DEFENCE AND DIPLOMACY

IN PURSUIT OF NATIONAL SECURITY

VOL. 11 NO. 4 ISSN 2347 - 3703 JULY-SEPTEMBER 2022

JOURNAL OF THE CENTRE FOR AIR POWER STUDIES

AIRBORNE EARLY WARNING AND CONTROL: CRUCIAL TO BATTLE MANAGEMENT

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Information and intelligence is a crucial starting point for military strategic advantage. For long, countries have been developing surveillance technologies.[1] Aerial balloons were the first to be used for air reconnaissance and intelligence collection. Elevated position gave them the "birds-eye view". Montgolfier brothers are credited with the first free (non-tethered) hot air balloon used by humans in 1783.[2] After the first heavier-than-air aircraft flight in 1903 by Wright Flyer,[3] aircraft began being used for visual and photographic surveillance. Aircraft altitudes increased over the years and so did coverage. Invention of better sensors like the radar, thermal sensors, and signal interception devices added to the type of surveillance. Satellites raised the vantage point even higher. Unmanned Aerial

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1. Dean Wilson (2012), "Military Surveillance", in Kairstie Ball, Kevin Haggerty and David Lyon (eds.), *Handbook of Surveillance Studies* (London: Routledge, 2012).
2. "The History of Hot Air Ballooning", Balloon Fiesta, at https://balloonfiesta.com/Hot-Air-History#:~:text=On%20September%2019%2C%201783%20Pilatre,balloon%20called%20'Aerostat%20Reveillon. Accessed on July 17, 2022.
3. NASA Archives, "Space History Photo: The Wright Brothers First Heavier-than-Air Flight", Space.com, September 6, 2013, at https://www.space.com/22676-the-wright-brothers-first-heavier-than-air-flight.html. Accessed on July 21, 2022.

Vehicles (UAV) brought greater flexibility. Satellite-based navigation increased accuracy in time and space.

The heightened tensions and need for dominance during the Cold War required constant surveillance of the adversary. Very high altitude, high speed, reconnaissance aircraft like the MiG-25, and SR-71 evolved. There was a requirement for monitoring the entire surface, sub-surface and airspace. Helicopter-based sensors were good for battlefield and sea surveillance, including for submarines. New surveillance and intelligence technologies and techniques such as digital imaging evolved. Even when the Cold War ended, the war-on-terror brought a new dimension. With the advent of secure high-speed data-links, high-definition video imagery from infrared sensors, and synthetic aperture radar (SAR), could be transferred from aerial platforms to the ground stations or even to other aircraft. Once the UAVs began operating in swarms, the aerial platforms began task sharing such as surveillance, electronic jamming, communication relay, and kinetic attacks. The US Defence Advanced Research Projects Agency's (DARPA) Collaborative Operations in Denied Environment (CODE)[4] programme was meant for this. From here evolved the Manned Unmanned Teaming (MUMT).

There was also a requirement to go beyond just airborne early warning but to exercise control over various elements of the battlefield. The airborne sensor platforms with a Command and Control operations room evolved early and were called the Airborne Early Warning and Control (AEW&C) aircraft.

AIRBORNE EARLY WARNING AND CONTROL AIRCRAFT

AEW&C aircraft carries an airborne radar that has the ability to detect aircraft, ships, missiles, surface vehicles, and a variety of other objects at far ranges. The high-altitude flight increases detection range vis-à-vis the ground radar. The aircraft has communications and other means to perform command and control functions. To be able to carry a large radar, have adequate electric power on board to

4. John Keller, "DARPA Launches CODE Program for UAVs to Share Information and Work Together", *Military & Aerospace Electronics*, April 29, 2014, at https://www.militaryaerospace.com/computers/article/16719249/darpa-launches-code-program-for-uavs-to-share-information-and-work-together. Accessed on July 17, 2022.

support the heavy electronics, and to have long range and endurance, the platforms are evolved from large airliners. There are Helicopter AEW systems mostly used by the navies. They act as airborne radar pickets. Airborne ground surveillance (AGS) aircraft are designed to detect and track ground targets, such as vehicles and slow-moving helicopters. However, they cannot be termed as an AEW&C aircraft.

AEW&C aircraft monitor the surface and air battle-space and can direct or support own platforms to engage adversary platforms and vehicles. For achieving this, they detect and track own and adversary aircraft, identify the hostile ones, and direct own platforms to engage them. Being large platforms, they too can be detected by the adversary and threatened. The aircraft thus has to be maintained at a safe distance from adversary ground and air-based defence systems. Modern AEW&C are equipped for aerial refuelling. They use their larger sensor detection range and mobility to keep themselves safe from any developing threat. These aircraft have an on-board rest area for rotational crew and controllers. They also have a pantry for serving meals.

ON-BOARD SENSORS

The radar is the primary sensor. Modern AEW&C have active electronically scanned array (AESA) radars. The radar is composed of a large number of Transmitter-Receiver (TR) modules transmitting simultaneously at multiple frequencies. The computer-controlled radio beams can be steered electronically in different directions without moving the antenna. Despite radiating powerful radar signals, they remain stealthy, and resistant to jamming. The radar provides 360-degree surveillance capability and can provide specific sector emphasis, and dynamically adjust to evolving tactical situations. Typically, the aircraft would operate at an altitude of around 9 km. The radar could have 400 to 500-km detection range and track a few hundred surface or air targets simultaneously. The radar could be placed on a revolving rotor-dome or on a linear antenna mounted on a strut atop the main fuselage. The aircraft have secure V/UHF, HF and satellite communications to direct other aircraft through voice communications. There are data-links to transfer data to ground/ship stations and other airborne or surface platforms. To cater to the

radar and other avionics, the aircraft requires larger electric power generation and cooling capacities.

The aircraft has a self-protection suite (SPS) and includes electronic support measures (ESM) equipment in the form of Radar Warning Receivers (RWR) for passively monitoring electromagnetic radiations for threat identification. It is equipped with missile approach warning system (MAW) to detect attacking missiles and to deploy possible infrared or chaff countermeasures or initiate a tactical manoeuvre. There is electronic support equipment for signals intelligence (SIGINT), and communications intelligence (COMINT) and electronics intelligence (ELINT). The operational cabin typically has 6 to 10 radar controller stations and consoles for directing offensive or defensive missions.

OFFENSIVE AND DEFENSIVE MISSIONS

AEW&C aircraft operate from land-based runways or aircraft carriers. The aircraft are also networked with ground-based military and civil radars for creating the complete air picture and enhanced situational awareness (SA). Ideally the AEW&C aircraft must fly with overlapping radar cover so as to leave no blind zones. They are used for both defensive and offensive air operations. It could mean directing own air defence fighters to intercept adversary aircraft, or warn and control own aircraft under threat of an adversary attack. AEW&C supports aerial missions attacking marine or land targets. The navies use them also to protect the carrier-groups, and augment their on-board command information centres (CIC). AEW&C also provide the intelligence, surveillance, target acquisition, and reconnaissance (ISTAR) functions. Many AEW&C aircraft have maritime or ground surveillance radars under the fuselage. Most also have electro-optical sensors that can operate in visible, near-infrared and mid-wave infrared spectrums, giving the ability for silent observation. Thus AEW&C offers air, maritime and ground surveillance ability simultaneously, as multiple-role options, or could be used for a dedicated mission. Alternatively, the missions could be switched in-flight.

The AEW&C gives a clear tactical edge to battle management through real-time analysis and supports the positioning of the fighter

aircraft within its on-board weapon envelope. ELINT and SIGINT data gathered can be used immediately to program its own EW suite. The EW suite provides high operational survivability in high threat environment. This information is also shared with others for processing. The 360-degree horizontal and vertical situational picture is generated from not only the on-board sensors but also by integrating data received from other sensors through data-links. The command and control (C2) system also allows mission planning and post mission evaluation.[5] The supervising mission director can monitor any control station or assign targets or engagements to different controllers. The many on-board C2 work-stations, with wide-screen high-resolution displays, enable operations controllers to support multiple missions in multidimensional and changing scenarios. Thus AEW&C are crucial for large force aerial engagements.

Even when friendly missions are flying deep in enemy territory, the AEW&C can give emanating threat warning or give directions for offensive engagement. The AEW&C will be able to simultaneously support air-to-air and surface attack missions, or even at sea. The world over, the AEW&C are combat-proven platforms. Being airliner-based platforms, serviceability and operational availability rates are high.

A classic aerial engagement in which both sides used AEW&C aircraft was in February 2019. The Pakistan Air Force (PAF) used Saab 2000 and the Indian Air Force (IAF) used the A-50I Phalcon and DRDO Netra. AEW&C were extensively used during Operation Desert Storm and later, Operation Iraqi Freedom. Though NATO is not directly involved in the Ukraine Conflict, NATO AEW&C are flying regularly and providing Ukraine with relevant tactical information.

MAJOR AEW&C AIRCRAFT

As early as 1944, the US Navy (USN) had an AEW aircraft that could detect low flying aircraft of around 160 km. Later, the Lockheed EC-

5. Praveen Duddu, "GlobalEye Airborne Early Warning and Control (AEW&C) Aircraft", *Airforce Technology*, November 16, 2021, at https://www.airforce-technology.com/projects/globaleye-airborne-early-warning-and-control-aewc-aircraft/. Accessed on July 22, 2022.

121 served extensively with US Air Force (USAF) and USN. The Soviet AEW, Tupolev Tu-126, entered service in 1965. The British initially operated the Skyraider AEW.1, and later Fairey Gannet AEW.3, and the somewhat unsuccessful Nimrod AEW variant.

AWACS (Airborne Warning and Control System) is a term specifically used for the system installed in the Boeing E-3 Sentry and Japanese Boeing E-767 AEW&C. The E-3 Sentry uses the Boeing 707 airliner as platform, and is operated by the USAF, NATO, French and Saudi Air Forces. France operates the E-3F and UK E-3D variants. The E-3 aircraft were inducted in 1977 and 68 were built till 1992 when production was stopped. They were extensively used in the Persian Gulf War. The Boeing E-767 AWACS is used by the Japan Air Self-Defence Forces. Only four were built, starting 2000.

The Northrop Grumman E-2 Hawkeye is a twin-turboprop AEW aircraft designed for USN. Its latest variant, the E-2D, first flew in 2007. Of the total 313 E-2s built, 88 were E-2D. It has aerial refuelling capability since 2019. Its APY-9 radar reportedly has the capability to detect fighter-sized stealth aircraft. The aircraft also operates from aircraft carriers. Japan, France, Mexico, Israel, Egypt, Singapore and Taiwan also operate the aircraft.

Boeing 737 based AEW&C aircraft is designated E-7A Wedgetail. The radar is located on a dorsal fin on top of the fuselage. It first flew in 2004. Fourteen have been built till date. The aircraft are operated by the air forces of Australia, Republic of Korea, and Turkey. The maximum detection range of the radar is 600 km.

The Beriev A-50 is the Soviet AEW&C based on the Ilyushin Il-76 transport aircraft that entered service in 1984. Nearly 40 were built. It has a large non-rotating disk radar-dome. IAF also operates 3 similar platforms with the Israeli Phalcon EL/W-2090 radar and avionics since 2009. Two more are on order. The Beriev A-100 is the new Russian AEW&C based on the Il-76MD-90A transport aircraft and is still under development. It will have an active phased array radar, and may enter service around 2026. In the early 2000s, Ukraine had offered the three-engine An-71 AEW to India that it claimed could detect 400 targets at up to 370 km range. The deal never went through.

The KJ-2000 is the Chinese AEW&C based on the Russian Ilyushin Il-76 platform. It was originally being evolved through a joint project between Russia, Israel and China, with the Israeli Phalcon radar and other avionics. Later Israel had to withdraw from the project because of the US pressure. China then developed indigenous systems. There is a phased array radar in a round radar-dome that does not rotate. The antennas are placed in a triangle and provide 360-degree coverage. Four aircraft were built between 2003 and 2007. KJ-3000 is reportedly a new variant with the next-generation radar. China also built eleven Shaanxi KJ-200 based on the four turboprop engine, Y-8 aircraft platform. The Y-8J is the AWACS variant with British GEC-Marconi Argus-2000, L-band pulse-doppler search radar in the nose-mounted radar-dome. ZDK-03 is the specifically designed variant of Y-8 for PAF and has a Chinese AESA radar. Four were ordered. Seventeen Shaanxi KJ-200 based on four turboprop engine, Y-9 aircraft platform were built. Chinese AEW&C are operated both by the PLA Air Force (PLAAF) and PLA Navy (PLAN). China is also developing the Xian KJ-600 based on twin-propeller Chinese Y-7 aircraft for the PLAN. It is targeted to be ready by 2024 to be deployed on Chinese Type 003 aircraft carriers.

"GlobalEye" AEW&C is based on the Bombardier Global 6000 ultra-long range jet aircraft. It uses the SAAB Erieye's ER (extended range) AESA radar and is operated by United Arab Emirates. Sweden uses the S 100D Argus ASC890 as its AEW platform. Ericsson Erieye PS-890 radar is mounted on the Saab 340. Pakistan has four Saab 2000 turboprop aircraft mounted with Ericsson Erieye AEW system since 2008. Though Lockheed P-3 was essentially a Maritime Patrol Aircraft, Pakistan Navy uses P-3C with Hawkeye 2000 AEW system. Meanwhile China and Pakistan are considering joint development of AEW&C systems. UK also operated two Britten-Norman Defender 4000 AEW aircraft till 2021. The CASA C-295 AEW&C prototype had EL/W-2090 AESA radar-dome, and was first revealed in 2011. None are operating yet.

Greece and Mexico use the Embraer R-99 with an Ericsson Erieye PS-890 radar for AEW role. Israel had developed the IAI/Elta EL/M-2075 Phalcon system mounted on a Boeing 707 initially. They currently operate Israeli Aircraft Industry's (IAI) EL/W-2085 AEW&C radar on Gulfstream G550. The radar is conformably mounted on aircraft wing root and fuselage side. Italy has also acquired two G550. Singapore

has ordered four with the EL/W-2085 sensor package. The NATO has an AEW&C Programme Management Agency with 16 member countries. NATO currently operates a fleet of 17 Boeing E-3A. Since NATO's area of operations includes the North Atlantic and the Mediterranean, the ability for sea targets is important. France has its own nationally managed E-3F fleet, which is to remain interoperable with the NATO fleet. The UK's E-3D fleet is an integral part of NATO's AEW&C forces but is fully funded by the UK. Aircraft are data-linked to the NATO ground-based air defence network. As it is difficult to find Boeing 707 spares for the E-3, could NATO switch to the E-7 was being contemplated.[6]

HELICOPTER AEW SYSTEMS

Radar mounted helicopters are being used in AEW role since the late 1950s. These were operated initially from aircraft carriers and later large ships. The Royal Navy realised in the 1982 Falklands War that not having AEW was a serious tactical handicap. Sea King ASaC.7 AEW helicopters were then introduced and operated till 2018. They could track 400 targets. Spain flies the SH-3 Sea King. Italy operates the three-engine AgustaWestland EH-101A AEW. The Russian Kamov Ka-31 is operated by the Indian Navy, and some other variants by the Russian Navy. Over 35 were built.

INDIAN INDIGENOUS AEW&C PROGRAMME

India's Defence Research and Development Organisation (DRDO) has developed the "Netra" AEW&C using Brazilian Embraer EMB-145 as platform. It uses an Indian AESA radar that gives 240-degree coverage. The first EMB-145i aircraft with full component of the antenna and its electronics made its maiden flight in December 2011 at Embraer facilities at Sao Jose dos Campos in Brazil. The aircraft has air-to-air refuelling capability. Three have been delivered to IAF starting 2015. The project was handled by DRDO's Centre for Airborne Systems (CABS) for system integration and testing. The Electronics and Radar Development Establishment (LRDE) developed the radar

6. Dario Leone, "Could NATO Turn to the E-7 As Its Newest Plane?", *The National Interest*, July 1, 2019, at https://nationalinterest.org/blog/buzz/could-nato-turn-e-7-its-newest-plane-65126. Accessed on July 20, 2022.

modules and array. The Defence Electronics Application Laboratory (DEAL) made the Data Link and Communication Systems.

The DRDO is meantime working on a larger AEW&C with longer range and 360-degree coverage based on the Airbus A320 platforms released by local air carrier, Air India. In September 2021, the Indian government cleared nearly Rs.11,000 crore project[7] to develop six new AEW&C aircraft for the IAF. Since the aircraft will be through paper transfer between two government departments, the platform cost will be low, and bulk of the expenditure will be on airframe modification and the on-board systems.[8] Various DRDO research laboratories will be engaged in developing the primary AESA radar, communication systems and data-link, self-protection suite, including electronic support measures, and identification friend or foe (IFF) system. There will have to be fluid dynamics and aerodynamic studies of the inter-play between the antenna array and the aircraft platform. There will be SATCOM connectivity. Ruggedised work stations would have to be designed. The aircraft would have to have electromagnetic pulse (EMP) protection. The aircraft will be fitted with a passive missile approach warning system (MAW). Aerial refuelling ability will be built-in.

There is also a DRDO proposal to have a Netra AEW&C based on EADS CASA C-295, since the aircraft already has a variant with EL/W-2090 360-degree radar-dome. It has become more relevant because the aircraft will now be built in India, and will mean cost savings.

WAY AHEAD

The future battle-space will be more complex and dynamic. To be able to handle advanced threats the AEW&C would have to have open mission systems (OMS) architecture[9] for battle management and command and control. This will allow greater flexibility to upgrade

7. Snehesh Alex Philip, "Modi govt okays 6 more 'eyes in the sky' for IAF, DRDO project to cost Rs. 11,000 crore", *The Print*, September 9, 2021, at https://theprint.in/defence/modi-govt-okays-6-more-eyes-in-the-sky-for-iaf-drdo-project-to-cost-rs-11000-crore/730697/. Accessed on July 18, 2022.
8. Ibid.
9. "AEW&C Open Mission Systems validated in operational environment, Boeing", *Defence, Technology*, November 9, 2020, at https://www.boeing.com/features/2020/11/aewc-open-mission-systems-validated-in-operational-environment.page. Accessed on July 20, 2022.

capabilities. OMS also allows software engineering and portability, and better human-machine interface (HMI) options. Wide-band AESA will add to operational capability and threat handling flexibility. Advanced state-of-the-art airborne moving target indicator (AMTI) capability would be important. The AEW&C's radar must have ability to dynamically adjust to emerging tactical situations.

As the world moves towards hypersonic threats, unmanned drone swarms, manned-unmanned teaming, the operational scenarios will become very complex. AEW&C platforms will become much more relevant and yet they would have to adapt and invent themselves to the ever-changing operational scenarios, and evolving dependable and combat worthy next-generation platforms.

China is currently developing the 'Divine Eagle' high-altitude, long-endurance,[10] counter stealth unmanned aerial vehicle into an AEW&C. This will be the world's first unmanned AEW&C aircraft, and at nearly 20-tonne maximum take-off weight, it will also be one of the largest UAVs ever produced. The aircraft is expected to operate at 25-km altitude at Mach 0.8.

The six new Airbus-based AEW&C aircraft will add to the three each of Phalcon and Netra platforms of the IAF. Interestingly, a much smaller country, Pakistan, already operates nine AEW&C, including four Shaanxi ZDK-03 K, and five Saab 2000 Erieye. With the Line of Actual Control (LAC) with China facing continuous showdown, it is all the more important to increase the numbers. For a continent-sized country like India and the threat from two major military powers in the West and North, there is a need of at least 10 large and 10 smaller AEW&C aircraft. The work on Indian AEW&C has been delayed for various reasons and is still under slow progress. India has been partnering with Israel for various radars and missile systems. A joint venture route could save on time and risks, and maybe even the cost. A strategically important project like this must get clear direction from the highest level of the executive and be closely monitored at apex level. The time to act is now, lest it becomes late.

10. Khalem Chapman, "Airborne Early Warning and Control: Detecting the Battlespace", Royal Aeronautical Society, September 18, 2018, at https://www.aerosociety.com/news/airborne-early-warning-and-control-detecting-the-battlespace/. Accessed on July 20, 2022.