Defence

AEW Nimrod technical description and cutaway
**Nimrod AEW.3**

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Cutaway by TIM HALL

Conceived in the air, bold-faced on the ground, the Nimrod AEW.3 is in a key element in Britain's revitalised air-defence triad. Unlike the other components—the Tornado F.3 interceptor and Uillage command and control network—the Nimrod airborne early warning (AEW) aircraft is a largely national project, and as such represents a massive investment—of money and confidence—in British technology.

Nimrod AEW owes its existence to Nato's collective inability to meet a deadline and to backroom research which survived repeated project cancellations to provide a timely alternative. Nato did eventually decide to go ahead, and Nimrod AEW will enter service within months of the first Alliance Boeing E-3A Sentry. "Going it alone" is not thought to have cost Britain more than its projected share of Nato AEW investment, and as such represents a massive investment—of money and confidence—in British technology.

Nimrod AEW can trace its history to the discontinuation of Royal Navy attack carriers and the subsequent assumption of fleet-protection duties by the RAF. British experience with AEW began in the mid-1950s when Elliot Brothers (now Marconi Avionics) was called in to vet the US AP-20 radar, licence-manufacture of which was planned to equip RN Gannets. Eventually the equipment was bought direct from America, but Marconi Avionics was nominated UK support company, anglicising and modifying the radar. Later, when BAe was asked to transplant AP-20 into RAF Shackletons, Marconi Avionics introduced various improvements which have kept the radar in service—and it is no up-to-date—until now.

Thoughts of a new RN AEW system surfaced in the mid-1960s when parallel work on British low-level attack aircraft such as the TSR.2 and P.1154 made it apparent that AP-20 could not cope with low-flying intruders. Plans for a Gannet replacement, labelled NAST 6166, were drawn up. A four-month study in early 1964 sketched out a carrier-based maritime aircraft in having radar with antennas, but the decision to phase out the carriers was made before work could progress.

At this stage it began to look as though the previously insoluble problem of producing a radar with genuine overland performance capable of being carried in a land-based aircraft was now within reach. A joint RAF/RN study led to project definition in 1968 of a suitable AEW system. This was killed off in 1970 because of the high technical risk and cost but the requirement remained unfulfilled and the design was kept on ice, being reworked periodically to capitalise on advances in semiconductor technology.

Before Britain became involved in the interminable Nato deliberations on the E-3, British Aerospace (then Hawker Siddeley) and Marconi Avionics drew up a number of options based on the E-3 and Nimrod airframes, using new and existing radars. At the time one promising solution appeared to be a Nimrod, which could have sufficient capacity for displays and avionics, with the AP-125 radome radar from the Grumman E-2C Hawkeye. This was option 2; option 4 was a Nimrod with Marconi Avionics radar and fore and aft scanners.

Justly doubting Nato's ability to pull off the timely multinational purchase of Boeing E-3 Sentry, the RAF authorised continued work on a back-up programme. It was politically, economically and technically desirable that a British project be supported as an alternative to the all-American AEW. In March 1977, when it appeared that the other Nato members would never settle their differences and pay their shares, the decision to develop Nimrod AEW was taken.

The British project was supported as an alternative to the all-American AEW system. The Nimrod AEW was a four-engine aircraft, and a fully-equipped development aircraft has flown and the deadline for delivery of the first service aircraft is mid-1983. It benefits the short timescale that much of Nimrod AEW is based on available equipment. The airframes themselves are modified Nimrod MR.1s—although seven of them have never seen operational maritime service—and some of the airframe systems are derived from the improved MR.3. The mission avionics suite uses new, but readily available computers and other hardware. But there is much that is new in Nimrod AEW and, although the major development responsibility is the Marconi Avionics mission systems avionics, providing a suitable platform has proven a challenging project for BAe.

Externally, Nimrod differs from the maritime aircraft in having radar aerials, each scanning 180°, mounted on the extreme nose and tail. The forward radome is shaped and positioned by the constraints of aircraft size, aerodynamics, pilot visibility and by ground clearance (the underside of the radome must clear the noseleg. The rear radome is mounted high on the tail to give sufficient take-off ground clearance. BAe had hoped to use the same profile fore and aft, but the pointed shape of the forward radome—evolved to meet aerodynamic, birdstrike and rain-erosion requirements—led to unstably flow breakdown over a similarly shaped aft radome. As a result, a separate, more rounded profile was developed.

By mounting the existing fin above the contours of the new rear fuselage the directional stability of Nimrod AEW is improved beyond that of the existing maritime aircraft, particularly since the destabilising bomb-doors-open condition no longer occurs. Test pilots report that the Nimrod AEW3 has even better handling and stability than the maritime aircraft. During approach and landing, the nose radome is surprisingly unobtrusive despite its size, say the pilots.

BAe-built pods for local electronic support measures (ESM) equipment are mounted on the wingtips. Each pod has fore and aft aerials covering uninterrupted quadrants. To minimise the lift increase at the tips because of these, the aerodynamicists have faired the pods under the wing section with no resulting increase in wingspan. The fintip fairing, which gives a useful increase in lift effectiveness through its endplate effect, is retained and eventually will house "special" equipment.

Maritime Nimrod's characteristic two-engine low-level patrol—the best way to make a four-jet airliner into an efficient long-range patrol aircraft—will disappear with AEW. First, patrol heights are greater, requiring four-engine power. Secondly, the massive avionics suite requires electrical power from all four engine-driven generators. The power supply is split into two completely isolated systems, the outer generators feeding the radar and the inner units driving the remaining avionics. The pulse-Doppler radar demands power in immense bursts which distort the supply waveform and make it unsuitable for use with sensitive electronics, for which a separate, high-quality supply is therefore required.

BAe is responsible for "air vehicle" avionics, including navigation and autopilot systems. The navigator is the primary link between the flight crew and the mission crew and his console is in the main cabin between flightdeck and tactical operator positions. The AEW navigation system is based on MR.2 equipment, doubled up and reconfigured where necessary. Two Ferretti FIN102 inertial navigation platforms are fitted to provide extremely accurate heading, position.
**Disposing of unwanted heat**

**HEAT generated by the mission avionics** is a significant problem for Nimrod engineers. Electronics generate the unwanted heat and, when densely packed, can prove difficult to cool. Nimrod’s AEW systems generate ten times the cabin heat load of the maritime versions, so the traditional cooling method of drawing cabin air over the electronics then dumping it overboard is impractical. A fluid with greater heat-transferring capacity is required.

Cooling can be further improved by immersing electronic components in a liquid which, if it has a high dielectric strength, allows high-voltage components to be closely packed together. A fluorocarbon has been selected for this purpose and is used to cool the radar transmitter, where potential differences of several kilovolts occur between adjacent stages. Components are immersed in TWT (traveling-wave tube) tanks. This fluid is, however, too heavy and expensive, about £70 a gallon for aviation use, for a very searching leak seeker. For general use where heat densities are lower, water-glycol with additives is used. Two closed-circuit systems are employed. Water-glycol (wet) is delivered to the equipment then forced through liquid heat exchangers. Many components have quite low heat densities. A dummy load for example, is a very searching leak seeker. For dielectric strength, allows high-voltage components to be closely packed together. A fluorocarbon and water-glycol are supplied to separate sections of each heat exchanger through two pumping systems. About 70 per cent of the total heat is transferred by the fluorocarbon and the remaining 30 per cent by water-glycol. Fuel from both wings is supplied equally to both heat exchangers and each wing dissipates the required heat load. If one exchanger can transfer the total heat load equally to both wings or a heat sink of limited capacity, the total heat load will one wing, depending on the defect.

Fuel is drawn from the nacelle tanks, passed through the heat exchangers and pumped back to the wing through existing top-hat stringers. When the fuel reaches the wingtips it is dumped into the coolant tank where it is cooled. The cooling system is designed to handle the fuel heats up. If the mission avionics are switched on for ground-operating or preflight checks, cooling occurs as the fuel flows out of the coolant tank and wing centre-section tanks which water-cooled heat exchangers are mounted on the upper fuselage. This fuel acts as a heat sink of limited capacity. For prolonged periods of operation the cooling trolley can be detached. Once air-cooled, the equipment then lowers its temperature before being pumped through the heat exchanger.

**Water-glycol cooled heat transfer**

**Left**

**Below Fluid/fuel heat transfer**

**Right**

**Water-glycol cooled heat transfer**

**Software philosophy—distributed processing**

**PAST development programmes involving extensive software (computer programming) tasks have often run into problems for a number of reasons. One too much dependence on large central computers; and continuously changing software specifications. The first leads to escalation, as development cost has a square-law relationship with computer size. The second, which comes from a belief that software can be modified easily, causes great uncertainties in the cost system.**

**Standard Nimrod fuel scheduling** is usually simplified to avoid the heat to one wing, depending on the defect. If the aircraft is parked and exposed to direct sunlight for any length of time, the fuel heats up. If the mission avionics are switched on for ground-operating or preflight checks, fuel in the wingtips is dumped into the coolant tank where it is cooled.

**If the mission avionics are switched on for ground-operating or preflight checks, fuel in the wingtips is dumped into the coolant tank where it is cooled. The mission avionics present a significant problem for Nimrod engineers.**

**First leads to cost escalation, as development cost has a square-law relationship with computer size. The second, which comes from a belief that software can be modified easily, causes great uncertainties in the cost system.**

**Nimrod AEW’s software philosophy is based on distributed processing using mini-processors, and structured development using prototype stages.**

**The central computer’s main task is the automatic initiation and maintenance of target tracks. Returns are monitored over a number of scans, which are then automatically recognised as new targets and displayed to the operator or rejected as noise. If necessary, a new track is initiated automatically. This remedies the operator’s dilemma of graphically plotting raw returns and drawing a track. It also means that AEW can provide target plots and tracks automatically to ground stations.**

**The AEW can handle “hundreds” of plots and reinitiate them at any stage of processing. The central computer, the ability to select minimum resolution, target identification, or sector display criteria is supplied. The operator can ‘hide’ all or part of the display, change each of the operator consoles, two in the avionics control section and one in the computer.**

**The operators act on a display located in the console memory by the central computer. Only the computer can act directly on the central computer.**

**Three operator consoles are displayed on the PFI. Symbols indicate the source of target information, building up to a double-pointed rectangle when target, RDF, ESM and data link information are involved. The rolling call cursor is used to designate targets for removal or in-depth examination.**

**Below the tabular display are six black “harbour” keys, the functions of which are displayed along the lower edge of the screen. The functions change with every key operation. In this way the operator is able to delve deeper and deeper into the database in search of target information.**

**For example, target speed, height, direction, range-bearing (or latitude/longitude), ESM classification, datalink classification, return strength, ESM response, codes and classification can be called up on a single page. There are six operator consoles, one with additional facilities for ESM control and one also tasked with handling the communications system.**

**There are more than 400 possible operator functions and the interface is the result of two years of development work by Marconi Avionics.**

**The continual modification of the software specification as experience will be developed.**

**Above**

The mission system operates at Marconi Avionics’ Radlett plant, where two scans are overlaid with each other. The word aerial is used relative to the aircraft. Left AEW’s capabilities and plans to get the aircraft into service are possible. From operational feedback a final software version incorporating service experience will be developed.
low-flying aircraft and low PRF for periodic updating of ship positions. The modes are interleaved—the occasional high-PRF scan is stolen for a low-PRF sweep. The radar is also frequency agile and incorporates electronic counter-countermeasures features. IFF interrogation is through the same aerial as the radar and responses are automatically associated with their radar returns before being passed to the data handling system. The integrated Loral ESM equipment detects and classifies radio and radar transmissions. By referring to a library of radar characteristics—such as frequency, pulsewidth, PRF and scan pattern—the system classifies the target from its emissions. Identification can be broad, so the operator can over-write his own classification and modify the library when necessary.

The initial AEW datalink will be the Nato Link 11. This system uses a central station which “polls” members of a network which broadcast the necessary data. All other members of the net listen until they are polled to transmit their own target information. In this way data on targets detected by aircraft, ships and ground stations can be supplied to all members of the network, giving each a complete picture of the tactical situation. Nimrod AEW will be able to communicate with Awacs, Royal Navy ships and the new UK air defence ground environment (Ukadge). The eventual datalink will be the spread-spectrum, countermeasures-resistant joint tactical information distribution system (Jtids).

Nimrod has a revolutionary communications system, perhaps the first “system” as such to be developed. The microprocessor-controlled telephone exchange has 11 major stations able to transmit and receive and ten minor “listen only” stations. HF, UHF and VHF radios are fitted. An operator selects the frequency band, frequency stud number and power level he requires and the communications system then selects the best available radio/aerial combination and tests it before handing over. The full system has been tested in a Nimrod MR.1 trials aircraft with a representative aerial distribution.

Nimrod AEW will provide early warning information to the air-defence network. The ground radars have limited performance against low-flying targets for purely geographic reasons and AEW will provide the means to continue the battle if the ground stations have been blinded, including guiding interceptors to targets. AEW was not designed to control offensive aircraft, although it will have a capability to do so, and it is not intended to uplift the battle commanders and aides required to direct such an operation. The Nimrod AEWS is predominantly a defensive aircraft.

RAF Nimrod AEW’s will be based at Waddington in Lincolnshire from around 1982. All 11 aircraft are to be in service by 1985. Because Britain’s air-defence region includes most of the North Sea and a sizeable slice of the North Atlantic, the Nimrod AEW is optimised for over-water use, just as Awacs was optimised for over-land use, providing Nato with a balanced force.

There have been a number of ground rigs built to test the avionic system. One is at Marconi’s Radlett plant and one is at BAe Woodford for integration of the mission system with the air-vehicle avionics. Of the six development avionics suites, two will fly in the second and third development Nimrods, one will be electrically and physically tested and one will be used for reliability trials.

The development programme includes three AEWS, all to be refurbished eventually to operational standard as part of the 11-aircraft total. There is also a trials Comet equipped with a prototype radar which has demonstrated that the equipment performs as expected. The modified Nimrod MR.1 equipped with the complete communications system has also completed a successful trials programme and is now being modified to an AEWS. The first development aircraft is well ahead on the aerodynamics flight trials and first flight of the second aircraft, the first scheduled to carry the mission system avionics, took place on January 23. This aircraft will be delivered to Hatfield for installation of the avionics. The third development aircraft will be used for service trials, making sure that the aircraft meets RAF specifications.