighter units and an Australian F-111 squadron would have been just one of over a hundred strike units. Australia's small air defence and strike forces would have been lost in the mass of over 2,000 coalition aircraft.

AEW&C is a very valuable and attractive capability. Specialised support capabilities such as AEW&C, EW and tankers are always in short supply. AEW&C is seen by the major powers as a meaningful contribution to air operations. By committing a few AEW&C aircraft, Australia would appear to be a major player, rather than just being another 'flag on the pole'

The commitment of AEW&C is actually a very low risk option. AEW&C aircraft are usually kept out of harm's way and have the situational awareness to avoid the enemy. In contrast to ground operations, casualties are unlikely. AEW&C aircraft are less likely to be lost than aircraft in direct contact with the enemy, such as strike or air defence aircraft.

Communications. In coalition operations led by the US, the so-called 'minimum entry level' is Link 16. Without Link 16, aircraft will be unable to communicate effectively and will be almost useless. The cost of fitting Link 16 to all of Australia's Hornets, F-111s, Orions, Hawks, transport aircraft and helicopters would be prohibitive. Even if Link 16 were to be fitted to all of our platforms, the process would take several years. The Wedgetails will have Link 16 and a wide range of other communications capabilities fitted from the beginning. Australian AEW&C will be compatible with any Western coalition operation.

Survivability. Modern electronic warfare systems can protect combat aircraft from many threats and greatly enhance their survivability in the battlespace. Most ADF combat aircraft lack comprehensive state-of-the-art electronic warfare self-protection (EWSP) systems. The Wedgetails will be the first ADF aircraft to enter service with state-of-the-art EWSP systems. They will be able to operate in high threat environments, alongside the forces of the major powers.

THE APPLICABILITY OF AEW&C TO AUSTRALIA

Australia has limited defence resources. The ADF is faced with a very unfavourable force-to-space ratio and the need to defend long, exposed SLOCS that must pass through some of the world's most troubled waters. Australia has been forced to adopt a pro-active maritime strategy. In the trackless, hostile expanses of northern Australia and the vast maritime approaches, air power is the only realistic solution to many critical problems including surveillance, reconnaissance, air defence and command and control.

AEW&C is very flexible. AEW&C can enhance conventional military operations, encompassed in the DAA mission. AEW&C can enhance military support operations, encompassed in the DRI and DGI missions. AEW&C can enhance law enforcement operations and other civil activities.

AEW&C is a valuable enabler in coalition operations. Australian AEW&C will be a meaningful contribution to American-led coalition operations. Australian AEW&C will be a vital component in Australian-led coalition operations. Interoperability is essential in coalition operations. AEW&C is the glue that cements interoperability.

CHAPTER SIX

THE IMPACT OF AEW&C ON THE AUSTRALIAN DEFENCE FORCE

The Government and the ADF have long recognised the need for an AEW&C capability, which has been enjoyed by many other countries and which is essential for Australia's defence.

Air Marshal Errol McCormack
Chief of Air Force[1]

The Wedgetails will enter RAAF service in about 2005. They will have the capability to enhance most ADF air, land and maritime operations. This chapter will briefly describe how AEW&C may be used to enhance ADF operations. A range of options will be examined, but a distinction must be drawn between the wide range of missions that the Wedgetails could conceivably perform and those that will be tasked, practised and resourced.

With a fleet of only six or seven aircraft, there will rarely be more than two airborne on task. The Wedgetails' services will be in great demand and will have to be 'rationed' out to the highest priority bidders. It will not be possible to satisfy all demands. The Wedgetails will usually have to be focussed on only a few roles at a time, depending on national priorities.

The author does not claim to be an expert on the operations of the various force elements of the ADF. Many officers and senior airmen in operational units and staff officers in various headquarters and project teams have been interviewed. In all cases, the experts consulted were experienced operators. In many organisations, the senior executives were interviewed. Most of the enhancements to ADF operations suggested in this chapter are ideas raised in interviews with Army, Navy and Air Force warriors and leaders.

SUPPORT FOR AIR OPERATIONS

The *Airborne* Early Warning and Control capability will primarily enhance *air* operations. Australian air power consists of the RAAF, Army Aviation, the Fleet Air Arm, Government agencies (such as Coastwatch and the Police) and civil aviation assets including QANTAS, Ansett, regional airlines and general aviation. The RAAF is Australia's main generator of air power and conductor of air operations.

The RAAF Force Element Groups (FEGs) whose operations will be most profoundly enhanced by the AEW&C capability will be the three combat FEGs. These are Strike Reconnaissance Group, Tactical Fighter Group and Maritime Patrol Group. The other

[1] *Australian Defence Report*, 19 August 1999, p. 4.

RAAF FEGs, Air Lift Group and Combat Support Group, will benefit indirectly from the AEW&C capability.

STRIKE RECONNAISSANCE GROUP

The F-111 Fleet

The Strike Reconnaissance Group (SRG) operates a fleet of General Dynamics F-111 bombers. The F-111 was conceived in the early 1960s as a multi role fighter-bomber. After technical problems and associated bad publicity, the F-111 matured into an outstanding strike aircraft.

F-111C. The original batch of 24 F-111Cs was ordered in 1963, built in 1968 and delivered in 1973.[2] Most have since been fitted with Pave Tack laser targeting pods, which facilitate very accurate delivery of laser-guided bombs (LGBs). The Pave Tack pod is about the size of a 2,000 pound bomb and fills the bomb bay of the F-111, so all weapons must be carried externally, on pylons under the wings.

In 1982, four ex-USAF F-111As were acquired to replace F-111Cs lost in accidents. The F-111As have since been modified to be virtually identical to F-111Cs. The role of the F-111C is long range precision strike. F-111s can strike targets on land (land strike) or at sea (maritime strike).

RF-111. Four F-111Cs have been fitted with photoreconnaissance pallets, which are a permanent fixture in their bomb bays. The sensors fitted include two video cameras, two vertical still cameras, two panoramic still cameras (high and low altitude) and an infra-red line scanner. The image on the attack radar display can also be recorded.[3] The reconnaissance pallet fills the bomb bay, so the RF-111 has a reduced weapons load and is not fitted with Pave Tack. The role of the RF-111 is reconnaissance.

F-111G. In 1993, 15 ex-USAF F-111Gs were acquired to spread the wear and tear of normal peacetime usage over a larger number of airframes and thus extend the life of type of the fleet.[4] The F-111Gs are former USAF Strategic Air Command bombers, originally designated FB-111As. They lack the Pave Tack system and are more suited to the delivery of unguided bombs. The F-111Gs are used primarily for training.

Recent Developments and Plans

More recently the RAAF acquired a number of airframes and a large number of spare engines from surplus USAF stocks in storage in the US. The RAAF now has adequate stocks of F-111 spares to keep the aircraft in service for decades. The current RAAF operational F-111 fleet totals 33 aircraft, including 17 F-111Cs, 12 F-111Gs and four RF-111s.[5]

The RAAF weapons inventory now includes the Lockheed Martin/Rafael AGM-142 air-to-ground missile. The AGM-142 has a 340 kilogram high explosive warhead,

[2] Wilson, S., *Military Aircraft of Australia*, Aerospace Publications, Canberra, 1994, pp. 123–124.
[3] Lake, J., 'Aussie Aardvarks : General Dynamics F-111', *Air International*, April 2000, p. 222.
[4] Wilson, *Military Aircraft in Australian Service*, pp. 124–125.
[5] *Australian Defence Report*, 19 August 1999, p. 4.

capable of penetrating hard targets such as concrete bunkers.[6] The weapon has a range of about 85 kilometres. It gives the F-111 a highly accurate stand-off capability and a world class 'hard target' killing capability.

The F-111 has much longer range and greater payload than any other RAAF strike aircraft. It is also the fastest aircraft in the RAAF inventory. In spite of its age the F-111 remains a very effective strike platform. American F-111s flew hundreds of successful precision strike sorties in Operation Desert Storm. The RAAF intends to keep the F-111 in service until the year 2020, by which time the aircraft will be over 50 years old.

The F-111 is Australia's only strategic bomber, but it was only ever one of many bomber types in the USAF, which still operates about 200 strategic bombers (about 90 B-52s, 90 B-1s and 20 B-2s). The USAF retired its F-111s from service for financial reasons. The Americans wanted to reduce current running costs to make funds available for force modernisation. The USAF F-111's strike role is now performed by the F-15E Strike Eagle, which is a strike version of the F-15 Eagle air superiority fighter.

Traditional F-111 Operations

The traditional F-111 strike mission has been a single aircraft flying at night or in foul weather, avoiding radar detection by flying very low, guided by Terrain Following Radar (TFR). The TFR emits a beam that is focussed on the ground and there is little chance of TFR emissions being detected. All other emitters (communications systems, navigation radar and attack radar) are used as little as possible, to avoid detection.

In Operation Desert Storm, Coalition forces enjoyed overwhelming air superiority and the greatest threat to friendly aircraft was the mass of relatively simple short range anti-aircraft weapons deployed by Iraqi forces. USAF F-111s flew in packs (strike packages) at medium altitude and were supported by large numbers of tankers and aircraft specialised in Electronic Warfare (EW) and Suppression of Enemy Air Defences (SEAD). Missions were still flown at night and large numbers of Precision Guided Munitions (PGMs) were used.

RF-111 missions also tend to be single aircraft sorties where surprise and speed are relied on to avoid enemy countermeasures. RF-111s are used for pre-strike reconnaissance, post-strike Bomb Damage Assessment (BDA) and more general reconnaissance missions.

Such has been the quality and size of air forces in the region that RAAF F-111s have been unlikely to encounter opposing fighters, so they have not required fighter escort. The RAAF has no air-to-air tanker capable of refuelling F-111s. In the absence of sophisticated GBAD or IADS in the region, the RAAF has not needed specialised EW

[6] *Jane's Air Launched Weapons*, March 1998, Issue 29.

or SEAD aircraft to support F-111 operations. RAAF F-111s have thus been 'lone wolves'. They approach their targets covertly and rely on surprise and speed to avoid enemy defences.

In the land strike role, the target will usually be fixed, such as a bridge, command centre, airfield or power station. Strikes against fixed targets can be planned in detail before take-off. The locations of defending missile batteries and anti aircraft guns should be known and factored into the pre-planned ingress and egress routes. The type of support required from other aircraft ('non strikers') is currently limited to reconnaissance, to provide the F-111 with the data to identify its target.

In the maritime strike role, the target is usually moving (a ship), so the targeting and routing problems are dynamic. The F-111 will need help to find the target and the defences may include mobile missile and gun platforms (warships). RAAF Orion maritime patrol aircraft often assist in F-111 maritime strike operations by locating and tracking target ships and guiding the F-111 to the vicinity. The Orion's endurance allows it to shadow a ship for hours, while remaining outside the ship's missile engagement zone (MEZ).

Lacking the physical mass of the USAF bomber forces, the RAAF F-111 force relies heavily on precision guided munitions (PGMs) to achieve mass *effect*. In the early stages of the air war in Vietnam key bridges survived mass attacks, involving hundreds of USAF F-105 fighter-bombers, each carrying many bombs. In the later stages of that war, a target could be destroyed by a single F-111 with a single PGM.

A Laser Guided Bomb (LGB) can be released from a range of a few kilometres, but the target must be illuminated by a laser designator, which can be on the F-111, another aircraft or the ground (Army personnel). An AGM-142 can be released from a range of as much as 80 kilometres and uses mid-course autonomous inertial guidance and then homes in on the target using imaging infra-red (IIR) or television (TV) guidance.

The AGM-142 is a true stand-off weapon (SOW) and is largely autonomous of the aircraft after launch. If a target is well defended by SAMs, an F-111 can launch an AGM-142 from a safe distance, outside the MEZ, and then escape. The F-111 may not be detected by the enemy until after weapons release. LGBs must be delivered from much closer in and the F-111 may have to loiter in the area to illuminate the target. Stand-off weapons reduce the risk to strike aircraft. A small bomber force can not afford attrition.

Some Ways AEW&C Can Enhance Strike Operations

RAAF F-111 crews look forward to having AEW&C support. Linkage to the Wedgetail will expand the situational awareness, flexibility and communications capability of F-111s.

Situational Awareness. A lone F-111 hurtling through the night at low level has limited situational awareness. The crew are virtually blind to any unexpected threat, such as a fighter, a SAM site or a radar site. Over water, a low flying F-111 may have no more warning of a nearby warship than the ship has of the F-111.

The F-111s currently have limited ESM in the form of the ALR-62 Radar Warning Receiver (RWR). RWRs warn the crew if a radar illuminates the aircraft and can give an indication of the type of radar and the direction from which the radar beam is coming. This can help the F-111 crew assess the threat and act accordingly.

In the endless contest between measure and countermeasure, ESM systems need regular upgrades or they become useless. There are plans to fit ALR-2002 RWRs to the F-111s. The prototype of ALR-2002 will be tested in the year 2000. If the ALR-2002 is successful, it will be fitted to the F-111 fleet over the next few years. It will be better than the old system, but far less capable than the ALR-2001 fitted to the Orions and Wedgetails.

The F-111s could gain far more information about the battlespace around them from the Wedgetail. There are plans to fit the F-111s with Link 16 (JTIDS). The F-111 fit would be 'receive only' mode. No firm deadline has been set for Link 16 installation.

The mass of tactically useful information available from many sources could be transferred to an F-111 via JTIDS, without the F-111 having to reveal its position by transmitting. The XO of one of the F-111 squadrons indicated the importance he attaches to such a capability by saying that he would like a large JTIDS display in the centre of the cockpit and that it would be his primary sensor and tactical guide.

Flexibility. Good mission preparation includes detailed planning and the planners try to anticipate every contingency. However, operational scenarios are dynamic and the unexpected can occur. Flexibility is one of the greatest qualities of air power.

Once an F-111 strike mission is underway it is difficult to change the plan. The Wedgetail will be capable of providing real time updates during strike missions. These updates can include weather reports, threat information and information on friendly forces.

In the Australian AO the weather can change significantly, much faster than the response times of conventional weather prediction and reporting services. The Wedgetail will be able to see weather developing over the route to and from the target and over the target area. Weather reports may impact on ingress/egress route choice or even target choice.

Enemy deployments and activities can also change significantly in a short time. During a mission, the Wedgetail can directly observe enemy air activity in the vicinity of friendly air operations (with its radar and other sensors) and the activities of enemy GBAD (with its ESM system). If the nature of the threat changes from that for which mission planners had prepared, the Wedgetail can inform strike crews of the new situation. The mission plan can then be modified. For example, if a SAM radar is detected dangerously close to the planned ingress route, the Wedgetail could warn the

strike crew and recommend a safer route. Such threat avoidance information will increase strike aircraft survivability.

When strike aircraft are operating in the vicinity of friendly missile launchers (in the form of fighters, warships or GBAD) there is always the chance of a tragic error. An F-111 could be mistakenly identified as a threat and shot down. The MEZs around warships are particularly dangerous places for aircraft.

Like F-111s, warships often seek to avoid enemy detection by not transmitting with their communications equipment or radars (electronically silent). This is known as emission control (EMCON). When F-111s are transiting through the MEZ of warships under EMCON the aircraft and the ships need to communicate to establish identities and safe lanes of passage. Communications between ships and aircraft are often imperfect. Their voice radio systems are often incompatible and most warships use Link 11, while most aircraft use Link 4A or Link 16.

The Wedgetail will be equipped with a full range of radios and Links 4, 11 and 16. It could do all the communicating and thus obviate the need for the F-111s or the warships to transmit, while also increasing both platforms' level of certainty about each other's identity and location.

The ability to retask strike aircraft after they have departed on a mission would increase the flexibility of air power. A small strike force cannot afford to waste sorties. A simple example of a tasking change would be an instruction to forget the planned primary target and proceed directly to a planned secondary target, because the primary target has just been eliminated by other means. A more complex change might involve passing the mass of data associated with the mission plan for a new target.

Once a strike force has flown beyond the horizon, updating the mission plan or changing it can be difficult. A nearby supporting Wedgetail could relay tasking changes in the format required by the strike aircraft, via datalink. The strike aircraft would not need to emit.

Communications. The flight profile of the traditional F-111 strike keeps the aircraft very low. At low altitude, the F-111 has very limited communications capability. The Wedgetail will be capable of performing a wide range of relay services, including:

a. communications relay between platforms in a strike package or between the strikers and NORTHROC (or headquarters, including HQAST and HQSRG);

b. data relay, where the AEW&C acts as the data fusion centre for strike ops;

c. direct data transfer, to share target info across the force, via AEW&C; and

d. imagery relay, for functions including pre-strike reconnaissance and post-strike BDA.

Tactical Situations

Air Control in Benign Environments. The F-111 can be fitted with air-to-air missiles (AAMs) and can perform the long range air defence mission. However, the F-111 is not a very manoeuvrable dogfighter, so this would only be done in cases where the mission is beyond the range of available Hornets and the threat environment is benign (there are no enemy fighters).

In one such scenario, enemy long range maritime patrol (or strike) aircraft could be shadowing RAN warships in the open ocean, beyond the range o RAAF Hornets or any other friendly fighter support. The enemy aircraft could follow our ships for long periods with impunity, by loitering outside their MEZs. The enemy aircrew would be confident that no fighter could reach them. An F-111 armed with AAMs could engage the shadowers. In such as case, the F-111 would need the support of a Wedgetail to arrange the intercept and surprise the shadowers. There would not be a CRU available.

In another scenario, Hornets on CAP missions might have difficulty filling the gap between the RAAF bases at Tindal and Curtin. An F-111 armed with AAMs could loiter longer than Hornets and engage unescorted reconnaissance or strike aircraft that were hoping to avoid the Hornets. A few F-111 sorties might save the Hornets having to make far greater rates of effort or free Hornets for other missions. In such a case, the F-111 would need the support of a Wedgetail to arrange the intercept and surprise the raiders. There would not be a CRU available.

Sensor-to-Shooter Relay. In a high threat area it may be preferable to have a relatively expendable UAV loitering and acting as the sensor platform to locate and fix targets. Less expendable manned strike aircraft need not be exposed. The strike aircraft may be an F-111 armed with an AGM-142 stand-off weapon. A supporting Wedgetail could control the UAV and relay the target data from the UAV (sensor) to the F-111 (shooter). The F-111 could then launch the weapon from long range, without entering the high threat area.

Third Party Targeting. Orions have a very long loiter capability and are thus best suited to shadowing enemy ships in the open ocean, far from land bases. F-111s have great speed and weapons capability and are thus best suited to the strike mission. A supporting Wedgetail could relay the Orion's picture of the target area to the F-111 and enable the F-111 to launch its stand-off weapons from beyond the range of its own sensors. The F-111 need never get close to the enemy ships' MEZs.

Surprise. One of the principles of war is surprise. An Orion and a Wedgetail (or two Orions) could loiter hundreds of kilometres from enemy ships and could passively locate and fix a target using their ALR-2001 ESM systems. The Wedgetail could relay the target data to an F-111, which could then launch a stand-off weapon from a safe distance. The weapon would arrive at the target without warning, as there would be no attack radar emission from any aircraft.

TACTICAL FIGHTER GROUP

The F/A-18 Fleet

The Tactical Fighter Group (TFG) operates a fleet of about 70 McDonnell Douglas F/A-18 Hornets. The fleet consists of 55 single seat F/A-18As and 16 two seat F/A-18Bs. The Hornets were delivered over the period 1984 to 1990.[7] Several of the avionics systems on the RAAF Hornets have been upgraded to F/A-18C standard.

There are plans to fit the Hornets with Link 16 in the near future. They may have Link 16 by the time that the Wedgetail AEW&C Boeing 737s enter service in 2004–2005.

Traditional Fighter Operations

Key issues affecting fighter operations include rate of effort, weapons, rules of engagement, sensors political imperatives and CRU support.

Rate of Effort. Like all modern American fighters, the Hornet has an excellent air search radar. However, in the air defence role the Hornets still rely on the support of a CRU.

Airborne Alert. In the traditional air defence operation, a fighter squadron and a CRU will be dedicated to defending a vital asset, such as a city or key base. In periods of very high tension, a pair of Hornets would be airborne continuously on Combat Air Patrol (CAP). The CRU would detect and identify all aircraft in the area and guide the Hornets into a position from which they could successfully engage any enemy aircraft. Depending on the scenario, a CAP may be required for weeks or even months, but incursions by enemy aircraft may be few and far between.

Maintaining a continuous CAP for weeks is a very expensive solution. A Hornet sortie lasts only a few hours, so many sorties must be flown each day. Tanker support can enable aircraft remain to airborne for longer periods, but the costs go beyond the large amounts of fuel that will be consumed. Significant maintenance effort (labour and spare parts) will be required and pilots will be fatigued.

In Operation Desert Shield, USAF fighter pilots had to maintain continuous CAP over large areas for almost six months. USAF Flight Surgeons had to prescribe drugs for the pilots. They took stimulants to keep them alert when flying and sleeping pills to help them rest. Even under close medical supervision, extended periods on such drugs can have serious side effects. Error rates increase. A small pilot force can be worn down by such activity.

Ground Alert. It would be much cheaper to keep the Hornets on the ground and only launch when there is an identified threat. However, the horizon limitation on land-based radar creates the old problem of warning time. Enemy aircraft can approach at low level and get close to the defended point before being detected. Modern high speed aircraft can strike with conventional weapons (such as gravity bombs and glide

[7] Wilson, *Lincoln, Canberra and F-111*, pp. 146–147.

bombs) and escape before the Hornets waiting on the ground can be launched to intercept them. Modern stand off weapons can be launched from outside ground-based radar detection envelopes.

An enemy can wear down a defending fighter force by pretending to attack but breaking off and retreating when defending fighters are launched. The short warning times given by ground-based radar will force the defenders to react to every incursion.

Many studies have tried to determine the optimal mix of airborne CAP, ground alert, tanker support and AEW&C coverage. The balance is different for each scenario.

Beyond Visual Range Weapons. RAAF Hornets are equipped with the latest American AIM-120 AMRAAM air-to-air missile. AMRAAM has a range of 50 kilometres, which is beyond visual range (BVR).[8] The Hornet's radar can 'see' even further.

Fighter pilots prefer to destroy enemy aircraft from as great a distance as possible and without warning. The closer a fighter gets to its target, the greater the chance that the target will become aware of the threat and either escape or fight back. A close range 'dogfight' between modern fighters is often a fairly even match. A small fighter force cannot afford the attrition inherent in fair fights.

The radar emissions from a CRU are overt and any aircraft that the CRU radar can detect should be aware of the CRU radar. Any Hornets under the control of the CRU can keep their location and intention secret by not emitting.[9] The Hornets can rely on the CRU to direct them towards the target and then let them illuminate the target with their own radars, just before they fire their missiles. If the only radar emitting is the CRU, an enemy cannot know how many fighters are in an area or precisely where they are.

Rules of Engagement. The decision to fire a missile at a target is a very serious matter and there are procedures to prevent errors. Even in wartime, airspace is often cluttered with innocent civilian traffic and friendly or neutral military aircraft. Rules of Engagement (ROE) specify the conditions for opening fire and the key issue is identification. The target must be positively identified as hostile before it can be engaged.

Target Identification. Traditionally, positive identification has been synonymous with visual identification (VID). The pilot has been required to get close enough to see the target and confirm its identity by its shape and markings. Long range cameras have been fitted to some aircraft to extend the range of VID and to provide a video record, in case it is needed for use as evidence in court.

Technology has provided electronic alternatives with far greater range than the human eye or a long range camera. A blip on a radar screen cannot be positively identified on

[8] *Jane's Air Launched Weapons*, November 1998, Issue 31. AMRAAM is the Advanced Medium Range Air to Air Missile. AMRAAM replaced the old AIM-7 Sparrow missile in the RAAF inventory.
[9] Unless the enemy fighters have radars that can detect the Hornets or the enemy force has AEW&C support. Also, effective enemy communications intelligence could detect ADF aircraft by their breaches of communications security and emission control.

the basis of its location and movement, but other sensors can provide accurate identification. Electronic identification (EID) can be made, using a range of sensors.

Identification Friend or Foe. Identification Friend or Foe (IFF) is an automatic system fitted to all military aircraft and most commercial aircraft. IFF equipped military aircraft can 'interrogate' each other and identify each other.[10] The system works well and military aircraft can use codes to avoid subterfuge, but military aircraft often fly with their IFF switched off, particularly in wartime. The US Army Blackhawk helicopters that were mistakenly shot down by USAF fighters in Iraq were flying with their IFF switched off.[11]

Electronic Support Measures. Modern ESM systems can identify radar types. If a particular radar type is unique to a particular platform, the ESM system will provide reliable EID. Even if a particular radar is fitted to several types of platforms, good intelligence of platforms in the region will allow identification by process of elimination and situational awareness. The great advantages of ESM are that its range exceeds that of the radars being identified, it is passive and covert.

Synthetic Aperture Radar. Synthetic Aperture Radar (SAR) can generate a profile picture of a target. If the target is a ship, the profile will often be enough to give a reliable EID. SAR can provide EID at long range, but its emissions make it an overt system. Naval vessels and military aircraft are usually fitted with Radar Warning Receivers (RWRs), which will automatically alert crew that a radar is illuminating their platform. The target's own ESM system may then identify the SAR and its platform.

Political Imperatives. The politicians who authorise ROE are usually very cautious about the issue of identification. They usually do not understand or trust EID and demand VID. The accidental destruction of an Iranian airliner by the American missile cruiser USS Vincennes in the Persian Gulf was a public relations disaster that politicians will cite as an example of the unreliability of EID technology.Political constraints can lead to difficult, even unworkable, ROE. Bad ROE can cause unnecessary risk to friendly forces.

CRU Support. A limitation on ADF air defence operations is the shortage of CRU support. The RAAF has only three CRUs (2 CRU, 3 CRU and 114 Mobile CRU). Even the mobile CRU cannot move quickly and takes time to set up at its new location. The six Adelaide class and eight ANZAC class frigates of the RAN have CRU capabilities and are more mobile than the RAAF land-based CRUs. However, the ships move slowly and may not be able to operate in the ideal location, due to enemy submarines, mines, dangerous shallows or a more urgent mission elsewhere.

[10] Civilian IFF systems just transmit a code. They do not actively interrogate other IFF systems. The purpose of civilian IFF is to inform ATC and avoid collisions.
[11] For a more detailed account of this tragedy, see Chapter 3.

In many cases, Hornets can deploy to an area and begin flying CAP faster than CRU support can be established. After the Iraqi invasion of Kuwait in 1990, the first USAF combat deployment of operation Desert Shield consisted of a squadron of F-15 fighters and a detachment of AWACS.[12] Without the CRU support provided by the AWACS, the fighters would have been much less effective.

Some Ways AEW&C Can Enhance Fighter Operations

Air Defence. In an air defence operation Hornets may be on alert on the ground or airborne on CAP. The CAP can be defending a point directly or at a distance by defending a barrier (BARCAP). A point CAP may be protecting a city (such as Darwin), base (such as RAAF Tindal) or some other vital asset (such as a port facility or the processing plant at a mine). The point defended may be overseas, during a UN or coalition contingency.

A BARCAP may defend a line set between the expected threat and whatever is to be protected. An example would be a 300 kilometre line running from east to west, with the centre of the line being 100 kilometres north of Darwin. Depending on the point of origin and range of enemy aircraft, preventing them from breaching the barrier may protect all of the Northern Territory.

A BARCAP may protect a group of ships at sea. The group may consist of a fleet of warships, a convoy of merchant ships or a combination of both. The ships may be conducting civil trade (mineral or agricultural exports or oil imports) or conducting a military operation (amphibious lift or sea control).

In any air defence operation there will be a limiting factor on how long the operation can be maintained. The limiting factor may be aircrew fatigue, aircraft attrition (accidents), aircraft wear and tear (maintenance effort) or just the financial cost. The impact of all of these factors can be reduced by AEW&C support. AEW&C support can permit lower levels of alert.

Levels of Alert. Airborne CAP is the most expensive level of alert and generates the greatest wear and tear on men and machines. Five minute alert may involve having the pilot sitting in the cockpit; the aircraft at the end of the runway ready to launch, armed and fuelled and with the engines at idle. Fifteen minute alert may involve having the pilot near the aircraft, resting in comfort; the aircraft may be on the normal flight line, armed and fuelled but not actually running.

In a given scenario, airborne CAP may be required in the absence of AEW&C support, but five minute alert or fifteen minute alert may be possible with AEW&C support. The cost savings and force preservation benefits can be significant over the long term.

Surprise. Most modern combat aircraft are fitted with ESM systems that warn the pilot if a radar beam illuminates the aircraft. These radar warning receivers (RWRs) usually give an indication of the type of radar and hence the nature of the threat. If a fighter is using its air search or fire control radar, an enemy fighter's ESM can be

[12] Mann, pp. 130–131.

expected to detect the emissions, at a greater range than the emitter can detect the radar return. The emitting aircraft will have given away its position, while the detecting aircraft can remain passive and undetected. The emitting aircraft is at a disadvantage when seeking to surprise an adversary in an air-to-air engagement.

In many of the contingencies envisaged for ADF operations, the Wedgetails will maintain a continuous surveillance presence. Adversaries will become accustomed to the signature of the Wedgetail's radar and communications systems. The mere fact that the Wedgetail's radar and communications systems are emitting will not necessarily indicate that ADF or other friendly aircraft are engaged in any particular activity in any particular location. With its 'God's eye view' of the battlespace, a Wedgetail will be able to guide a Hornet to an intercept in a good ambush position, without the Hornet needing to turn on its active radar or communication systems. The first indication that an enemy fighter pilot will have of the Hornet's approach will be a fire control radar snapping on, as a missile is fired from a good position.

A fair fight can end in success or failure. The result will hinge on pilot quality, equipment quality and luck. A well-laid ambush is more likely to lead to the destruction of the enemy for no loss to friendly forces. A small air defence force can not afford attrition.

Pilot Situational Awareness. Fighter pilots must be aggressive to achieve their mission, but they must not disregard their own safety and blunder around fearlessly. The Wedgetails will give RAAF fighter pilots the best situational awareness they have ever enjoyed. Greater situational awareness will make them more confident. Increased confidence will lead to greater aggressiveness, without increased risk. The AEW&C capability can increase fighter pilot aggressiveness while at the same time increasing their safety.

Battle Manager Situational Awareness. The Wedgetails will have a much larger view of the battlespace than surface based microwave systems, without the loss of detail and precision associated with OTHR. Airspace managers will be able to have finer margins for error in airspace management. Battlespace managers will be able to see all enemy air activity at all altitudes out to greater ranges. Air defence assets (fighters and SAMs) can be cued or sequenced more tightly and used more efficiently, as there will be fewer surprises and more time to organise the action.

Strike. Just as F-111s can perform the air defence mission (in some scenarios) Hornets can perform the strike mission (though not as well as the F-111). US Navy Hornets are primarily strike assets and did the job well in Operation Desert Storm. Following the American model, Hornets could operate far out into the region, supported by tankers and Wedgetails.

AEW&C would have the same advantages on a Hornet strike operation as it would on an F-111 strike operation. These would include threat updates, weather updates, force coordination, tasking changes, sensor-to-shooter relay and increased chances of achieving surprise.

MARITIME PATROL GROUP

The Orion Fleet

The Maritime Patrol Group (MPG) operates two squadrons of Lockheed P-3C Orions. The first squadron batch of P-3Cs was delivered to Number 10 Squadron in 1978/79. The second squadron batch was delivered to Number 11 Squadron in 1985/86.[13] The Orions will probably remain in service until after the F-111s and Hornets are replaced in the year 2020. The Chief of Air Force (Air Marshal McCormack) has said that: 'The Life-of-Type is 2015 and with no obvious replacement in sight … we'll probably have to extend their life as much as we can'.[14]

The Orions are undergoing an extensive mid-life update and upgrade to AP-3C standard. The whole Orion fleet will be upgraded by the time the Wedgetails enter service. The new standard retains the original acoustic sensors for ASW, but replaces the acoustic data processing system with a more capable system. The radar system will be significantly upgraded, from a simple surface search radar to a much more modern SAR/ISAR. The new radar will facilitate improved terrain mapping and imaging, enabling it to picture a ship's profile for identification.

Identification Technology

A recent upgrade included the installation of a fourth sensor station to manage the non-radar/non-acoustic sensors. These sensors include an ESM system for passive EID and an Infra- Red Detection System for passive VID at night. A future option is a long range video system, for passive VID in daylight, from a safe distance.

The ALR-2001 ESM system fitted to the Orions is similar to what will be fitted to the Wedgetails. With a comprehensive 'library' of radar signatures for comparison, the ALR-2001 should be capable of identifying individual radar types. The ESM system will be able to identify a target (such as an ANZAC class frigate) on the basis of the radar type detected and previous intelligence of which regional platforms mount that radar system.

Stand-Off Weapons

RAAF Orions have been fitted with the McDonnell Douglas AGM-84 Harpoon anti-shipping missiles since the early 1980s. The Harpoon carries a 220 kilogram high explosive warhead and has a range of 120 kilometres.[15]

Under Project Air 5418, the RAAF is investigating the possibility of acquiring a family of state-of-the-art stand-off weapons. One of the family may be a long range anti-radar missile to complement the Harpoon.[16]
The true potential of such BVR weapons cannot be realised if traditional VID rules are applied. The AP-3C will have several long range EID capabilities that will often

[13] Gillett, R., *Australia's Military Aircraft*, Aerospace Publications, Sydney, 1987, P. 106.
[14] *Australian Defence Report*, 19 August 1999, p. 4.
[15] *Jane's Air Launched Weapons*, July 1998, Issue 30.
[16] Ferguson, G., 'Australia Creeps Towards Missile Purchase', *Australian Defence Magazine*, October 1999, Yaffa Publishing, Sydney, p. 6.

enable it to make adequate EID and launch a stand-off weapon from a safe distance. A small maritime strike force can not afford attrition.

Orion Maritime Patrol Operations

Change of Emphasis. During the Cold War the most important roles of the Orion were anti-submarine warfare (ASW) and maritime strike (anti-shipping). The American-led Western alliance relied heavily on sea trade and adopted a maritime strategy designed to ensure sea control. The Soviet-led Warsaw Pact adopted a sea denial strategy based primarily on large numbers of submarines.[17] Western maritime forces were organised into a global network that sought to track Soviet submarines from the moment they left port until they returned to port.[18]

Australian Orions operating out of Australia and Malaysia, patrolled the archipelagic waters to the north, filling the gap in coverage between USN Orions operating out of Japan, Hawaii and the Philippines in the Pacific and Diego Garcia in the Indian Ocean.

During the 1980s, the value of the resources in Australia's Exclusive Economic Zone (EEZ) came to be appreciated and EEZ protection became a political priority. Orion patrols were integrated with the activities of RAN patrol boats and government agencies including Police, Customs, Quarantine and Immigration. The targets of all this protective activity included illegal fishing vessels, illegal entry vessels (drug and people smugglers) and any other activity harmful to the EEZ, such as pollution.

As part of Australia's foreign aid program, Orions also patrolled the EEZs of the impoverished microstates of the Western Pacific. These nations have tiny landmasses and populations, but huge EEZs and great potential wealth.

The implosion of the Soviet Union ended the Cold War and virtually eliminated the submarine threat. In the 1990s the world has focussed more on economic issues. EEZ protection, drug smuggling and illegal immigration have taken precedence over ASW and maritime strike. The Orions now spend much of their time on surveillance duties in the northern approaches to the continent. MPG still devotes resources to maintaining ASW and strike skills and continues operations out of Malaysia.

Mission Profiles. The Orions are based at RAAF Edinburgh, near Adelaide. They often fly long transit flights cruising at high altitude, but in their operational roles they spend much of their time flying at low level (below 1,000 feet) and medium level (up to 10,000 feet).

On a typical maritime strike sortie an Orion would approach the target at low level to avoid detection and pop up only for occasional radar sweeps and to launch stand-off weapons, before escaping at low level. On an ASW sortie an Orion will often fly low in order to launch sonobuoys to acoustically detect submarines, use its magnetic

[17] The Soviets also had large numbers of maritime strike aircraft and warships, but vastly superior US forces would have easily overwhelmed the aircraft and ships. The Soviet submarines were the main threat at sea.

[18] Ball, D., *Provocative Plans*, Strategic & Defence Studies Centre, Australian National University, Canberra, 1991.

anomaly detector (MAD) to magnetically detect submarines, visually search for periscopes and launch ASW torpedoes. On mining sorties Orions must fly low to drop the mines. On EEZ patrol Orions often fly low to identify vessels. On SAR Orions often fly at low level to locate small vessels in distress or life rafts, often in rough seas and foul weather.

Communications. Orions have a range of HF, VHF and UHF radios. When operating alone or with other aircraft, HF communications are used. When operating with surface forces, VHF/UHF will often be necessary. The range of VHF/UHF communication equipment is limited to the nearby horizon (line-of-sight). An aircraft on a low level task must climb higher to conduct VHF/UHF communications with distant units. Time would be wasted descending to perform the task, climbing out to communicate with other units and descending again to return a low level task.

Survivability. An Orion has no active defence against a missile or a combat aircraft. A fifty year old attack aircraft, such as a little A-4 Skyhawk, can destroy an Orion with its World War Two vintage guns. Orion must either avoid detection or keep a safe distance from threats as they lack the speed to outrun modern fighters.[19] Orions usually avoid emitting whenever possible and rely on their passive EW sensors to detect enemy aircraft and ships at sufficient range to enable them to avoid detection.[20]

Situational Awareness. If it is not using its own radar, the situational awareness of a low flying Orion is limited to detecting ships and aircraft that are emitting with their radar or communications. Platforms that are not emitting will not be detected until they are within visual range.

An Orion can use its own radar if the nature of the threat is known, from intelligence reports or the observations of other friendly forces in the vicinity. In operations against ships or submarines, an Orion is safe as long as it remains aware of and outside the Weapons Engagement Zone of any enemy ships in the area. The Orion's radar has no air search capability, therefore it is useless for detecting aircraft.

Some Ways AEW&C Can Enhance Maritime Patrol Operations

The Orion fleet is about three times the size of the Wedgetail fleet, so the Orions will continue to be the workhorses of RAAF surveillance in the air sea gap and beyond. The Wedgetails will be in demand for many tasks and will not be able to spend as much of their time on maritime surveillance as the Orions. Depending on the scenario, the Orions will often work without Wedgetail support.[21]
When Wedgetail support is available it will confer the same advantages on maritime operations as it will on strike and air defence operations. These will include the usual situational awareness, flexibility and communications advantages. An aspect of enhanced communications likely to be unique to the Orions (and perhaps the RF-111s) will be imagery relay. Much of the imagery collected by Orions may be able to

[19] If an Orion becomes aware of an approaching fighter soon enough, it can use its superior endurance outlast slow fighters, which often lack the fuel to close the gap in a timely manner.
[20] An Orion may use its radar intermittently. The target may know that the Orion is out there but will be unable to track it with ESM. It will appear to pop up in different locations and may even appear to be more than one aircraft.
[21] In some surveillance operations in the air sea gap, Orions may get priority for AEW&C support.

be relayed, via satellite and/or Wedgetail. The Americans already have the capability. The RAAF is investigating the option.

Being the slowest of the RAAF's combat aircraft and the most defenceless, the Orion will benefit most from the ability to passively share in the greatly expanded picture of the battlespace. As the Orions stalk around the ocean, the increased awareness of threats and consequent ability to avoid those threats will increase Orion survivability.

Having the longest endurance of any RAAF combat aircraft, the Orions will probably be the RAAF's greatest contributors to as well as customers for the recognised air and surface picture relayed by the Wedgetails.

As the RAAF element that works the closest and most often with the RAN, the Orions will benefit from the increased integration and reduced confusion that Wedgetails can bring to joint maritime operations in the open ocean, far from land bases. This will be particularly useful in coalition or UN operations far from Australia, if procedural and interoperability issues are resolved.

AIR LIFT GROUP

The Air Lift Fleet

The RAAF airlift fleet includes five Boeing 707 long range tanker/transports, 24 Lockheed C-130 Hercules long range transports, about a dozen De-Havilland Caribou STOL transports and a few BAe HS-748 light transports. The fleet is distributed among six squadrons based mainly at Richmond and Townsville.

Air Lift Operations

Airlift is at the heart of Australia's strategy of defence in depth. It provides the essential mobility to project power from well-established and supplied bases in the south-east to remote areas in the north or offshore. Airlift enhances combat power by allowing a degree of manoeuvre that would be impossible in many remote areas of Australia, where the terrain and lack of roads or railways severely hamper surface movement. In some areas at some times of the year the weather prevents surface vehicular movement. Air transport is then the only option.

The airlift fleet has two broad types of operations. These are strategic airlift and tactical airlift. Just as a B-52 can undertake strategic bombing or tactical bombing, the strategic and tactical airlift roles are not platform specific. A Hercules can do either, however the 707s tend to specialise in strategic and the Caribous tend to specialise in tactical.

Strategic Airlift. The strategic airlift role tends to be long range operations, moving personnel and materiel into the theatre (or AO) from the south-eastern bases. Much of the strategic airlift role is similar to airline operations. In Operation Desert Storm, chartered civilian airliners performed much of the strategic airlift, moving hundreds of thousands of personnel and thousands of tons of general cargo.

Strategic airlift tends to involve sorties between established airheads, with paved runways, taxiways and parking areas, permanent air traffic control (ATC) facilities and efficient cargo handling systems. Strategic airlift roles include strategic mobility, aeromedical evacuation, scheduled (airline style) services and special forces (SF) insertion, support and withdrawal. Helicopters can also provide SF support.

Tactical Airlift. Tactical airlift provides mobility within an AO. The tactical airlift role tends to be short range operations, moving troops and equipment from the well established airheads to rough landing strips in the field or between rough landing strips. Landing fields are often just small areas of flat open grass or dirt, with no ATC or cargo handling facilities. The tactical landing fields are usually in or near the battlespace.

Tactical airlift operations include airborne (parachute or helicopter) operations, logistics support, aeromedical evacuation and special forces missions. Tactical airlift may involve landing to unload personnel and cargo or dropping them by parachute. In the case of helicopters, dropping may be by rope, at the hover.

Helicopters. Helicopters also provide tactical airlift. However, the RAAF no longer operates helicopters. The Army operates the helicopters used for battlefield mobility. The RAN operates its own rotary-wing fleet for tasks including ASW, over-the-horizon targeting and utility transport.

Some Ways AEW&C Can Enhance Air Lift Operations

No air force has plans to fit datalink to its transport fleet. US Special Forces (SF) may see a need for JTIDS situational awareness on their small fleet of combat-oriented special operations aircraft and Australian SF may follow suit. Even without direct linkage to the Wedgetails, RAAF transport operations will benefit indirectly from the AEW&C capability.

Strategic airlift sorties will usually spend most of their time cruising at high altitude, through friendly (or at least non-threatening) airspace. Strategic airlift aircraft should only need protection in the vicinity of the AO airhead. Wedgetails on barrier patrols should keep the threat out of the airhead area, if not the whole AO.

Tactical airlift will often be in or near threatening areas. If a Wedgetail is on area patrol, the situation will be dynamic and threats may emerge quickly. Friendly fighters and SAM systems in the area will be available to counteract threats. Tactical airlifters may be threatened by passing enemy aircraft and the Wedgetail or some other component of the airspace management organisation may have to divert the airlifter or

even abort its mission. The Wedgetail will often be the only platform with visibility of the dynamic situation and the communications capability to give timely warnings and effective directions.

The main value of AEW&C to airlift operations will be the enhanced security and greater confidence that airlifters will get from having the airspace in their vicinity under positive control. The 'customer' airlifter need not know that an enemy fighter was nearby, as long as the Wedgetail crew divert the airlifter around the threat and enable it to complete its mission.

The Tanker Fleet

The RAAF operates a fleet of four Boeing 707 tankers. They are very old ex-QANTAS airframes. They were converted to tankers using an Israeli design and the conversion involved minimal changes to the aircraft's internal plumbing. The fuel load available for transfer from the RAAF 707 tankers is much less than similar sized tankers in other air forces, such as the USAF KC-135. The RAAF 707 tankers provide the ADF with little more than a training capability, rather than an operational AAR capability.

There are two air-to-air refuelling (AAR) systems in use in Western air forces; these are the hose method and the boom method. Most air arms around the world have hose tankers.

To refuel from a hose tanker the receiver aircraft flies behind the tanker, which unreels a flexible hose. The receiver then guides the probe on its nose into the basket at the end of the tanker's hose. The receiver does most of the manipulation.

To refuel from a boom tanker, the receiver aircraft flies close behind and below the tanker and a crewman on the tanker guides the tip of its rigid, telescopic boom into a receptacle on the receiver's upper surface. The receiver just maintains its position (formation flying) and the boom operator does most of the manipulation. The USAF and a few other air forces have boom tankers.

The boom method is capable of transferring fuel at a much faster rate, so each receiver spends less time in the demanding refuelling position and more receivers can be refuelled in a given time. The hose system can be fitted into a compact pod that can be carried by small aircraft. Even a fighter can act as a hose tanker (often colloquially referred to as buddy refuelling). Boom tankers tend to be larger and more expensive than hose tankers and are so highly specialised that they can perform few other tasks (besides limited airlift).

RAAF tankers have hose reel pods fitted to their wingtips, but are not fitted with booms. RAAF tankers can only refuel aircraft fitted with probes. The only ADF aircraft currently fitted with probes are the Hornets. The Wedgetails will be capable of refuelling from both hose tankers and boom tankers. The F-111s are fitted with boom receptacles and can only refuel from boom tankers. The Orions are already have greater endurance than any other RAAF aircraft, so a refuelling capability is not necessary.

Traditional Tanker Operations

Modern fighter and attack aircraft carry most of their payload of bombs, missiles, electronic pods or additional fuel tanks on pylons under their wings. External ordnance carriage imposes aerodynamic drag penalties. An aircraft carrying ordnance has much less range and endurance than when it flies 'clean'. All aircraft have maximum take-off weights and more weapons or pods can only be carried at the expense of fuel. More weapons equals less range.

An aircraft capable of AAR can take-off with a small fuel load and lots of ordnance and then top up its fuel tanks in flight. Aircraft can refuel several times during a long transit flight, between base and target. They can refuel just before entering the high threat target area, so that they can afford to burn lots of fuel to manoeuvre and evade at high speed, then exit the area close to empty and refuel again for the trip home. For 50 years, AAR has given American bombers true *global* range and the ability to strike any point on earth, from bases in the US.

On many occasions, combat aircraft have been damaged in the target area and have escaped with leaking fuel tanks and no hope of getting home without AAR. In such cases AAR reduces friendly attrition. During the Falklands War, an Argentine tanker flew forward to meet a damaged strike aircraft that was losing fuel at a high rate. The damaged aircraft had to remain coupled with the tanker all the way home, as it was losing fuel as fast as the tanker could pump it in. If the British had been using AEW aircraft, they would have been aware of the situation and could have sent a fighter to destroy the Argentine tanker and the strike aircraft. If the Argentines had been using AEW, the tanker crew would have known whether the move was safe and could have been aggressive without undue stress.

AAR can increase payloads so that fewer sorties are required to achieve the effect desired on the target. AAR can extend the reach of air power, so that smaller, cheaper aircraft can achieve the results that would otherwise require expensive long range bombers. AAR can reduce attrition. Therefore AAR is a force multiplier. Tankers are high value targets, which must be used carefully and are normally not used in risky situations.

Ideally, tankers should accompany combat aircraft as close as possible to the target. In Vietnam, the Persian Gulf and the Balkans, American tankers maintained continuous presence in designated areas near the edge of the combat zone, flying endless racetrack patterns. Fighters would simply join the queue and top up at these 'flying gas stations'. The Americans could not have risked the high value tankers, so close to enemy air bases, without the situational awareness provided by nearby AEW&C patrols. Any threat to the tankers could be detected early and fighters could be scrambled to protect the tankers.

Some Ways AEW&C Can Enhance Tanker Operations

The principal enhancement that AEW&C can make to tanker operations is to increase tanker crews' situational awareness and subsequently their confidence. Tankers will be able to operate more aggressively, confident the situational awareness conferred by AEW&C will enable them to skirt close to danger, but always pull back when necessary.

RAAF tankers will be able to support combat aircraft much further into an AO, maximising the force multiplier effect. RAAF tankers will be able to perform the continuous flying gas station service near threatening areas, as America and NATO tankers have in the past. RAAF tankers will be able to dash forward to nurse home damaged Hornets or F-111s in what will be informed, calculated risks rather than blind bravado.

Though the RAAF has no plans to fit Link 16 to the 707 tankers, other air forces have included Link 16 in mid-life upgrades. The RAF has fitted Link 16 to three of its Lockheed 1011 Tristar tankers and three of its BAC VC-10 tankers. The JTIDS connectivity was seen as an urgent operational requirement for tankers that are frequently operating near high threat areas such as Iraq and the Balkans.[22]

Even without the datalink, RAAF tankers can be kept out of harm's way by manual guidance (over voice radio) from the Wedgetails. An automated datalink would save time and relieve Wedgetail crews of the task.

SURVEILLANCE & CONTROL GROUP

The Surveillance & Control ORBAT

The Surveillance and Control Group (SCG) is the newest FEG in the RAAF. SCG operates a range of sensor systems, including OTHR (the JORN sites of 1RSU), microwave air defence radars (2 CRU, 3 CRU & 114 Mobile CRU), remote EW sensors, the ADF Air Traffic Control (ATC) flights and an interface with the civilian national ATC network. The organisation of the SCG is shown at Annex F. SCG also has access to intelligence supplied by several Defence and Government agencies.

SCG was created by grouping together all existing and projected RAAF surveillance assets, other than the tactical assets operated by MPG. The formation of SCG was a consequence of the ADF's recognition of the importance of surveillance in the national defence strategy espoused in SR97.

SCG has an extensive Command & Control (C2) structure to integrate all of the sensor inputs to form a Recognised Air Picture (RAP) and distribute it to forces in the field and higher headquarters. This network consists of NADOC, NORTHROC & EASTROC.

ADF ATC Flights

The ADF has 11 ATC flights. They are located at Adelaide (RAAF Edinburgh), Brisbane (RAAF Amberley), Darwin (RAAF Darwin and RAAF Tindal), Newcastle (RAAF Williamtown), Nowra (Naval Air Station), Oakey near Brisbane (Army Aviation base), Perth (RAAF Pearce), Sale near Melbourne (RAAF East Sale), Sydney (RAAF Richmond) and Townsville (RAAF Townsville).

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[22] *Jane's Defence Weekly*, 20 October 1999, internet entry: http://defweb.cbr.defence.gov.au/jrl/janes/jdw99/jdw03651.htm

These cover most of the capital cities and most of the major ADF bases. In other words the ADF ATC network has coverage of many of the high value targets in Australia.

Civilian Air Traffic Control (ATC) Network

The civilian ATC network includes many microwave radars, which cover many areas not covered by the ADF ATC network. Between them, ADF and civilian ATC networks cover all of Australia's capital cities and regional centres, many small towns and many economically important resource extraction activities. Most of the areas not covered are of little interest. Few enemies will bother to bomb empty wastes of the Simpson Desert or the Kimberley region.

ATC radars can provide good target data around likely focal points of enemy activity. This data can be fused into the RAP in the same manner as CRU radar data.

Procedural data on aircraft in uncontrolled airspace and not in areas of radar coverage will help to sort civil aircraft and other non threatening traffic from enemy aircraft and illegal civilian traffic (smugglers).

The interface with Air Services Australia's ATC network provides an excellent and otherwise not affordable extension to ADF surveillance assets. The sum of the sensors and command and control systems is the national air defence system. It does not provide blanket coverage of the entire continent and all approaches, but it will cover most of areas of defence interest, particularly the northern approaches and vital assets.

Impact of Wedgetail on Surveillance & Control Group

SCG is a very recent creation, albeit built on the strong foundation of the Air Defence community (41 Wing). The other flying FEGs (ALG, MPG, SRG and TFG) have operated aircraft for decades and have long-established cultures. The operators, maintainers and managers in those FEGs have mastered the art of air operations and have a good understanding of such critical functions as crew resource management (team dynamics), risk management and flying safety. The introduction of the Wedgetail aircraft will require a major culture change in the Air Defence community, which was previously focussed on operating land based sensors (microwave radars and OTHR) and land based command and control.

The Air Defence specialisation will need to develop an aircrew stream and master the airmanship skills that are ingrained in the other aircrew specialisations (Pilot, Navigator and Airborne Electronics). The handful of RAAF and RAN officers who have served on exchange aboard American E-2 Hawkeyes and E-3 AWACS and British E-3 AWACS will provide a starting point. They range in rank from Wing Commander (Commanding Officer level), through Squadron Leader (crew leader/supervisor level) to Flight Lieutenant/Flying Officer (operator level).

Wedgetail Crewing. There will be ten consoles on the Wedgetail, but initially only six operators per crew. The usual peacetime constraints on personnel numbers will preclude higher levels of crewing. In any case, the process of recruiting, training and qualifying Wedgetail crews will take years to build up the numbers to allow even six

per crew. Seven flight crews and associated training and staff positions within SCG will create a need for over 60 Wedgetail crew.

The current plan is for all of the Wedgetail mission crew to be AIRDEF officers. They will be given training in whatever additional skills they require. Other specialists may be carried in special circumstances.

Crew Specialisation. A USAF AWACS carries a crew of over a dozen. A US Navy Hawkeye carries a crew of three. Both aircraft perform the AEW&C mission effectively. The AWACS crews consist of three teams (surveillance, control and maintenance), including officers and non-commissioned. The much smaller Hawkeye crews have to be more multi-skilled.

The current concept is for the Wedgetail crew to consist of six multi-skilled operators, at identical multi-function consoles. Some may be performing surveillance tasks while others are controlling aircraft. Some tasks will be less demanding than others and a hierarchy will be developed to progress operators through the skill levels. In each crew, different operators will have different levels of skill and experience, but the intention is for all operational crew to have the basic skills to perform most tasks.

On missions lasting eight hours or more, operators will need rest periods. Periods spent on the more demanding tasks may be interspersed with periods on the less demanding tasks. The balance of numbers dedicated to surveillance as opposed to control will vary from one mission to the next and at various times during a mission. If narrowly specialised crew were carried, crew flexibility would suffer.

For example, if an ATC expert was included, that officer could not perform surveillance or control tasks. It could even be argued that there would be a need to carry two ATC specialists, as one might not have the opportunity for adequate rest periods during a long mission. Crew size could mushroom if too many specialisations were involved. Even an aircraft as large as a Boeing 737 has space limits. To overcome this problem, AIRDEF officers will be trained in any additional skills required. SCG staff are investigating what is required to give AIRDEF officers a basic ATC qualification. USAF and RAF AWACS crew have such qualifications.

Some tasks may require specialisation. The ALR-2001 ESM system is relatively new to the RAAF and only the Orion operators have used it. The Orion operators believe that the ALR-200 is sufficiently complex and demanding to require a specialist operator. They argue that the mass of information provided by the system can only be effectively interpreted and exploited by a dedicated operator with significant experience. Some experts believe that the datalink communications management function will often be a full time job, requiring specialist experience.

Ultimately, the six crew may be trained to be capable of performing most surveillance and control tasks at a basic level. Some will have reached higher levels of competence and be able to supervise the others, while a few will specialise in ESM and perhaps datalink management. The skill set for all six crew positions may have 90 per cent commonality, with specialised training modules for the other ten per cent.

Personnel for No 2 Squadron. The bulk of the personnel in No 2 Squadron will probably be AIRDEF. There will also be pilots, maintenance specialists and the usual support staff. The bulk of the maintenance and logistics may be 'contracted out', so the squadron may be predominantly operators.

If it can be predicted that certain specialists from outside the AIRDEF speciality will be required to temporarily join crews for specific operations, there are two ways of providing them. Small numbers of selected specialists could be permanently posted to the squadron, so that they can learn the procedures and culture of AEW&C and become familiar with the operating environment. Alternatively, specialists could be temporarily attached from other units, as required.

Temporarily attached personnel would have less familiarity with and understanding of the AEW&C culture. The total number of personnel in the Wedgetail squadron will be constrained to a few hundred. There will be little scope for permanently posting additional specialists for infrequent contingencies. The expedient of temporarily attaching extra specialists is the most affordable alternative.

In some unusual contingencies, personnel from external agencies may be seconded temporarily. Specialists from Coastwatch, Customs, Police, Foreign Affairs and other organisations may occasionally be needed. However, such secondments to the squadron will be rare, perhaps limited to pre-mission briefings and planning assistance. Observers and advisers from other agencies would usually be located at the operations centre or headquarters controlling the operation. So they would normally be at NORTHROC or HQNORCOM, rather than on a Wedgetail.

Training in SCG

As with all RAAF training, an occupational specification will be drafted. It will list the competencies (knowledge, skills and attitudes) that Wedgetail operators will require. The FEG has its own training unit; the Surveillance and Control Training Unit (SACTU). SACTU will design and conduct most of the Wedgetail crew training.

The Air Defence Controllers course provides the core skills required for Wedgetail mission crew. If an existing ADF course provides an additional skill set that Wedgetail operators will need, it may be more expedient to send them to the school conducting that course, rather than duplicating the course in SACTU training. The Orions are already fitted with the ALR-2001 ESM system that will be fitted to the Wedgetails. As MPG already has a mature ALR-2001 training and operating culture, SCG may 'subcontract' to MPG for ESM training.

The gestation period for Australian AEW&C has taken decades and contacts with American and British AEW&C communities are well established. SCG is progressing with a thoroughly planned phase-in strategy, developed by AEW&C experienced operators, who have studied other nations' experience and have learned from their mistakes. The introduction of the AEW&C capability may turn out to be the best planned and smoothest transition to a new capability in the history of the RAAF.

SUPPORT FOR LAND AND MARITIME OPERATIONS

Since the early stages of World War Two, surface force commanders have accepted that enemy control of the airspace over their forces makes success on the surface difficult if not impossible. Friendly air superiority is usually seen as an essential pre-condition for successful operations. The great German blitzkrieg victories were won under the cover of Luftwaffe dominance of the air.

During this period, considerable resources were devoted to ground based anti-aircraft defences. Army combat and support units deployed large numbers of anti-aircraft guns, often supported by searchlights and radars. The decks of warships were crowded with anti-aircraft guns and associated equipment. Air force bases were ringed by large numbers of anti-aircraft guns.

Since the latter stages of World War Two, Western armies and navies have been able to base their force structures and planning on the assumption that friendly air superiority was assured. Over the last 50 years, the Americans and their NATO allies devoted massive resources to their air forces. Western air forces have usually attracted larger budget allocations than armies and navies. Army and navy budgets have included large amounts for army aviation and fleet air arms, so the resources devoted to air power have actually exceeded those devoted to all the traditional surface forces combined.

SUPPORT FOR LAND OPERATIONS

In every war since 1945, Western armies have enjoyed the benefits of air superiority. They have been able to conduct their operations without the need to divert many resources to anti-aircraft weapons or to passive defence measures such as camouflage and concealment.

In Vietnam, the extensive use of helicopters for surveillance, reconnaissance, mobility, logistics support and casualty evacuation would have been impossible in the face of enemy air opposition. Today the ADF is heavily reliant on slow vulnerable transport aircraft and helicopters for operations in the vast areas of the Australian area of operations (AO). Such aircraft are virtually defenceless.

The Australian Army appears to base its doctrine, organisation and equipment holdings on the assumption that the ADF will have air superiority in the airspace above army units. As a consequence, the Australian Army has no anti-aircraft artillery (AAA) and only a very limited surface to air missile (SAM) capability. Most Australian Army units are defenceless against air attack.

The Australian Army's fundamental expectation of the RAAF is that it will control the airspace over Army forces on the ground. If the RAAF can neutralise enemy air action against friendly forces, then the Army can get on with its business.

As the army gets on with it business, under the RAAF air defence umbrella, there will also be a requirement to deconflict friendly air activity and artillery operations.

The Army's secondary expectation of the RAAF is that it provide close air support (CAIRS) and battlefield air interdiction (BAI). In these flying artillery roles, RAAF Hornets and F-111s can move large quantities of high explosive (HE). The ability to deliver HE on short notice and with great accuracy, to any point of the battlefield, can be very useful to a small infantry army with very limited artillery resources. However, TFG and SRG will have many 'customers' clamouring for the services of the Hornets and F-111s. Air power is a scarce resource in the ADF. Even the USAF can not generate sufficient CAIRS and BAI to satisfy the US Army, hence the periodic arguments between the US Services over roles and missions.

The Australian Army also expects the RAAF to provide air transport support and air logistics support. The Army also expects to benefit from the knowledge gleaned from RAAF airborne surveillance and reconnaissance activities.

Airborne Air Defence

Air defence coordination is a classic AEW&C role. If the RAAF achieves and maintains control of the air over friendly ground forces, the Army will not need to worry about interference from enemy aircraft. This would be the ideal situation. Friendly forces had such total control in Vietnam and Desert Storm.

Lacking the resources of the American superpower, the ADF cannot assume such a situation. The ADF may have to accept a situation where the RAAF can inflict a degree of attrition on enemy air strike packages, but not annihilate them.

Air Raid Warning

If the air defence effort fails and an enemy air raid is approaching friendly forces, timely warning is needed. Friendly forces need to know when and where the enemy will strike, which direction the enemy is coming from, how many enemy aircraft are involved and what type of aircraft and weapons are involved. Such information enables friendly forces to take effective passive and active defence measures.

Passive defence measures against air attack include putting all personnel on alert, dispersal, camouflage, concealment, decoys, physical protection (such as trenches, revetments, bunkers or armour), emission control (EMCON) and putting post-attack recover & emergency medical services on heightened alert. Most of these measures

are routinely in effect at all times. The extra effort made when a raid is expected, often stop or slow other activity. Air raid warnings stop the normal business of most units. False alarms waste effort, slow operations and adversely affect morale.

Active defence measures against air attack include the range of ground based air defence systems, as explained below.

Ground Based Air Defence

A natural complement to the *airborne* air defence capability provided by the RAAF is *ground based* air defence (GBAD) provided by the Army. GBAD can be in the form of guns (AAA) or missiles (SAMs). The GBAD systems can deal with any enemy aircraft that 'leak through' the airborne defences.

In the 1950s, most Western armed forces replaced anti-aircraft guns with missiles. In the early 1960s the RAAF formed Number 30 Squadron, which was equipped with 16 British Bloodhound SAM launchers. The SAMs were based at RAAF Base Williamtown and were intended to give the fighter force a secure base from which to operate. The SAMs could deploy to any forward base from which the fighters needed to operate. The Bloodhounds were never very effective and they were withdrawn without replacement in 1968.[23]

Since the withdrawal of the Bloodhound SAMs, the Australian Army has maintained the ADF's only GBAD capability. The 16th Air Defence Regiment is a unit of the Artillery Corps, equipped with British Aerospace Rapier SAM systems and Swedish Bofors RBS-70 man-portable air defence systems (MANPADS).

Rapier. The Rapier system was developed in Britain in the 1960s. It is trailer-mounted and requires Landrovers for mobility. Each of the 12 fire units consists of a launcher, a dozen missiles, a radar and supporting equipment. At any time up to four missiles can be mounted on the launcher.

The Rapier is a small missile. It is only a little over two metres long and weighs only 42 kilograms. The warhead contains only half a kilogram of explosive. The range of the missile is less than ten kilometres, with an altitude limit of less than five kilometres. The Rapier radar can 'see' about 30 kilometres, but has the usual horizon limitations at low altitude.[24]

RBS-70. The RBS-70 system was developed in Sweden in the 1970s. The RBS-70 battery consists of three troops, each with four fire units and one radar (a total of 12 missile launchers and three radars). A fire unit consists of a few soldiers, a few missiles and a launch pedestal capable of mounting and launching one missile at a time. All components of the RBS-70 system are man-portable.

[23] Stephens, A., *Going Solo*, Australian Government Publishing Service, Canberra, 1995, p. 350–351.
[24] *Jane's Weapon Systems*, 1988/89, p. 184.

The RBS-70 missile is even smaller than the Rapier and about half the weight. The missile has similar range and performance as the Rapier.[25] The advantage the RBS-70 has over the Rapier is greater mobility. The RBS-70 fire unit can be set up and operated in a few seconds by two soldiers. RBS-70 requires less space at the launch site and fewer vehicles in support.

GBAD Capability. In the 1950s and 1960s, the Americans deployed thousands of SAM launchers and hundreds of radars to defend their key military bases and major cities from bomber attack. Many of the American missiles had long range and large warheads and there were so many radars in the CONUS that there was virtually total continental coverage, with early warning radars scanning out into the surrounding oceans.

The Rapier and RBS-70 SAM systems are capable of providing point defence only. The missiles have very small warheads and short range. The limited number of launchers and radars gives the ADF the capability to protect only a handful of small targets (such as key military bases or command and control centres) or even fewer large area targets (such as a city or an army field unit).

Unlike fighter aircraft and warships, GBAD can remain on station indefinitely and regardless of weather conditions. It can be seen as a force multiplier. GBAD can provide force protection in a bubble of battlespace. By providing a safe base from which to launch attacks, it is an enabler of offensive action. Effective GBAD systems can replace expensive fighter aircraft in the defensive role and free them for offensive action.

GBAD Command and Control. The Air Defence Ground Environment (ADGE) coordinates ADF air defence at all levels. The GBAD unit is a component of the ADGE. The fact that all the other components of the ADGE are RAAF units while the GBAD unit is an Army unit is of no consequence.

The function of the GBAD command and control system is to ensure that a SAM launcher is in the right place at the right time with sufficiently timely warning to be able to engage any enemy aircraft that threatens the vital asset being protected. Ideally, the enemy aircraft should be engaged *before* it reaches its target.

When an enemy air raid threatens friendly ground forces the nearby CRU will advise the Air Coordination Cell within the responsible Army HQ, by telephone or radio. The headquarters will then warn all subordinate units. The GBAD unit answers directly to the CRU, which will communicate directly with the Rapier or RBS-70 Battery Command Post (CP), again by telephone or radio. The battery CP will then alert one or more of the SAM fire units, again by telephone or radio.

Soldiers at individual fire units have complained that by the time they have been alerted as to the location of a threat, it is often too late. In exercises, an 'attacking' F-111 has often been overhead or gone, while the missile fire unit was still in the process of receiving notification of an incoming raid. The target of the 'attack' was 'destroyed' before a SAM could engage.

[25] *Jane's Weapon Systems*, 1988/89, p. 213.

Such a hierarchical, manual system would have been adequate for the needs of the Battle of Britain, when aircraft approached at speeds of 300 to 400 kph. The system is inadequate for dealing with modern aircraft that can approach at speeds exceeding 800 kph.

Another flaw in the system is its dependence on the presence of a CRU, of which there are only three. Each CRU has a single radar with a small detection envelope (a 'bubble') of a few hundred square kilometres and the usual horizon limitation at low level. Most foreseeable Australian AOs are vast and the detection envelopes of the few SAM radars and even fewer CRU radars are relatively tiny.

The Future of Australian GBAD

The RBS-70 will reach 'Life of Type' (LOT) in 2005. The Rapier reaches LOT in 2000. In the absence of an immediate replacement a program to extend the Rapier's LOT is in progress.[26]

Joint Project 117 is currently in the early stages of selecting a replacement for the Rapier SAM system. No specific system has yet been chosen, but the intention is to get a far more capable system than the Rapier. Most of the systems on the market today have at least twice the capability in terms of range and lethality and are more mobile and can deploy faster. The range of options includes advanced laser systems.[27] The Rapier replacement is unlikely to enter service before 2009.

However, if the ADF simply grafts a new SAM system into the existing GBAD framework, the overall capability to defend against strike aircraft will be little better. The threat has grown faster than the ADF's GBAD capability. Modern aircraft can launch stand-off weapons at distances of more than 20 kilometres from the target.

The introduction of the Wedgetail AEW&C and the many other improvements being made to the ADGE present an opportunity for a quantum improvement in GBAD capability. Current ADF GBAD systems are old 'stand alone' systems. Connecting the new GBAD systems directly to the AEW&C (via Link 16 at Battery CP level or lower) could facilitate earlier SAM launches, to intercept incoming enemy aircraft long before they come within the detection envelopes of the GBAD radars.

Airspace Management

The Army's standard field artillery (105 mm) and medium artillery (155 mm) fire explosive projectiles high into the air. Mortars (83 mm and 120 mm) can also lob shells high into the air. Passing aircraft could inadvertently collide with these

[26] Cotterill, D., 'JP 117 Shifts to the Right', *Australian Defence Magazine*, June 2000, p. 42.
[27] Cotterill, p. 42. The US /Israeli Tactical High Energy Laser (THEL) is an example.

projectiles, with catastrophic consequences. During operations, it is essential to ensure that artillery and friendly aircraft do not occupy the same space at the same time. Artillery and aircraft must gain clearance before they use airspace.

Airspace management is performed by RAAF personnel in the Joint Offensive Support Coordination Cell (JOSCC) at the Deployable Joint Force Headquarters (DJFHQ). Clearances to aircraft and artillery can be performed either procedurally or positively.

Procedural Clearance. Procedural clearance is done by comparing aircraft flight plans with artillery fire plans. If a flight plan predicts that an aircraft will be in the vicinity of an artillery fire lane, either the artillery or the aircraft will be advised to divert from their plan, depending on which has the higher priority. A helicopter transiting through an artillery fire lane may have to be called by radio to confirm its actual position. The aircraft may then be warned off or the conflicting artillery fire mission may be delayed until the helicopter is safely out of the way. Procedural clearance is often imprecise and requires large safety margins.

Positive Clearance. Positive clearance requires real time observation of aircraft movements, usually by radar. Such clearance is rarely possible with current ADF capabilities. If there was an AEW&C aircraft flying above the battlefield, one of the surveillance operators on board would be monitoring all aircraft movements in the battlespace and could provide immediate positive clearance. Positive clearance can be more accurate than procedural clearance and the safety margins can be far finer, thus interfering less with operations.

Artillery/aircraft clearance is a potential task for AEW&C aircraft, but such a rare and valuable asset will usually be busy on more complex and important tasks. An alternative to tasking the AEW&C aircraft with clearances is to provide the JOSCC in the DJFHQ with a (receive only) datalink terminal to display the Recognised Air Picture (RAP) transmitted from the AEW&C aircraft. JOSCC staff can then consult the RAP direct and provide positive clearances, interfacing with Army units in the same manner as is currently used for procedural clearances. The Army ‘customer’ will get the usual service without needing to change current procedures and without even being aware of any change in methods.

SUPPORT FOR MARITIME OPERATIONS

Modern aluminium warships have very little armour protection, and carry large quantities of flammable and explosive materials and fragile electronic equipment. They are very vulnerable to air attack. A ship need not be sunk outright. Simply disabling its electrical power systems is enough to remove it from the battle. One anti-ship missile, such as an Exocet or Harpoon, is usually enough to disable a modern frigate.

Since the withdrawal from service of the aircraft carrier HMAS Melbourne, the Australian fleet has lacked any organic fixed-wing air capability at sea and has had to rely totally of land-based RAAF air support. The fleet can only rely on continuous RAAF fighter cover when operating within a few hundred kilometres of a land base.

In the open ocean, the fleet can sometimes get support from F-111s and Orions. The F-111s are excellent maritime strike platforms. The Orions are excellent platforms for maritime strike, ASW and surface surveillance. However, the F-111s and Orions can not guarantee early warning of approaching enemy aircraft and missiles and they can do little about such threats.

The fleet is not defenceless. The frigates have powerful radars, excellent fire control systems and lethal, long range SAMs. Once a target has been located and identified, the ship's SAM system has a very high probability of hitting the target. The hard part is actually finding the target in a timely manner.

A warship's sensors (including radar, IR and EW) can only detect threats in a small 'bubble' of a few hundred kilometres radius at high altitude, tapering to less than 20 kilometres radius at the surface. This detection limitation is further complicated by the fact that modern strike aircraft and their stand-off weapons are very hard to find as they will usually approach at low level and they are becoming increasingly 'stealthy'.

Stealth

The quality often referred to colloquially as stealth, or more correctly low observability, is not new. The Lockheed SR-71 Blackbird high altitude reconnaissance aircraft entered service in 1966 and had many stealthy features in common with modern stealthy aircraft. Stealth is a means of evading or postponing detection by radar or other sensors.

Thermal Detection of Aircraft. In the case of thermal sensors, the stealthy aircraft's hot engine exhaust is the emission to be reduced or masked by some means. The exhaust may be located on the wing upper surface, so as to be masked by the wings when the aircraft is seen from below, as in the F-117 and B-2. The exhaust may be directed in a direction that dissipates it quickly, as in helicopters that direct the exhaust up into the rotors. Cool air may be mixed with the hot exhaust, to reduce the heat source.

Radar Detection of Aircraft. No metal aircraft can be invisible to radar. Stealth anti-radar techniques include reducing the amount of radar energy reflected off the aircraft and reflecting energy in predictable directions.

The amount of energy reflected can be reduced by coating exterior surfaces of the aircraft with Radar Absorbent Material (RAM), which reduces the strength of the radar return. Some essential aircraft components (such as engine fans) will always reflect radar energy. These parts can be buried inside the aircraft structure, out of the radar's line-of-sight, to reduce the strength of the radar return.

Aircraft can be shaped to reflect radar energy in predictable ways. If the radar beams can be reflected in predictable directions, mission planners and aircrew can plan and fly routes that will aim the radar reflections away from known enemy detection sites. This beam diversion technique is the reason for the unusual shape of the F-117 Stealth Fighter.

Detection of Missiles. The main air threat to ships is from missiles. When a missile is approaching a ship, that ship's sensors have only a very small target to detect. The

frontal surface of the missile has an area of a few square centimetres and the hot exhaust is masked by the entire missile. Another platform in the battlegroup will have a side view of the missile (several metres long) and a clear view of the exhaust. The other ships (and aircraft) in the battlegroup can warn the target ship, but manual (voice radio) warnings are time-consuming and next generation anti-ship missiles will be supersonic. An automated datalink early warning system is needed.

For several years, Western navies have been working to link all of the sensors on all of the platforms in a battlegroup, for automated detection, tracking and warning of all missiles in the area. The USN calls this a Cooperative Engagement Capability (CEC).

Cooperative Engagements

If an AEW&C aircraft is supporting a battlegroup, the aircraft will usually be in a better position than the ships to detect and identify incoming enemy aircraft and missiles. Much of the advantage of AEW would be lost by waiting for aircraft to come within the detection range of the ships' sensors. Modern maritime strike aircraft will usually launch stand-off weapons, such as Exocet or Harpoon missiles, from up to a hundred kilometres away. Such launch distances are far beyond a warship's MEZ. RAN frigates' SAMs have the range to engage aircraft over the horizon. Much of the advantage of these BVR weapons will be lost by waiting for the target to appear on the horizon.

Integrating the sensors of all battlegroup participants, including the AEW&C aircraft, in a CEC arrangement would greatly increase engagement ranges and success rates. If the RAP generated by the Wedgetail is transmitted to the frigates by datalink, they can use their powerful anti-air capability to defend all friendly platforms in the area.

An AEW&C aircraft operating beyond the range of land-based fighter cover in support of a RAN battlegroup may itself be threatened by enemy aircraft. The Wedgetail would have to either run away or it could shelter within a ship's MEZ.

New Technology: New Ways of Doing Business

In this age of joint warfare, traditional single Service parochialism is wasteful. Australia lacks the resources to allow each Service the luxury of maintaining a totally self-sufficient air defence force structure. The Army's GBAD systems, the Navy's anti-air warfare (AAW) ships and the RAAF's fighters, AEW&C and ADGE/IADS must be seen as a whole. The three Service components working together can achieve effective air defence. Individually, they are inadequate.

The old force structure, now phasing out of service, was the product of the technologies and strategies of the 1960s and 1970s. As each element of the old force structure reaches the end of its life of type, it should not just be automatically replaced by a similar system. There are alternatives. A case in point is the RAN's AAW ships.

The Perth class guided missile destroyers (DDGs) have been excellent AAW platforms, but they are old and due for retirement. Plans for their replacement have been shelved. In some quarters, the RAN's current generation of frigates are perceived to lack adequate AAW capability to operate safely in the region. The recent

decision not to proceed with the comprehensive upgrade of those frigates has led to calls for the immediate acquisition of more capable AAW ships.[28]

One proposed solution was the acquisition of a few second-hand American Kidd class DDGs.[29] The target date of 2002 was suggested, so as to avoid a gap in the RAN's AAW by replacing the DDGs as they retire. There are at least two flaws in the argument.

Firstly, in the current financial environment, the Defence budget cannot support such a major project (probably at least one billion dollars), unless some other major project is cut or cancelled. Most major acquisition projects currently in train are too far advanced to cut. The AEW&C project is an obvious target. The cancellation or significant postponement of the AEW&C project would be precipitate. Any major change to recently reviewed acquisition strategy should be investigated and considered in great detail and without haste.

Secondly, though the Kidds' SM-2 missiles have an impressive range of more than 130 kilometres, their sensors face the same limitations as those of the existing frigates, whose missiles can already fly beyond the radar horizon. The early warning and cooperative engagement capabilities offered by AEW&C would add far more value to the air defence of a RAN task force than a slightly bigger MEZ with no extension of sensor range.

The credible contingencies for ADF maritime operations in high threat environments are coalition operations, perhaps in the archipelago of South East Asia, the South China Sea or further afield (such as the Persian Gulf). If Australia's coalition partners lack the political will to allow RAAF AEW&C aircraft, Hornets and F-111s to operate from their land bases in the area, the political sense of ADF involvement should be questioned.

Some RAN officers argue that: '*It is unthinkable that the modern (RAN) fleet should not be at the vanguard of such efforts*'.[30] The reality is that a third or fourth order power like Australia can not afford to have a fleet capable of battering its way into any place, at any time and operating independently. Only the Americans can afford that.

Rather than just automatically replacing the DDGs with a similar platform, a more imaginative approach would be to look at the synergies available with new systems, particularly the Wedgetail AEW&C capability. In the absence of AEW&C and other

[28] Shevlin, J., 'Maritime Air Warfare for the RAN', *The Navy*, Navy League of Australia, Canberra, pp. 22–24.
[29] Grazebrook, A.W., 'RAN Presses Urgent Need for Modern Air Warfare', *Asia Pacific Defence Reporter*, December 1999, pp. 46–47.
[30] Shevlin, 'Maritime Air Warfare for the RAN', p. 23.

such force multipliers and enhancers, an air force may need 'smarter' air defence and strike aircraft. In the presence of AEW&C, a navy may not need the most powerful state-of-the-art AAW ships.

If the RAN's DDGs can only be acquired at the expense of the RAAF's AEW&C, the priority should go to the more flexible and effective force multiplier. The RN Task Force in the Falklands included many powerful state-of-the-art AAW ships but lacked AEW&C. The British suffered heavy losses and were almost driven away from the Falklands.

Some Ways AEW&C Can Enhance Naval Operations

The valuable service that Wedgetail can provide to the fleet is greatly expanded situational awareness. The AEW&C capability increases the warships' surface picture and low level air picture form a circle of 20 kilometres radius to one of at least 200 kilometres radius.

Wedgetail can show the battlegroup commander what is *over the horizon*. Many naval warriors have stated that if they can see the enemy; they can hit it or avoid it. The certainty and peace of mind that comes with AEW&C would have been a great advantage to the commander of the British Task Force off the Falklands.

The commander of the Falklands Task Force commander did not claim that a few more DDGs would have been decisive. He did write that: '*surface ships must have AEW ... for survival in open water.*'[31] He would probably have been happy to swap some DDGs ships for a few AEW&C aircraft.

THE DOWNSIDE OF AEW&C

No weapon system is without flaws or drawbacks. Even AEW&C has its downside. The ADF must be aware of the potential pitfalls and avoid them.

AEW&C is not the dominant element of air warfare. It is an important element, but victory is not assured by the presence of AEW&C; nor is defeat inevitable in the absence of AEW&C. However, AEW&C confers a great advantage and the absence of AEW&C makes victory more difficult to achieve.

Over-Reliance on Technology

AEW&C will never be a substitute for the basic skills of airmanship, sound procedures, individual responsibility and common sense. A case in point is the accidental shooting down of two US Army Blackhawk helicopters in Iraq by 'friendly' fighters. The investigation into the tragedy concluded that the fighter pilots had inadequate helicopter recognition *skills*. The air force AWACS crewmen were unsure

[31] Woodward, *Memoirs of the Falklands Battle Group Commander*, p. 292.

of the extent of their *procedural* control over and *responsibility* for army aircraft. The helicopter pilots lacked the *common sense* to ensure that they made proper use of their IFF systems.[32]

With or without AEW&C, the human beings in the organisation will still be required to think and take responsibility. They will still need the elementary skills of their trades.

American fighter pilots achieved a two-to-one kill ratio in air combat in Vietnam. This compared very unfavourably with the ten-to-one kill ratio achieved in Korea, only a decade earlier. A major cause of the American fighter pilots' loss of superiority was identified to be the loss of basic dogfighting skills. American pilots had become too reliant on unreliable missiles and radars. The US Navy instituted its famous 'Top Gun' school to teach fighter pilots the 'lost art' of air-to-air combat. The USAF instituted its less famous equivalent (Red Flag). Basic skills are still necessary.

Since World War Two, the American military has often been criticised for its apparent over-reliance on technology. However, as the electorate's tolerance for casualties (friendly, collateral and even enemy) diminishes to almost zero, there is a growing imperative to substitute technology for flesh and blood. Some army officers pine for the 'good old days', when heroic cavalry or infantry charges were celebrated in the popular press, songs and poetry and became the stuff of regimental legends. A quick reality check will indicate that the famous 'Charge of the Light Brigade' (in the 1850s) and the heroic infantry assaults at Gallipoli (1915) would be seen today as such bloody disasters that public outrage would immediately end the war and the careers of the generals involved.

The Western military has consciously chosen to minimise human effort and risk and to maximise the use of technology in warfare. Technology can help win battles far more quickly and with fewer casualties. Technology used cunningly, as part of the coherent system, improves effectiveness. America's wars since 1945 have been far less costly in blood than those earlier conflicts where huge masses of manpower were used. Air power is the ultimate expression of the technological approach to war. AEW&C is an important element of modern air power.

Many underdeveloped countries with large populations still rely on mass manpower. They can not afford high technology air power. Western nations have intentionally avoided adopting low technology doctrines or force structures. We will not allow ourselves to be dragged down to the level of low technology and high casualties

A False Sense of Security

AEW&C can give a level of situational awareness that is often described as a 'God's eye view'. Yet, even the level of surveillance assets available in Operation Desert Storm (including fleets of tactical reconnaissance aircraft, AWACS, JSTARS, ELINT and satellites) did not give the commander and his forces *total* knowledge of the battlespace. The sheer mass of data available can overwhelm the capacity of the

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

human elements of the system to master and use it effectively. Human error can always contrive a way to 'snatch defeat from the jaws of victory'.

Even with AEW&C, there can still be nasty surprises in air warfare. For every measure there is a countermeasure. Enemy ingenuity can create tactical ploys that might reduce the effectiveness of systems in some situations. The enemy can think and act in ways we did not predict. Terrain and weather conditions can be other than ideal. Computer software can have glitches. Electronic hardware can malfunction. Crewman can make mistakes.

The greatest mistake would be to assume that AEW&C has given us total knowledge of the battlespace. We would then plan and conduct operations on the premise that everything will go as planned. Such plans and operations would be very brittle. A false sense of security can result from over-reliance on technology. Planners and operators must still allow for a range of contingencies and never be complacent.

AEW&C as a Multiplier

An astute observer has pointed out that as well as being a *force* multiplier, AEW&C can be a *risk* multiplier. AEW&C aircraft are very expensive, as are the crew who operate the onboard systems and the supporting facilities. AEW&C aircraft tend to be physically vulnerable.

Reliance on AEW&C can provide an opportunity for the enemy. As force multipliers, they are high value targets. The loss of AEW&C aircraft will impact seriously on capability and force a significant change of tactics. If we cannot afford to lose an AEW&C aircraft, we must devote resources to its protection. This diversion of resources reduces the overall force multiplication effect.

Political Errors

The force multiplier effect of AEW&C can have an unintended side effect. If the purchase of one weapon system can increase the effectiveness of many other weapon systems, some politicians may think that fewer of those systems will be needed to achieve the desired effect.

When the USAF advocated the acquisition of a few more B-2 stealth bombers, the effectiveness of stealth was overemphasised by some stakeholders. The USAF presented scenarios where a few stealth bombers could perform a mission that would require many times more conventional aircraft, including specialised support aircraft, such as tankers, EW, and fighter escorts. Some ill-informed politicians then argued that if 100 stealth bombers could perform missions that would require 1,000 conventional aircraft, then 500 stealth bombers could replace the entire USAF tactical inventory. It was a simplistic argument.

In a few cases, the AEW&C capability may appear to obviate the need for other capabilities. In some other cases, the AEW&C capability may reduce the need for other capabilities. However, many ADF capabilities are already at minimal force levels and at or below critical mass for maintaining healthy career streams and expertise base and generating meaningful sortie rates.

It would be a mistake of oversimplification to operate fewer fighters, bombers or patrol aircraft on the rationale that AEW&C can make the fewer as effective as the previously larger force. The existence of an AEW&C capability in the ADF in the year 2020 should not be seen as an excuse to replace 70 Hornets with 20 new fighters. The same must be said for all ADF force elements.

CONCLUSION

AEW&C is not a panacea, but it will greatly improve the effectiveness of all ADF combat elements. It will be a force multiplier in most scenarios.

AEW&C and Air Operations

In air operations, AEW&C support will reduce attrition and increase the probability of success. It will enhance all types of missions.

In strike, air defence, maritime patrol, transport and tanker operations AEW&C support will confer much greater situational awareness to the crews of the aircraft and to those responsible for the command and control of those aircraft. That situational awareness will make operators more confident and enable them to be more aggressive, while practising better (informed) risk management.

The great communications power of the Wedgetails will enhance the flexibility of air operations. Strike sorties will be used more efficiently and will be more responsive to changing situations. Air defence will be more efficient with longer warning times and better control.

The communications power of the Wedgetails will also make cooperative engagement possible in a variety of air operations. The Wedgetails' ability to provide better BVR identification and targeting information will enable the Hornets, F-111s and Orions to get the most out of existing and planned stand-off weapons, such as AMRAAM, AGM-142 and Harpoon.

AEW&C and Land Operations

In land operations, AEW&C will give better warning times for enemy air raids, a better chance of defeating those raids and greatly expanded situational awareness. In partnership with new surface surveillance aircraft, AEW&C will give land commanders a clear idea of what is *on the other side of the hill.*

AEW&C and Maritime Operations

Just as AEW&C support will make aircrew more confident and aggressive as a result of improved situational awareness, warship commanders will also be more confident and more aggressive, while practising better (informed) risk management. With AEW&C support commanders at sea will know what is *over the horizon*.

The fleet already has a cooperative engagement capability (CEC). The Wedgetails' enormous sensor sweep and communications power will greatly expand the bubble of awareness of naval task force commanders. This will reduce the chances of strike aircraft getting close enough to launch their stand-off weapons and then escape. It will also reduce the chances of their anti-ship missiles hitting their targets. The expanded CEC will make the task of shadowing RAN ships far more dangerous.

AEW&C AND THE ADF

AEW&C will not solve all the ADF's capability problems and shortfalls. It will not guarantee success or bring instant, bloodless victory in every contingency. Much of the business of war will go on as before. However, AEW&C will give commanders and operators greater certainty. It will help clear the fog of war.

AEW&C will be one of the few ways in which the ADF can offset the increase in capabilities in the region and elsewhere. It will enable the ADF to get the most out of the few platforms available. AEW&C will be a major factor in keeping the ADF in the forefront as a quality force.

CHAPTER SEVEN

THE BIG PICTURE: AEW&C DEFENDING AUSTRALIA'S INTERESTS

Information superiority is now an accepted part of US military strategy.
Lieutenant General James C. King
National Imagery & Mapping Agency[1]

PIECES OF THE PUZZLE

Over the period 2001 to 2010, the ADF will introduce into service a diverse range of new reconnaissance and surveillance systems. The fixed sensors of Surveillance and Control Group (SCG), including new microwave and over-the-horizon radars, the new AEW&C aircraft, new Army airborne platforms and upgraded Navy platforms, will constitute a greatly expanded range of ADF surveillance capabilities.

Many of these projects were initiated over a decade ago. Though each Service originally planned the capabilities in isolation, they will dovetail neatly. An overarching command, control and communications environment will ensure close integration of these capabilities into a joint surveillance network. This network will cover much of the continent and a wide arc of the approaches, from north-west to north-east.

The ADF will have state-of-the-art surveillance capabilities over a continuum, from focal area surveillance, through broad area surveillance to wide area (regional) surveillance. The network will cover the spectrum from the tactical level, through the operational level to the strategic level.

ARMY SURVEILLANCE SYSTEMS

The Army's reconnaissance and surveillance capabilities are very limited. Army reconnaissance and surveillance assets include three Army Aviation Reconnaissance Squadrons, a few Armoured Reconnaissance Regiments, three Regional Surveillance Units (RSUs) and the SAS Regiment.

The aviation squadrons operate a few dozen Bell OH-58 Kiowa light helicopters. The armoured units operate a few hundred M-113 and ASLAV light armoured vehicles. The Kiowa helicopters and M-113 armoured vehicles are older than the soldiers who operate them. The RSUs consist of a few hundred Reserve infantry, scattered across northern Australia. The SAS are among the best Special Forces in the world, but there are only a few hundred of them and they are in very high demand for other tasks.

[1] *Armed Forces Journal International*, May 2000, p. 21.

The area over which the Army can maintain effective surveillance is tiny, compared to the scale of the Australian AO. The Army's principal surveillance sensor is still the human eye.

Over the next decade, the ADF plans to introduce several new airborne systems into Army service. The new Army systems will greatly increase ADF reconnaissance and surveillance capabilities at the tactical end of the spectrum. They will include significant EW and surface surveillance capabilities.

One of the new systems will be an armed reconnaissance helicopter. The other new system will satisfy a longstanding requirement for Focal Area Airborne Surveillance (FAAS) and Broad Area Airborne Surveillance (BAAS).

Helicopters

Project Air 87 will replace the aged Kiowa and Iroquois helicopters currently in the Army inventory with a state-of-the-art armed reconnaissance helicopter (ARH). The ARH will have significantly greater capability than its predecessor, in terms of sensors, survivability and firepower. The ARH 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 be made soon. Up to 30 aircraft will be delivered over the period 2003 to 2007.[2]

Light Aircraft and Unmanned Aerial Vehicles

Joint Project 129 will introduce a totally new airborne surface surveillance capability to the ADF. The project is still in its initial phase. DSTO scientists are conducting modelling and operational analysis to determine the ideal sensor mix, platform mix and 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), inverse synthetic aperture radar (ISAR) 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 light aircraft and UAVs. The types and numbers of manned aircraft and UAVs are yet to be determined.

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

[2] 'Airscene', *Air International*, June 1999, p. 328.

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.

The UAVs will 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 helicopters and will be a more economical means of surveillance than the large, complex Wedgetails.

Though not primarily intended for the FAAS role, the ARH will carry EW sensors and a radar. The radar will be capable of detecting moving targets in the air or on the ground, along its line-of-sight. As helicopters usually operate at low altitude, the ARH's radar picture will cover only a small area. The Kiowas and Iroquois have no radar.

The ADF will have a range of options for each FAAS task. The ARH will be a more capable and survivable platform than the Army's current generation helicopters and light aircraft, which have been in service for over 35 years. The ARH 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 be cheaper to operate and more expendable than manned aircraft, so they will be available for the most hazardous tasks.

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 a $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.[3]

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 generated by the AEW&C Wedgetail. Australian

[3] 'Airscene', *Air International*, April 1999, p. 194.

involvement in the Global Hawk program increases the likelihood that such a UAV may be selected for the ADF BAAS requirement, but other systems could still be acquired instead or as well.

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 would complement ADF broad area surveillance.

AIR FORCE SURVEILLANCE SYSTEMS

Wide Area Surveillance

In peacetime, the Jindalee Operational Radar Network (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 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 recognise anomalies and identify 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 capability can provide precise surveillance and the accurate real-time control required for effective air operations.

MULTI-TIERED SURVEILLANCE

JORN, AEW&C, large surveillance aircraft (Wedgetails and sometimes Orions), small surveillance aircraft and surveillance UAVs 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.

In each scenario, 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 ROCs for fusion. The system will have built-in redundancy. Either ROC will be capable of controlling operations anywhere in either AO.

The 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 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.[4]

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.[5] 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.

[4] O'Donoghue, R., 'EASTROC Construction Begins', *RAAF News*, June 1999, p. 23.
[5] *Ibid*., p. 23.

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 the raw data that is then processed and forwarded to Australian Defence Headquarters and Strategic Command. The intelligence is also available to the Australian Theatre Joint Intelligence Centre (ASTJIC) for integration with operational level data.

The combination of the data from mobile sensor platforms, fixed sensors, the ADGE 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 regional 'knowledge dominance' and could be decisive in enabling ADF units to perform their missions efficiently and effectively.

The ADF is not the sole source of Australia's intelligence. Law enforcement agencies have extensive and diverse intelligence capabilities. These agencies include Federal and State Police, Customs, Immigration, Quarantine and the EPA. Other government departments and agencies, including the National Security Agency and the Department of Foreign Affairs and Trade, alsohave impressive intelligence capabilities.

There is a danger that such diverse agencies, with their differing roles and perspectives, may not realise the full value of the intelligence that they gather. Opportunities to achieve synergies and enhance the strategic intelligence picture may be lost. For example, a civilian agency may fail to appreciate the military significance of a piece of intelligence or several agencies may each note one case of a certain type of event and assume it to be isolated and insignificant, when the events actually constitute a significant trend.

In 1947, the Central Intelligence Agency (CIA) was created to ensure that the United States would never again be caught by surprise, as happened at Pearl Harbour in 1941. Inquests into the Pearl Harbour debacle had concluded that sufficient intelligence of Japanese intentions was available in the United States. Unfortunately, the many agencies within various civilian and military departments (including the State Department, War Department and Navy Department) had enough pieces of the puzzle between them, but nobody put it all together until it was too late.

Since World War Two, most Western nations have endeavoured to integrate their national intelligence gathering capabilities to improve intelligence support to the national security agenda. Beyond the mundane objective of cost cutting, this integration has led to great synergies and a clearer picture of the world (better situational awareness).

AEW&C is an important link in the intelligence gathering and distribution network. The potential to provide a real-time tactical and operational level picture to headquarters excites many in the intelligence community as well as many commanders of combat forces.

GOVERNMENT AGENCIES

Many agencies of the Commonwealth Government have responsibilities offshore, in the Australian EEZ and beyond. Their responsibilities encompass a wide range of non-military issues that impact on national security, in the broad sense. These issues include protecting the valuable resources in the EEZ and controlling entry to the country. The agencies are the first line of defence against illegal immigration, drug and other smuggling, fisheries poaching, exotic diseases, illegal pollution and other criminal activities. They are also involved in safety.

These agencies include Immigration, Customs, Quarantine, Fisheries, Police, Environmental Protection, Coastwatch and Search and Rescue. These agencies have limited resources, particularly in terms of command and control capabilities, specialised airborne platforms and long range sensors. Under the provisions of Defence Assistance to the Civil Community and Defence Force Aid to the Civil Power, these agencies may call on the ADF for assistance in situations where the requirements are beyond their resources. The Wedgetails will have many capabilities that these agencies will find useful.

COASTWATCH

Mission

The Australian Customs Service is the government agency tasked to facilitate trade and the movement of people across the Australian national border, while detecting and deterring unlawful activity at the border. Coastwatch is the civil aerial surveillance arm of Customs, which protects Australia's coastline and exclusive economic zone (EEZ). Coastwatch plays a key role in detecting illegal fishing, illegal entry vessels, drug smugglers, quarantine breaches and environmental pollution.[6]

Assets and Tasking

Coastwatch manages and coordinates Australia's civil coastal and offshore surveillance programs using a combination of contracted aircraft, RAN patrol boats, RAAF aircraft and the sea-going vessels of the Customs fleet.

Coastwatch's contracted air surveillance assets are concentrated in Western Australia at Broome, the Northern Territory at Darwin and in Queensland at Thursday Island and Cairns. As of December 1999, these assets included visual surveillance aircraft and radar/electro-optical surveillance aircraft. The visual air surveillance fleet includes six Pilatus Britten Norman Islander aircraft and one Shrike Aero Commander

[6] *Coastwatch: An Overview*, Australian Customs Service, Canberra, 1999, p. 1.

light aircraft. The radar/electro-optical air surveillance fleet includes three De Havilland Dash 8 aircraft, three Reims F406 light aircraft and one Bell Longranger light helicopter.[7]

Each year, the ADF dedicates 250 flying hours of Orion offshore patrols and 1,800 sea days of RAN patrol boat time to Coastwatch activities. The Customs boat fleet provides 900 sea days of support.[8]

The Coastwatch AO covers the Australian coastline (37,000 kilometres), Australia's offshore territories (including Antarctica), the Australian Fishing Zone (AFZ) and the 200 nautical mile EEZ. The offshore maritime area is larger than mainland Australia. Australia's offshore territories include well-known places close to home, such as Norfolk Island, and distant little-known places, such as Heard Island (over 4,000 kilometres south west of Perth).

Coastwatch Clients

The activities of Coastwatch are determined by the surveillance needs of client government agencies. These clients include the Australian Customs Service, the Australian Fisheries Management Agency, the Australian Federal Police, the Australian Natural Conservation Agency, the Australian Quarantine and Inspection Service, the Department of Environment and Territories, the Department of Immigration and Multi-Cultural Affairs, and the Great Barrier Reef Marine Park Authority

Coastwatch Costs

Coastwatch is a very cost effective surveillance organisation. On an annual budget of about $35 million, Coastwatch conducts surveillance of 80 million square kilometres of ocean each year. The overall annual air surveillance effort equates to 15,000 fixed-wing flying hours and 1,000 helicopter flying hours.[9] Small civilian contract aircraft are much cheaper to operate than large complex ADF aircraft. The average cost of operating Coastwatch aircraft is $2,000 per flying hour, while a RAAF Orion costs over $40,000 per flying hour.

The threat to Australia is real and Coastwatch operations produce results. In the six month period from August 1998 to February 1999, 757 illegal fishing vessels were detained and 98 illegal immigrant vessels were detected. Only 12 illegal immigrant vessels avoided detection and landed unannounced.

Coastwatch Focus

Until recently, Coastwatch focussed its surveillance efforts on the northern approaches to Australia, as the perceived threat (particularly illegal immigration and drug smuggling) was from that direction. However, recent events on the east coast led to government direction to expand the AO to include the east coast. The Coastwatch budget is thus stretched further.

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[7] *Coastwatch: An Overview.*, p. 7.
[8] *Ibid.*, p. 6.
[9] *Ibid.*, p. 7.

The ADF surveillance effort tends to concentrate on large vessels, over 25 metres in length. Coastwatch concentrates on the smaller vessels which are of little interest to the ADF, thereby dovetailing with the ADF to cover the full range of national surveillance requirements.

Support Requirements

At the strategic level, comprehensive intelligence is essential to ensure efficient use of scarce surveillance resources. Coastwatch shares intelligence with other government agencies, including the ADF, the Australian Bureau of Criminal Investigation, the Australian Federal Police, and the Department of Foreign affairs and Trade. The aim is to have the initiative by knowing in advance what is coming and where it is going.

At the operational and tactical levels, Coastwatch often needs to call on the ADF for specialised high technology surveillance capabilities. Even when a vessel is expected, it must be located, identified and tracked, so that action can be taken. RAAF aircraft are sometimes the only platforms with the necessary range and endurance to perform the task. ADF long-range surveillance systems are far more capable than anything Coastwatch will ever be able to afford.

The information provided by JORN, the ADGE, RAAF Orions and RAN patrol boats is essential to Coastwatch operations. Coastwatch is interested in new ADF surveillance capabilities, including the ADF's experimental high frequency surface wave (HFSW) surveillance of coastal waters, the ADF's extensive command and control aparatus (both the information systems and physical assets) and the RAAF's AEW&C Wedgetail.

Wedgetail Support for Coastwatch

American operations in the Caribbean and elsewhere have proven that AEW&C can significantly enhance law enforcement activities to prevent a range of illegal practices, including drug trafficking, illegal immigration and poaching. Criminals often outgun the police and sometimes have better intelligence than the police, but no criminal organisation can counter the electronic sophistication of state-of-the-art AEW&C.

Aircraft or boats engaged in criminal activity are unlikely to be fitted with ESM systems or radar warning receivers. A Wedgetail in support of a Coastwatch operation could loiter a great distance (beyond visual range) from the suspected aircraft or boat, monitor the suspect with the primary sensor, and coordinate shadowing and interception. AEW&C could use its powerful communications capability to coordinate Coastwatch surveillance of huge areas in remote regions.

SEARCH AND RESCUE

Mission

The responsibilities of the Commonwealth and State governments for Search and Rescue (SAR) are specified in the National SAR Plan. Lost bushwalkers, cross country skiers and 4WD adventurers are a matter for the state police and other state government agencies; as are small boats, such as pleasure craft and fishing boats, on internal waterways and along the coast. Ships missing in the open ocean and aircraft missing over land or sea are a Commonwealth responsibility. By international agreement, Australia is responsible for SAR in a huge area of the earth's surface, including much of the Indian, Southern and South Pacific oceans.

AusSAR is the Commonwealth government agency that coordinates maritime and aviation SAR activities. AusSAR is based in Canberra, where the Rescue Coordination Centre (RCC) is located. The RCC's role is strategic planning and coordination of the SAR effort, usually by telephone or voice radio. The RCC does perform 'real time' active control of operations.

Assets

Search. The main search platforms are small fixed-wing aircraft. However, AusSAR owns and operates no aircraft or boats. AusSAR has memoranda of understanding (MOUs) with dozens of commercial and state government aircraft operators under which aircraft may be hired for SAR work.

Rescue. The main rescue platforms are helicopters and AusSAR has MOUs with commercial and state government helicopter operators. Most of the pilots of those aircraft have little or no experience or formal training in SAR and the aircraft are not specially equipped for SAR. The aircraft operators are businesses, flying passengers and freight for profit. They are not dedicated to SAR, so an aircraft may be committed to a charter flight when AusSAR calls.

ADF Support

In cases where the search area or rescue location is beyond the range of small commercial aircraft, AusSAR may seek assistance from the ADF. A well known recent example of ADF participation in SAR is the rescue of round-the-world yachtsmen from the Southern Ocean near Antarctica, thousands of kilometres from Australia. This required search by long range RAAF Orion and Hercules aircraft and rescue by a helicopter off a RAN frigate.

ADF aircraft are particularly useful because they have great range and endurance, excellent communications suites and can drop survival equipment, such as inflatable boats, shelters, radios and food. ADF assets can be made available for SAR in the same manner as for bushfires, floods and other emergencies.

When a ship or aircraft goes missing the alarm will be raised in one of three ways. A distress beacon may be activated and its transmissions detected by authorities via

satellite or detected and reported by a third party (such as a nearby commercial aircraft or 'ham' radio operator). Alternatively, the crew of a ship or aircraft in distress may send a MAYDAY call by radio. Finally, a person associated with the ship or aircraft may note that it is overdue and notify authorities.

Distress Beacons

About 1,000 distress beacons are activated in Australia each year. A beacon gives AusSAR a relatively small search area. The RCC arranges by telephone for aircraft to participate in the SAR effort. The more remote the search area; the fewer assets will be available locally.

Ideally the search aircraft will locate the victim, and a continuous presence (analogous to a CAP) will be maintained over the site until the rescue helicopter or ship arrives. The aircraft on CAP will monitor the situation, maintain a 'picture' and report events to AusSAR coordinators. AusSAR usually sets up a forward operative at the base from which the search aircraft are operating. The AusSAR representative will liaise with local stakeholders, including Police, State Emergency Services and hospitals and coordinate the search effort.

The briefings and search plans for pilots are prepared at the RCC and faxed to the forward operative for distribution to the searchers. The search aircraft are often light aircraft with one pilot and (sometimes) an observer. They search at low altitude, relying mainly on their eyes. Their only surveillance equipment may be binoculars.

The search aircraft radios often only operate along line-of-sight, so at low altitude their communications range is very limited. Searchers will be 'offline' for hours and report only at the end of a sortie, often by telephone. The ideal solution to the problem of providing timely communications would be a high-flying communications relay aircraft.

Compared to the pace of an air defence operation, the SAR system is currently slow and inflexible. There is no real-time management of search aircraft and the RCC has no visibility of how well its well-meaning amateurs are performing their tasks.

Searches without Beacons

When a ship or aircraft is overdue and presumed missing it may be anywhere between its point of origin and destination. The search area may be huge. In such cases there may be dozens of aircraft searching a corridor thousands of kilometres long. Coordinating so many aircraft with nothing more sophisticated than mobile phones and a few radios is difficult. The pilots' lack of familiarity with the task and associated procedures only compounds problems.

Limitations

In cases of maritime SAR, rescue by helicopter is possible only within a few hundred kilometres of the coast or a helicopter-capable ship. The usual rescue platform is a ship, diverted from its planned course and vectored to the victim by the RCC.

The existing AusSAR system is adequate for most SAR situations and has served Australia well. However, in high intensity searches in remote areas, the current capability is marginally effective.

AusSAR staff recognise the limitations of their system. AusSAR lacks an airborne Direction Finding (DF) capability, for locating victims quickly. They also lack long range communications, which would facilitate tight control over search assets. They have no automated communications relay capability, to speed reporting and tasking. Nor do they have an airspace management capability in remote areas, particularly as Air Service Australia is being commercialised and is changing the way it provides airspace management services. AusSAR also lacks a surface surveillance sensor more capable than the human eye.

Top Cover

To address these deficiencies, AusSAR is in the early stages of a study to provide an airborne command and control and communications relay capability. The 'Top Cover' study could lead to a requirement for a small fleet of specially equipped aircraft or some form of cooperative arrangement with commercial aviation contractors.

The likely solution to the Top Cover requirement will have some capabilities in common with the Wedgetail.

Costs

The total AusSAR budget is less than $20 million per year. Much of the budget is committed to maintaining the coastal radio network and various essential training activities around the country. Only a few million is left for aircraft operations. AusSAR cannot afford expensive solutions.

Wedgetail Support for SAR

If a Wedgetail was available to support a high intensity search in a remote area, the value added would be significant. The Wedgetail could provide many of the capabilities that AusSAR lacks.

The Wedgetail could provide an airborne DF capability, to locate victims much faster and could provide fast, effective communications relay for tasking and reporting. The Wedgetail could provide effective airspace management, where large numbers of aircraft are involved, and there is a need to ensure flight safety and the efficient use of assets (supervision). The Wedgetail could provide a surface surveillance (radar) capability many orders of magnitude better than the human eye.

The Wedgetail could provide real time command and control, with greatly enhanced situational awareness for AusSAR leaders if they had a Link 16 (receive only)

terminal at the forward operative's CP and the RCC. The Wedgetail also has significant endurance on task, to perform CAP over a victim.

Several existing ADF platforms already have some of these capabilities. The RAAF Orions and Hercules already provide some of these services (communications relay, DF and surface surveillance by radar) and RAN ships can do some (airspace management, command and control and DF). However, a Wedgetail could do all of them and do most of them better.

Other Issues

The AusSAR forward operative will usually establish an ad hoc command post at the base from which the SAR aircraft are operating, usually the local airport. The command and control facilities available at the typical rural airport are minimal. If a Wedgetail was to be dedicated to a SAR operation, there might be value in having an AusSAR representative aboard the Wedgetail. Whilst a Wedgetail is not an Airborne Command post in the military sense, it has much better facilities than a remote rural airport.

Though the Wedgetails are not Airborne Command Posts (ACPs) in the military sense, their command, control and communications capabilities will be way beyond anything to which AusSAR has previously had access.

The Wedgetail's communications and sensor suites are several orders of magnitude better than the rented commercial assets available in most SAR operations. The existing arrangements and resources are adequate for most SAR operations but high intensity searches and SAR operations at a great distance from the Australian coast require ADF support.

In scenarios where ADF support is provided, a Wedgetail would be an invaluable command and control platform and would greatly improve the communications connectivity.

WEDGETAIL — ENHANCING AUSTRALIA'S DEFENCES

The value of AEW&C to Australia can be expressed in tactical, operational or strategic terms. At the tactical and operational levels, AEW&C can enhance all of the core air power capabilities of the ADF. At the strategic level, AEW&C can contribute to all of the defence strategies defined in Government policy.

CORE AIR POWER CAPABILITIES

The Air Power Manual (APM) defines five core air power capabilities. These are control of the air, precision strike, precision engagement, rapid force projection and information exploitation.[10]

Control of the Air

Control of the air is the ability to use the air and the surface below it, without being threatened or attacked effectively by enemy air power.[11] Control of the air is the prime air power capability. It is the principal mission of the Hornet fighters of Tactical Fighter Group (TFG).

A universally accepted lesson of 20th century military history is that success in battle is much more likely under the protective mantle of friendly control of the air. Conversely, operations in the face of enemy control of the air are much more difficult and success can be very expensive, in terms of material and human losses.

The APM lists three degrees of control of the air. These are local air superiority, air superiority and air supremacy.[12] Beyond these degrees is absolute control, also known as air *dominance*. The new American F-22 Raptor fighter is described as an air dominance fighter. Only the Americans have the resources to seriously contemplate air dominance.

Local Air Superiority. Local air superiority is control of the air for a limited period of time, over a limited area. Local air superiority prevents enemy air power from posing a *serious* threat to friendly forces or operations in the area. Local air superiority can be defensive (over a friendly naval task force at sea or over a friendly land force, area or city) or offensive (over an enemy naval task force, land force, area or city).

The USN pioneered AEW for the specific purpose of helping its task forces to establish and maintain local air superiority, during power projection operations in the Pacific in 1945. During Operation Desert Storm, AEW&C aircraft enabled Coalition forces to establish local air superiority at any time and place they chose. Facilitating local air superiority remains a standard function of AEW&C.

Air Superiority. Air superiority applies for a more lengthy period of time, over a larger area. Air superiority prevents enemy air power from posing any threat to friendly forces or operations. It can be seen as local air superiority extended to cover an entire AO.

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[10] *The Air Power Manual*, Third Edition, RAAF Air Power Studies Centre, Canberra, 1998, p. 35.
[11] *Ibid.*, p. 36.
[12] *Ibid.*, p. 37.

ADF doctrine states that air superiority is essential for successful offensive or defensive operations. As was the case during Operation Desert Shield, ADF forces would then be able to conduct a wide range of air, land and sea operations under the umbrella of that air superiority.

Air superiority could be established and maintained by means of ground based systems alone. Ground Based Air Defence (GBAD) systems controlled by integrated ADGE have inflicted prohibitively heavy losses on air forces in past conflicts.

However, to deal with modern air threats the GBAD systems would have to be for more capable (and expensive) than the Rapier and RBS-70 systems currently in ADF service. GBAD is far less mobile than fighter aircraft. A force of Hornets could establish air superiority over the Darwin area one day, over a naval task force hundreds kilometres to the west the next day and over an Army brigade hundreds of kilometres inland the day after. To perform the same tasks with GBAD would require three sets of GBAD assets (perhaps hundreds of SAM launchers). AEW&C aircraft have the same flexibility advantage over a ground based ADGE. In a fluid campaign, a few AEW&C aircraft can be as effective as dozens of ground based radar units.

The ADF has to operate in a vast AO and lacks the resources to field the large numbers of ground based systems required to provide coverage of that AO. Aircraft are a more cost-effective means of achieving control of the air in Australia's context. The planned RAAF AEW&C force of six or seven Wedgetails will be capable of maintaining continuous AEW&C support over two different areas, with each patrolled by a squadron of Hornets. The ADF will be able to maintain air superiority over large areas.

Air Supremacy. Air supremacy applies when enemy air power presents no threat to national sovereignty or to friendly air, land or sea operations. Air supremacy requires overwhelming force and is rarely achieved.

In Vietnam, Free World forces enjoyed air supremacy as a result of the mismatch between the tiny North Vietnamese Air Force and the overwhelming mass and quality of American air power. In Operation Desert Storm, Coalition forces achieved air supremacy as a result of overwhelming superiority over the Iraqi Air Force across the full range of air capabilities. State-of-the-art AEW&C played a crucial enabling role in both conflicts. In both cases, the enemy had no AEW&C.

The ADF enjoyed air supremacy in East Timor by default. The opposing militias had no organic air power and no nation chose to provide them with air support. Whether the ADF could establish air supremacy in the face of the active resistance of a regional adversary air force is arguable and would depend on the scenario. A few relatively low quality fighter aircraft could present the ADF with a problem akin to that which the Argentines presented to the British in the Falklands campaign.

The availability of ADF AEW&C aircraft would help to deter a potential adversary from attempting to interfere with ADF operations. As in Operation Desert Storm, small force of ADF fighters coordinated by AEW&C would constitute a shield, behind which vulnerable ADF transport aircraft, helicopters and surface units could operate freely, in a benign environment.

Offence: the Best Defence?

Air operations aimed at achieving control of the air can be offensive or defensive.[13] Offensive operations are termed Offensive Counter Air. Defensive operations are termed Defensive Counter Air.

Offensive Counter Air. Offensive Counter Air (OCA) measures involve seeking out and reducing the enemy's air power capabilities and their threat to friendly control of the air. In an OCA campaign, the targets may include the enemy air defence system, aircraft on the ground, aircrew and ground crew, command and control systems, air bases and supply nodes.

In Operation Desert Storm, Coalition forces conducted the most intensive, comprehensive and successful OCA campaign in history. AEW&C aircraft provided essential command, control and communications to a large, diverse force, which flew thousands of sorties in a small, crowded AO over a period of just a few weeks.

The principal ADF OCA platform is the F-111, but the ADF has only a few. Hornet fighters can also perform the OCA mission, but higher priority tasking may reduce the number of Hornets available for OCA to a few also. The ADF can not afford attrition, so AEW&C support will be essential to help OCA strikes get into and out of enemy airspace with a minimum of exposure to enemy defences.

Defensive Counter Air. Defensive Counter Air (DCA) measures deny the enemy control of the air by attacking enemy air power *in the air* and nullifying its effects. The most famous DCA campaign was that conducted by the RAF in the Battle of Britain (1940).

The British conducted another DCA campaign in the Falklands (1982) without the benefit of AEW&C and many of the ships in the RN task force were sunk or damaged. In contrast, Coalition forces in Operation Desert Storm were not subjected to any attacks by Iraqi aircraft and were able to conduct their operations at will. A 'lucky shot' by a very inaccurate Scud SSM caused the only Coalition casualties due to Iraqi air action.

Given the lack of mass and redundancy in the ADF, force protection will be essential in any operation. DCA will be a vital task for TFG in many scenarios. AEW&C support will be essential to enable the few available Hornet fighters to conduct a successful DCA campaign.

[13] *Air Power Manual*, p. 37.

Precision Strike

Precision strike is the ability to use air power to destroy or neutralise targets.[14] The principal precision strike assets of the ADF are the F-111 bombers of the Strike Reconnaissance Group (SRG). Several other ADF platforms are capable of precision strike, but it is not their prime function.

During the recent UN-sponsored peace enforcement operations in the former Yugoslavia, air power was the principle means used to compel the Serbs to cease their operations in Kosovo. Western governments were reluctant to commit ground forces as they feared friendly casualties. The trend is likely to continue.

Political leaders also feared causing civilian (collateral) casualties so the decision-making power was moved up the chain of command. Pilots often had to waste time seeking approval from commanders to attack vehicles that they believed to be tanks or artillery pieces. Generals in headquarters hundreds of kilometres away were making decisions that should have been left to the captains and majors in the cockpits of aircraft on the spot. The array of sensor platforms available over the battlefield was sufficient to identify targets, but the time lost double-checking and authorising action often gave the enemy the chance to escape. NATO forces were thus unable to capitalise on the inherent speed, flexibility and responsiveness of modern air power because of overly restrictive rules of engagement.

Nevertheless, NATO aircraft flew thousands of sorties in a high threat environment, evaded hundreds of Serbian SAMs and successfully struck many targets, for the loss of only two aircraft and no aircrew. The impressive results were made possible in large part by the support provided by a few AEW&C aircraft.

ADF AEW&C aircraft could enhance ADF land and maritime strike operations as well. The propensity to reduce attrition would be particularly valuable to our small force.

Precision Engagement

Precision engagement is the ability to engage an opponent without applying firepower. Precision engagement activities can include surveillance, reconnaissance, tracking a submarine, shadowing a ship or land unit, airborne insertions and extractions, fighter sweeps through contested airspace or intelligence operations.[15]

All of the RAAF FEGs and the air components of the RAN and Army can take active part in precision engagement operations. Orions of the Maritime Patrol Group (MPG) can perform surveillance, reconnaissance, submarine tracking and ship shadowing. Transport aircraft of the Air Lift Group (ALG) and the helicopters of Army Aviation and the Fleet Air Arm can perform surveillance, reconnaissance, shadowing and

[14] *Air Power Manual*, p. 38.
[15] *Ibid.*, p. 39.

airborne insertions and extractions. TFG Hornets can perform fighter sweeps. SRG RF-111s can perform high speed, long range reconnaissance and intelligence gathering.

SCG Wedgetails will be the ADF's pre-eminent surveillance platforms, but the Wedgetails will also be capable of coordinating and enhancing the other platforms' precision engagement operations. The early warning and communications capabilities of the Wedgetails will facilitate the maintenance of air superiority in the airspace around aircraft on precision engagement missions, and enhance the situational awareness and survivability of all participants. The command and control capabilities of the Wedgetails will help to maximise the efficiency of such operations.

Rapid Force Projection

Force projection is the deployment of military power to locations in or near an area where the government has decided to significantly increase its strategic influence on the basis of force.[16] Force projection can involve the deployment of air power, land power, maritime power or some combination of them.

Air power force projection is the most rapid form of power projection. It can entail the forward deployment of fighter, strike or maritime patrol aircraft to northern bases or to overseas bases. The deployment of combat aircraft away from their main operating bases in the south generates the requirement for logistics support and personnel movement, which will create work for the ALG transport fleet. It may also generate demand for tanker support.

The unscheduled deployment of F-111s to a forward base such as Darwin or Butterworth would be a significant 'signal' in times of heightened tension. It would be a strong deterrent to a potential adversary within strike range. AEW&C support would be valuable in several ways. The radar emissions from continuous AEW&C patrols would be detectable over 500 kilometres away and would signal capability and intent. If strike operations became necessary, AEW&C would help the strike aircraft, reconnaissance aircraft and supporting tankers operate more safely in or near enemy territory. The certainty would enable friendly forces to be more aggressive, at a reduced level of risk.

Land power force projection can entail movement by surface transport, including sea, road or rail. Rapid land power projection must be by air. It creates work for the ALG transport fleet and can also involve civil air assets, such as QANTAS and Ansett passenger and cargo aircraft. The deployment to a forward location such as Darwin of an Army brigade on short notice to move (NTM) would signal that Australia was ready, willing and able to make a timely response to a contingency.

[16] *Air Power Manual*, p. 40.

In such a scenario, AEW&C would be very useful in helping establish air superiority in whatever areas ADF transport aircraft are picking up, transiting and delivering. Force projection by air is difficult (if not impossible) without secure staging bases and deployment areas. Transport aircraft are very vulnerable and neither ALG nor the Army's combat forces can afford attrition from enemy interference.

Maritime power force projection entails the forward deployment of warships, which can be poised close to the edge a nation's territorial limit for extended periods (months). Air support for a naval task force would depend on the scenario, the level of threat and the distance from an air base.

In such a scenario, the air support may involve Orion, providing ASW and anti-ship support. It may involve full fighter cover with AEW&C support and strike aircraft on call. It may just involve AEW&C support, which would significantly extend the naval task force commander's 'bubble' of awareness, from line-of-sight to hundreds of kilometres. At either end of the spectrum of support, the increased awareness provided by AEW&C would reduce the uncertainty and risk for friendly forces and increase the pressure on a potential adversary.

Information Exploitation

Information exploitation involves the use of aerospace power to provide the knowledge required to conduct successful air, land or sea operations.[17] Superior information exploitation leads to the knowledge edge. The Americans now talk of 'information superiority' and consider it to be an important part of their national strategy. Knowledge is power.

Information exploitation is at the heart of the AEW&C concept. An AEW&C aircraft carries no bombs or missiles and can take no physical action against a target. The great value of AEW&C lies in its ability to increase the effectiveness and suvivability of the other platforms.

The ADF's warriors are fond of saying '*if we can find it; we can kill it*'. The accuracy and reliability of modern precision guided munitions (PGMs) are such that 'locking on' to a target virtually guarantees a hit and the destructive power of modern weapons is such that a hit will usually be a 'kill'.

Unfortunately, it works both ways. If an opponent can find us and target us with a PGM, we can be killed. As has always been the case in war, victory will go to the side with the better situational awareness, the better decision-making processes and the faster reactions.

At the operational and tactical levels, AEW&C is a critical link in the system for achieving situational awareness and distributing commanders' decisions to forces in action, in a timely manner. At the tactical level, AEW&C also provides excellent real-time force coordination. Most battlefield and theatre information can be moved upwards and downwards via the AEW&C conduit.

[17] *Air Power Manual*, p. 41.

Much of the data gleaned by reconnaissance and surveillance platforms may be passed back up to the intelligence organisation and higher command via AEW&C's datalink systems. The reconnaissance and surveillance platforms include a wide range of aircraft, UAVs and even ships and land vehicles in remote locations. The platforms may be too far from a fixed point of entry to the ADF C3I system for linkage or may lack connectivity to other forces in an operation as a result of interoperability mismatches. Meaningful intelligence can flow in the opposite direction. This has been added to from many other sources and processed (value added) by intelligence agencies.

In many scenarios, the only timely means of exercising command and control over far flung fighting forces will be AEW&C. The chain of command from Australian Defence Headquarters, through Headquarters Australian Theatre, a Deployable Joint Force Headquarters, a Regional Operations Centre and the Air Defence Ground Environment will often have to pass through an AEW&C aircraft to get to aircraft in action.

STRATEGIC POLICY

The Australian Government's strategic policy defines three basic tasks for the ADF. These are Defeating Attacks on Australia (DAA), Defence of Regional Interests (DRI) and Defence of Global Interests (DGI).[18]

Defeating Attacks on Australia

The DAA mission involves many scenarios that generate requirements core to AEW&C tasks. In most credible scenarios, the surveillance power and command and control power of AEW&C could be decisive. In most scenarios, air superiority will be a decisive advantage and will significantly reduce friendly losses.

Defence of Regional Interests

Australia lacks the resources to unilaterally secure all of its interests in the region, so the ADF needs assistance to perform the DRI mission. We would have to act in coalition with our allies and regional neighbours.

As a rich nation with high levels of technological competence, Australia could contribute AEW&C to such coalition operations. AEW&C would enhance coalition interoperability and constitute a very valuable force multiplier, particularly in the kinds of air and maritime operations likely in our region. AEW&C would also greatly increase the probability of success in any unilateral operations that Australia chose to conduct.

[18] *Australia's Strategic Policy*, Department of Defence, Canberra, 1997. Hereafter referred to as ASP97.

Recent coalition operations in East Timor would have been enhanced by the addition of AEW&C. Attempts by small groups of militia or Special Forces to 'slip in' undetected by boat or aircraft would be virtually impossible in the face of a continuous Wedgetail patrol over the area.

Unilateral ADF operations to evacuate Australian citizens and others from places in the region (such as Cambodia) would also be enhanced by AEW&C. The overt presence of AEW&C and fighters would deter potential adversaries from attempting to interfere with airlift operations by vulnerable transport aircraft.

Defence of Global Interests

Australia lacks the resources to unilaterally secure all of its interests all over the world, so the ADF needs assistance to perform the DGI mission. We would have to act in coalition with allies and under the auspices of organisations such as the UN. Compared to an infantry force, a Wedgetail detachment would be far less likely to incur domestic political costs, for example casualties or international political embarrassments such as alleged involvement in atrocities or misconduct.

In American-led coalition operations, a few Australian AEW&C aircraft would be welcome. American AEW&C assets are usually overtasked around the world. AEW&C would be seen as a significant contribution, with more political value than infantry or a frigate.

Many UN operations involve the air and maritime forces of many nations, some of which have no history of interoperability with Western forces and lack the ADF's technological and operational sophistication and technical resources. Combined operations with the forces of such nations can be dangerously disorganised and AEW&C can be crucial. Again, Australian AEW&C would be a high value low risk contribution.

CONCLUSION

AEW&C is not the *most* important element of a defence force, but it is important. History has shown that operations without AEW&C support are less likely to be successful. AEW&C adds value to most air, land and maritime operations. In many credible Australian scenarios, AEW&C can provide a decisive advantage.

The situational awareness generated by AEW&C is often described as a 'God's eye view' of the battlespace. In concert with other surveillance systems and command and control systems, AEW&C can clear the 'fog of war' and reduce friction.

The ADF already operates, or is in the process of acquiring, most of the capabilities that define a modern 'information age' defence force. AEW&C is one of the last major capabilities missing from the ADF order of battle.

AEW&C aircraft are not the *only* means of performing the range of missions for which the Wedgetails are intended, but they are the most cost-effective and flexible alternative. The AEW&C Wedgetails will fill a serious, longstanding gap in ADF capabilities. They are an important piece of the puzzle.

ANNEX A

ELECTRONIC WARFARE TERMINOLOGY

Electronic Warfare (EW)

Use of the electromagnetic spectrum and directed energy to control the electromagnetic spectrum or to attack the enemy.

Electronic Attack (EA)

Also known as Electronic Counter Measures (ECM).
Use of the electromagnetic spectrum or directed energy to attack personnel, facilities or equipment, with the intent of degrading, neutralising or destroying enemy combat capability.
EA can be active or passive.

> **Active EA** includes jamming, flares, deception, manipulation and imitation.
>
> **Passive EA** includes chaff, and signature reduction (or 'stealth')

Electronic Protection (EP)

Also known as Electronic Counter Counter Measures (ECCM).
Actions taken to protect personnel, facilities or equipment from any effects of friendly or enemy employment of EW that degrades, neutralises or destroys friendly combat capability.

Electronic Support (ES)

Also known as Electronic Support Measures (ESM).
Actions taken to search for, intercept, identify and locate sources of radiated electromagnetic energy, for immediate threat recognition; in support of EW operations and other tactical actions, such as threat avoidance, homing and targeting.
ESM includes:

> **Communications Intelligence** (COMINT) — the technical material and intelligence information gleaned from electromagnetic communications transmissions, such as radio and telephone.
>
> **Electronic Intelligence** (ELINT) — the technical material and intelligence information gleaned from electromagnetic non-communications transmissions, such as radar.
>
> **Signals Intelligence** (SIGINT) — the fusion of COMINT and ELINT.

ANNEX B

THE ELECTROMAGNETIC SPECTRUM

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

Notes

1. Air surveillance radars tend to operate in the upper half of the UHF band range (approximately 1.5 to 3 GHz). Examples of operational systems include:

APS-20	Guardian/Skyraider	E/F bands
APS-145	E-2 Hawkeye	upper UHF
APY-2	E-3 AWACS	E band
Erieye	Swedish Argus	E/F bands
Phalcon	Israeli 707	D band

2. Surface surveillance radars tend to operate at higher frequencies, in the middle of the SHF band range (approximately 8 to 10 GHz). Examples of operational systems include:

APY-3	E-8 JSTARS	I band

3. The part of the electromagnetic spectrum where most radars operate can be represented by the diagram below:

Band	VHF	UHF				SHF					
Letters	A	B	C	D	E	F	G	H	I	J	K

Frequency	30 MHz	300MHz	3 GHz
Wavelength	10 m	1 m	10 cm

ANNEX C

AEW&C TYPES
(BY NATION OF ORIGIN)

Brazil

Embraer EMB-145 twin turbofan (Swedish ERIEYE radar)

Britain

Westland Sea King AEW Mk 2 helicopter (Searchwater radar)

China

Harbin Z-8 heavy lift helicopter (radar unknown)

Shaanxi Y-8 four engine turboprop (British Skymaster radar)

Israel

Boeing 707 four engine turbofan (PHALCON radar)

Russia

Antonov An-71 MADCAP twin turbofan

Ilyushin A-50 MAINSTAY four engine turbofan

Kamov Ka-31 helicopter

Yakolev Yak-44 twin turboprop

Sweden

Saab 340 twin turboprop (ERIEYE radar)

United States

Boeing E-3 Sentry (AWACS) four engine turbofan

Boeing E-767 AWACS (Japan only) twin turbofan

Grumman E-2 Hawkeye twin turboprop

Lockheed EC-130V AEW&C Hercules four engine turboprop

Lockheed P-3 AEW&C Orion four engine turboprop

ANNEX D

NATIONAL AEW&C FLEETS
(BY THE YEAR 2005)

FIXED-WING

Operator	Number	In Service	Type
Australia	7	2004	Boeing 737 Wedgetail
Brazil	5	2000	Embraer EMB-145
Britain	7	1990	Boeing E-3 AWACS
Chile	1	1995	Boeing 707 / Phalcon
China	4	2000	Shaanxi Y-8 / Skymaster
Egypt	6	1987	Grumman E-2 Hawkeye
France (Air Force)	4	1990	Boeing E-3 AWACS
France (Navy)	3	1997	Grumman E-2 Hawkeye
Greece	4	2002	Embraer EMB-145
India	3	2005	Beriev A-50 Mainstay
Iraq (held by Iran?)	2	1989	Ilyushin Il-76 Adnan
Israel	6	1978	Grumman E-2 Hawkeye
Japan	13	1982	Grumman E-2 Hawkeye
Japan	4	1998	Boeing 767 AWACS
Mexico	4	2003	Embraer EMB-145
NATO	18	1982	Boeing E-3 AWACS
Russia (Air Force)	26	1984	Beriev A-50 Mainstay
Russia (Navy)	3	?	Antonov An-74 Madcap
Russia (Navy)	?	?	Yakolev Yak-44
Saudi Arabia	5	1986	Boeing E-3 AWACS
Singapore	4	1987	Grumman E-2 Hawkeye
South Africa	2	1990	Boeing 707 / Phalcon
Sweden	6	1998	Saab 340 Argus
Taiwan	6	1995	Grumman E-2 Hawkeye
United States (Navy)	80	1964	Grumman E-2 Hawkeye
United States (Air Force)	32	1977	Boeing E-3 AWACS
United States (Air Force)	1	1991	Lockheed EC-130 Hercules
United States (Customs)	6	1986	Lockheed P-3 Orion
TOTAL	**262**		

ROTARY-WING

Britain	9	1982	Westland Sea King
China	4	2003	Harbin Z-8
India	4	2001	Kamov Ka-31
Spain	2	1990	Westland Sea King
TOTAL	**19**		

D2

NOTES

The majority of AEW&C operators have **six or more** aircraft in service. Such a fleet enables an operator to maintain an AEW&C capability airborne on at least **two** stations for **extended periods**.

Some operators have only **three or four** aircraft. Such a fleet enables an operator to maintain an AEW&C capability airborne on **one** station for **extended periods**.

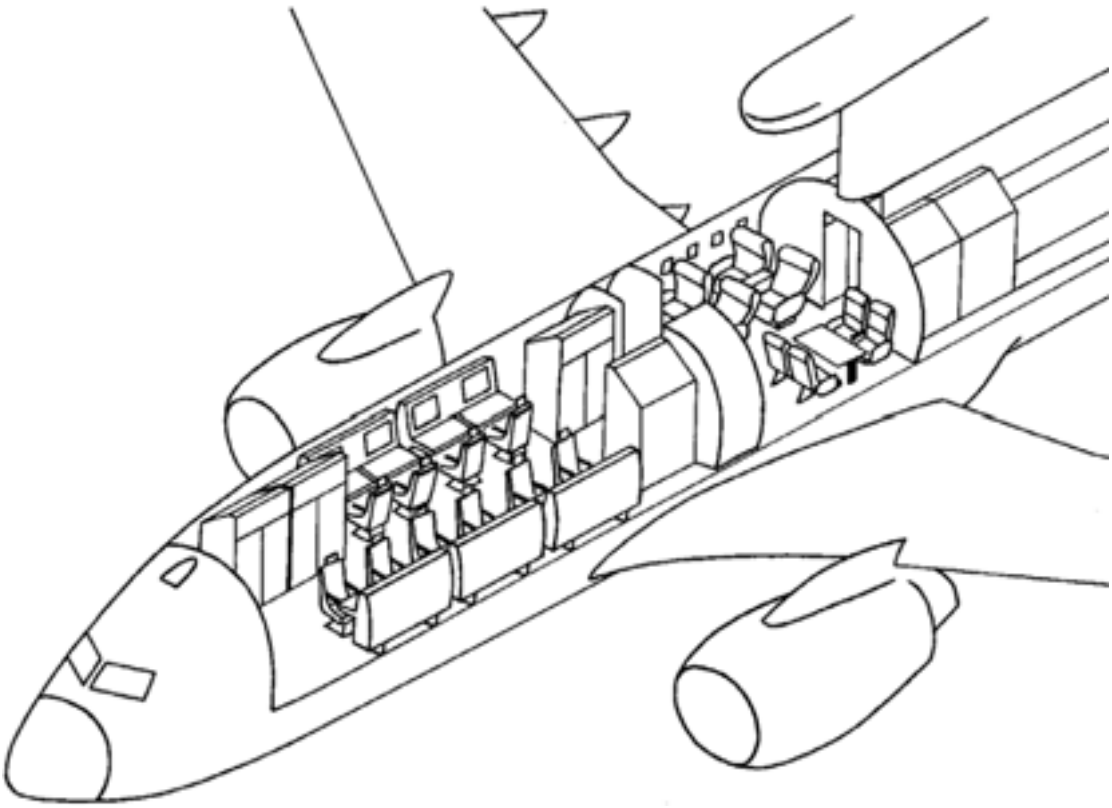
A few operators have only **one or two** aircraft. Such a small fleet has **no sustained capability** and is for trials or 'proof of concept' purposes only.

WORLD AEW&C ORBAT (BY 2005)

Operator	Fixed-Wing	Rotary-Wing	Total
Australia	7	-	7
Brazil	5	-	5
Britain	7	9	16
Chile	1	-	1
China	4	4	10
Egypt	6	-	6
France	7	-	7
Greece	4	-	4
India	3	4	7
Iraq (held by Iran?)	2	-	2
Israel	6	-	6
Japan	17	-	17
Mexico	4	-	4
NATO	18	-	18
Russia	29	-	29
Saudi Arabia	5	-	5
Singapore	4	-	4
South Africa	2	-	3
Spain	-	2	3
Sweden	6	-	6
Taiwan	6	-	6
United States	119	-	119

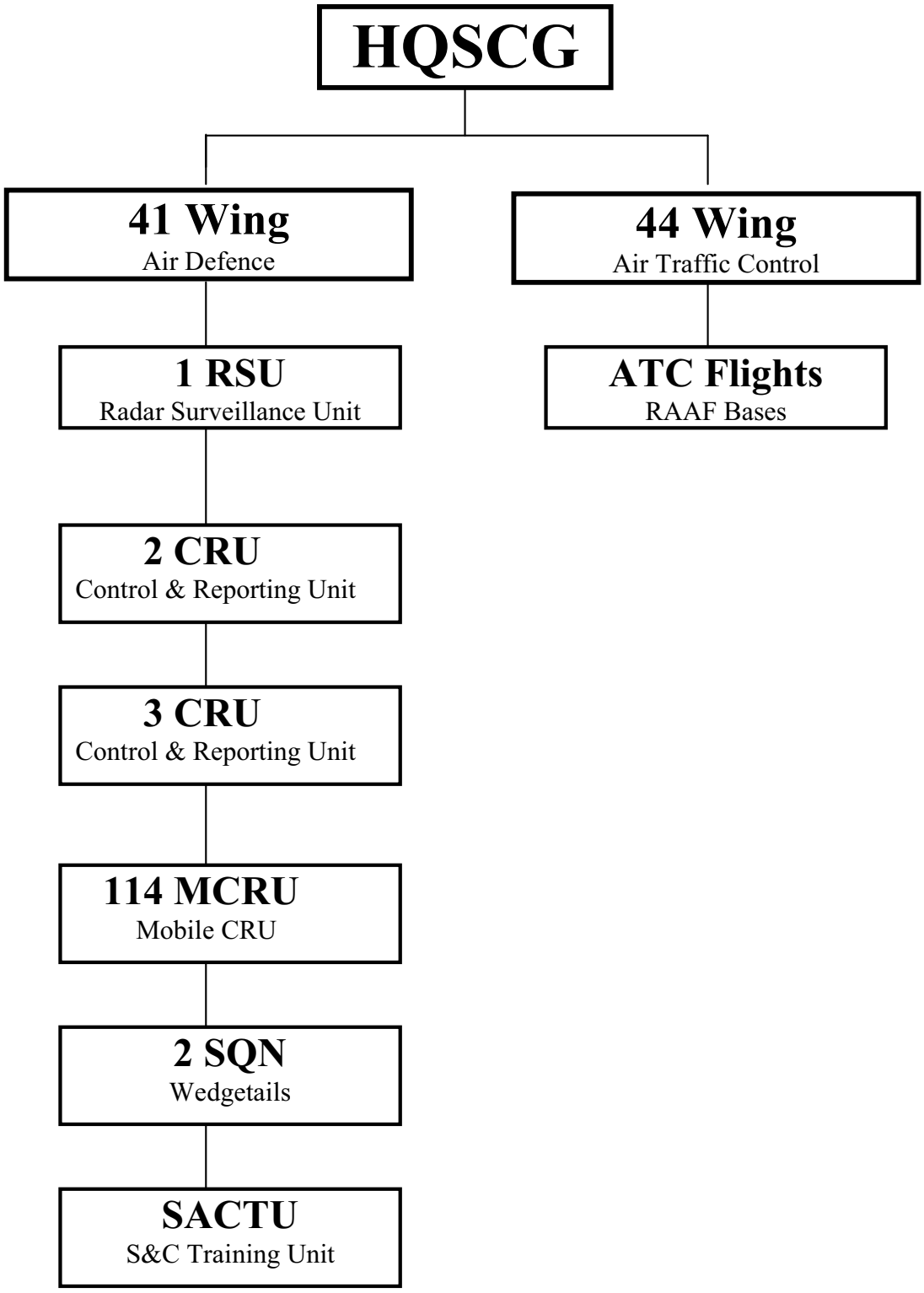
ANNEX E

WEDGETAIL AEW&C BOEING 737
INTERIOR LAYOUT



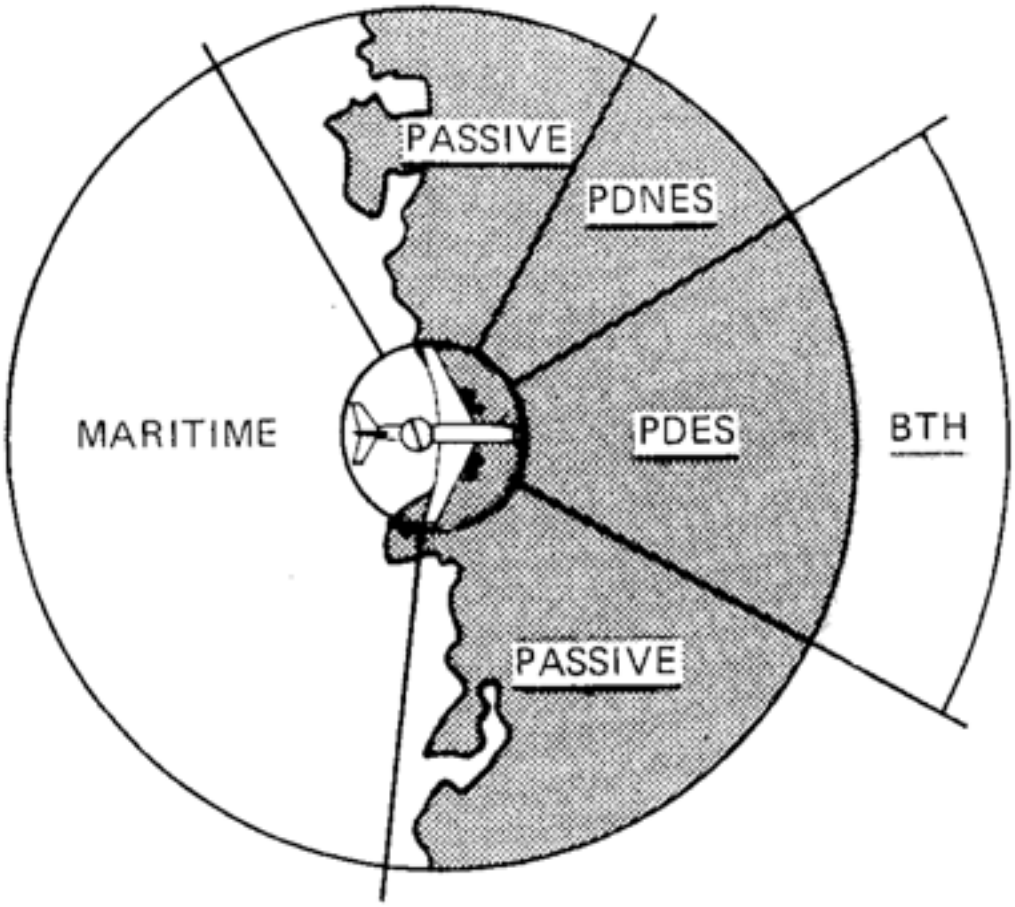
ANNEX F

SURVEILLANCE & CONTROL GROUP



ANNEX G

TYPICAL AEW RADAR MODES



Typical Radar Mode Utilisation

The diagram shows the radar mode options available for a Boeing E-3 AWACS.
The modes can be varied in one scan (about ten seconds). The modes shown are:

MARITIME	Low PRF to detect slow moving surface targets
PASSIVE	Radar switched off over areas where surveillance is not needed
PDNES	Pulse Doppler, No Elevation Scan Provides data on target range and bearing only
PDES	Pulse Doppler, Elevation Scan Provides data on target range, bearing and height
BTH	Beyond The Horizon Detects high flying targets beyond the cut-off range for low-flying targets

BIBLIOGRAPHY

Allport, D., 'AEW Aircraft Survey', *Air International*, March 1995.
Anglim, S., 'Boyd Loops, Ace Factors and Fighter Combat', *RAF Air Power Review*, Summer 1999, London, 1999.
Arnett, E., *Military Capability and the Risk of War : China, India, Pakistan and Iran*, Oxford University Press, London, 1997.
Australia's Strategic Policy, Department of Defence , Canberra, 1997.
Ball, D., *Provocative Plans*, SDSC, ANU, Canberra, 1991.
Barker, A.J., *Suicide Weapon*, Ballantine Books Ltd, London, 1971.
Barnett, J, *Future War: An Assessment of Aerospace Campaigns in 2010*, Air University Press, Maxwell Air Force Base, 1996.
Bond, B. & Melvin, M., (Ed), *The Nature of Future Conflict*, Occasional Paper No 36, Strategic & Combat Studies Institute, British Army, UK, 1998.
Braybrook, R., 'Enhancing the Hawkeye', *Air Pictorial*, July 1999.
Braybrook, R., 'Forward to the Past', *Air International*, August 2000.
Browne, J. & Thurbon, M., *Electronic Warfare*, Brassey's, London, 1998.
Brungess, J., *Setting the Context : SEAD and Joint Warfighting in an Uncertain World*, Air University Press, Maxwell Alabama, 1994.
Chadwick, F., *Gulf War Fact Book*, GDW, Bloomington Illinois, 1991.
Chamish, B., 'Phalcon : Israel's AWACS', *Air International*, April 1994.
Coastwatch: An Overview, Australian Customs Service, Canberra, 1999.
Connery, D., 'Air Defence in the Amphibious Tactical Lodgement – The Role of GBAD', *ADF Journal*, July / August 1998.
Cotterill, D., 'JP-117 Shifts to the Right', *Australian Defence Magazine*, June 2000.
Covault, C., 'USAF Technology Advances to Forefront', *Aviation Week & Space Technology*, 5 April 1999.
Davis, L., *MiG Alley : Air to Air Combat Over Korea*, Signal / Squadron Publications, Carrollton Texas, 1978.
Drendel, L., *A History of the USAF Tactical Air Forces 1970–1977*, Squadron/Signal Pub Inc, Michigan, 1978.
Drendel, L., *Air War Over Southeast Asia*, Squadron/Signal Pub Inc, Texas, 1984.
Drew, D., 'Air Power in Peripheral Conflict', *The War in the Air: 1914 to 1994*, RAAF Air Power Studies Centre, Canberra, 1994.
Duus, A., *Aerostat Availability in Northern Australia*, DSTO Client Report AOD 96/05, 1996.
Ferguson, G., 'Australia creeps towards Missile Purchase', *Australian Defence Magazine*, October 1999.
Francillon, R., 'Messenger of the Gods', *Air International*, January 1995.
Francillon, R., 'SAAB S-100 Argus', *Combat Aircraft*, May 1998.
Friedman, N., *US Destroyers: An Illustrated Design History*, Arms & Armour Press, London, 1982.
Fulghum, D., 'Electronic Intelligence', *Aviation Week & Space Technology*, 5 May 1997.
Garner, D., 'ABCCC: The Eyes of the Battlespace', *Air Force Magazine*, July 1999.
Gilbert, M., *First World War Atlas*, Weidenfeld & Nicolson, London, 1970.
Goodman, G., 'Chief Advocate for Jointness', *Armed Forces Journal International*, December 1999.

Goodman, G., 'Aerospace Force', *Armed Forces Journal International*, September

2000.
Grazebrook, A., 'RAN Presses Urgent Need for Modern Air Warfare', *Asia Pacific Defence Reporter*, December 1999.
Griehl, M. and Dressel, J., *Zeppelin: The German Airship Story*, Arms & Armour Press, London, 1990.
Grossnick, R., *US Naval Aviation: 1910 –1995*, US Naval Historical Centre, Washington DC, 1997.
Gunston, B., *Rockets & Missiles*, Salamander, London, 1979.
Harding, S., *US Army Aircraft since 1947*, Airlife Pub Ltd, Shrewsbury UK, 1990.
Harknett, R., 'The Risks of a Networked Military', *Orbis: Journal of World Affairs*, Winter 2000.
Hawke, A., *Address to the Royal United Services Institute (Victoria)*, 27 April 2000.
Hewish, M., 'Lords of the Skies', *Jane's International Defense Review*, July 1999.
Hillsdon, R., 'Lighter-than-Air Surveillance Systems', *Air Power: Global Developments & Australian Perspectives*, Brassey's, Sydney, 1988.
Hirst, M., *Airborne Early Warning*, Osprey Publishing, London, 1983.
Horner, C., 'New Era Warfare', *The War in the Air: 1914–1994*, RAAF Air Power Studies Centre, Canberra, 1994.
Hoyle, C., 'High Flying Assets', *Jane's Defence Weekly*, 21 July 1999.
Hudson, H., *Northern Approaches: A Report on the Administration and Management of Civil Coastal Surveillance in Northern Australia*, Department of Transport & Communications, AGPS, Canberra, 1988.
Huerto, D., *Command and Control of Philippine Maritime Air Surveillance*, RAAF Air Power Studies Centre, Canberra, 1999.
Jane's All the World's Aircraft, Jane's Information Group, Couldson UK.
Kaminski, T., 'US Army Airborne Reconnaissance', *Combat Aircraft*, AIRtime Publishing, Narwalk CT.
Kaplan, G., 'Maritime Air power for Australia', *The Navy*, July 2000, Canberra.
Kresa, K., 'Progress through Process', *Armed Forces Journal International*, December 1999.
Kopp, C., 'Strategic Tanker Transports for Australia', *Air Power International*, Volume 4, Number 2, 2000.
Kopp, C., 'Wegetail – Australia's Pocket AWACS', *Australian Aviation*, June 1999.
Kopp, C., 'RAAF AEW Program begins to Mature', *Australian Aviation*, June 1996.
Kopp, C., 'Airborne Early Warning and Control', *Australian Avi*ation, November 1994.
Kopp, C., 'AEW and AWACS', *Australian Aviation*, March 1989.
Kopp. C., 'Why Australia needs an AEW Capability', *Australian Aviation*, June 1983.
Lake, J., 'The Hawkeye Abroad', *Air International*, December 1997.
Mann, E.C., *Thunder and Lightning : Desert Storm and the Airpower Debates*, Air University Press, Maxwell Alabama, 1995.
Mann, P., 'Belgrade called Victor in War's First Phase', *Aviation Week & Space Technology*, 26 April 1999.
McLean, M., 'The Militarisation of Space', *RAF Air Power Review*, London, Spring 1999.
Merskey, B., & Polmar, N., *The Naval Air War in Vietrnam*, Nautical & Aviation Pub Co, Annapolis, 1981.
Moorman, T., 'The Explosion of Commercial Space and the Implications for National Security', *Airpower Journal*, Spring 1999.
Morrocco, J., 'UK's Astor Eyed as NATO Springboard', *Aviation Week & Space*

Technology, 8 March 1999.
Murray, W., 'Drifting Into the Next Century : The USAF and Air Power', *Strategic Review*, Summer 1999.
Natkiel, R., *Atlas of World War Two*, Bison Books, London, 1985.
Nemecek, V., *History of Soviet Aircraft*, Willow Books, London, 1986.
Nicholls, M., Embraer's New Stars, *Air Forces Monthly*, July 1999.
Nordeen, L. *Air Warfare in the Missile Age*, Smithsonian Institute Press, Washington DC, 1985.
O'Dell, R., 'Boeing E-3 Sentry Variants & Capabilities', *RAF Air Power Review*, Summer 1999, London, 1999.
O'Donohue, R., 'EASTROC Construction Begins', *RAAF News*, June 1999.
Pacific Defence Reporter, Annual Reference Edition, 1908/81, Peter Isaacson Pub Pty Ltd, Melbourne, 1980.
Palmer, J., 'AEW Aircraft: The GEC Avionics Proposal', *Air Power*, Brassey's, Sydney, 1988.
Peebles, C., *Guardians: Strategic Reconnaissance Satellites*, Ian Allen Ltd, London, 1987.
Penna, D., 'The Ascendance of Airborne Early Warning', *Australian Aviation & Defence Review*, March 1981.
Pocock, C., 'U-2000 and a Long Way Beyond', *USAF Yearbook 1999*, RAF Benevolent Society, London, 1999.
Pocock, C., 'ASTOR', *RAF Yearbook 1999*, RAF Benevolent Society, UK, 1999.
Pocock, C., 'The Eyes Have It', *Air International*, April 1997.
Reade, D., 'Frisbee Hercules', *Air International*, November 1993.
Reade, D., 'US Customs Service P-3 Air Force', *Air International*, May 1993.
Redding, R., & Yenne, B., *Boeing: Planemaker to the World*, Bison Books, Greenwich Connecticut, 1983.
Report of the Aircraft Accident Investigation Board, US Army UH-60 Blackhawk *helicopters 87-26000 and 88-26060*, Executive Summary, 27 May 1994.
Ripley, T., 'Israeli Air Power into the 1990s', *Air International*, September 1993.
Roos, J., 'The Cutting Edge', *Armed Forces Journal International*, May 2000.
Saunders, K., 'The Stars Look Down', *USAF Yearbook 1999*.
Schneider, B., and Grinter, L. (Ed), *Battlefield of the Future*, US Air War College, Air University, Maxwell Air Force Base, 1998.
Scott, C., 'Forcing the Peace', *RAF Air Power Review*, Spring 1999.
Sharer, W., 'Command and Control: The Navy Way over Kosovo', *Proceedings*, October 1999.
Sherman, J., 'How the Rest of the World is Responding to the RMA', *Armed Forces Journal International*, December 1999.
Shevlin, J., 'Maritime Air Warfare for the RAN', *The Navy*, January / March 2000, Navy League of Australia, Canberra.
Shine, C., 'Restructuring the Australian Army', *ADF Journal*, July / August 1998.
Simpson, R., 'Boeing E-3 Sentry', *Air Pictorial*, March 1987.
Stokes, M., *China's Strategic Modernisation*, Strategic Studies Institute, US Army War College, 1999.
Treadwell, T., *The Ironworks: Grumman's Fighting Aeroplanes*, Airlife Pub Ltd, Shrewsbury UK, 1986.
United States Air Force Yearbook 1999, RAF Benevolent Fund, RAF Fairford, 1999.
Veres, A., 'JSTARS Shines in FOAL EAGLE 97', *Asia Pacific Defence Forum*, Summer 1998.

Wall, R., 'Upgrades Proposed for Enhanced E-2C', *Aviation Week & Space Technology*, 26 April 1999.
Wall, R., 'New ABCCC Tactics used in NATO Air Strikes', *Aviation Week & Space Technology*, 26 April 1999.
Wall, R., 'Joint STARS Changes Operational Scheme', *Aviation Week & Space Technology*, 3 May 1999.
Wall, R., 'E-2Cs become Battle Managers', *Aviation Week & Space Technology*, 10 May 1999.
Waters, G., *Gulf War Lesson One: The Value of Air Power*, RAAF Air Power Studies Centre, Canberra, 1992.
Woodward, J., *Memoirs of the Falklands Battle Group Commander*, Book Club Associates, London, 1992.
Yenne, B., *Lockheed*, Bison Books, London, 1987.
Yenne, B., *McDonnell Douglas: A Tale of Two Giants*, Bison Books, London, 1985.