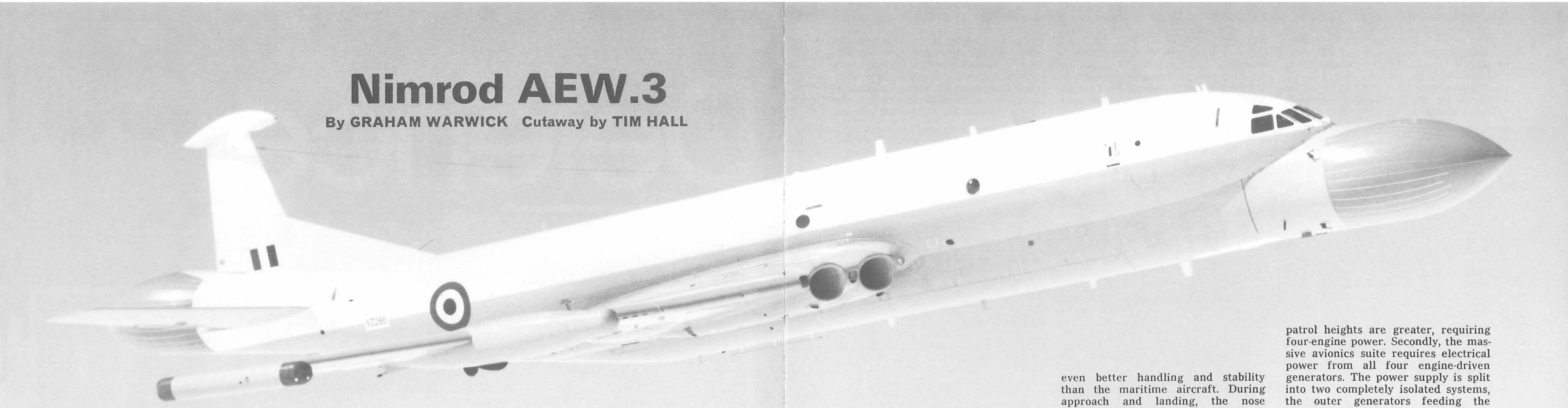
WEEK ENDING 7 FEBRUARY 1981
FLIGHT INTERNATIONAL

Defence

AEW Nimrod technical description and cutaway

Nimrod AEW.3

By GRAHAM WARWICK Cutaway by TIM HALL



CURVACEOUS in the air, bulbous on the ground, the Nimrod AEW.3 is a key element in Britain's revitalised air-defence triad. Unlike the other components—the Tornado F.2 interceptor and Ukadge 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, 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, however, and the expertise generated far outweighs the offset benefits UK contractors would have received.

The 11 Royal Air Force Nimrod AEW.3s will work with Nato E-3As, probably under a unified command, so the Alliance has not lost anything. Apart from commonality, that is, and there are three sides to that argument: the RAF, for its part, will receive an aircraft optimised for the air defence of Britain and with much in common with maritime Nimrods; Nato will benefit from the tactical permutations possible with two aircraft of differing capabilities; and the Warsaw Pact will have two independent systems to contend with.

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 APS-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 navalising the radar. Later, when BAe was asked to transplant APS-20 into RAF Shackletons, Marconi Avionics introduced various improvements which have kept the radar in service—if not 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 APS-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 AEW aircraft with fore and aft 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 748 and Nimrod airframes, using new and existing radars. At the time one promising solution appeared to be a Nimrod, which had enough capacity for displays and avionics, with the APS-125 rotodome 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 Sentries, 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 Awacs. 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 announced. Today, two systems aircraft, an aerodynamic trials airframe and a fully-equipped development aircraft have flown and the deadline for delivery of the first service aircraft is mid-1982.

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.2. 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 system avionics, providing a suitable platform has proved 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 aerial size, aerodynamics, pilot visibility and by ground clearance (the underside of the radome must clear the noseleg towbar). 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 unsteady flow breakaway over a similarly shaped aft radome. As a result, a separate, more rounded profile was developed.

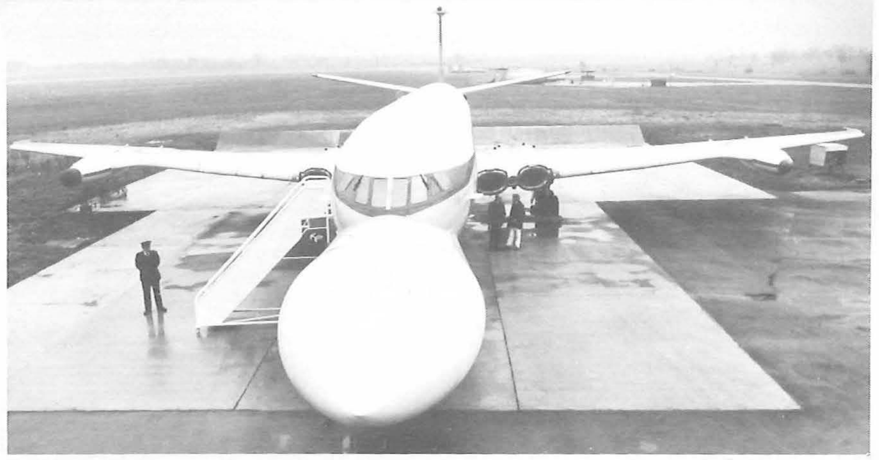
By mounting the existing fin above the contours of the new rear fuselage the directional stability of Nimrod AEW is improved beyond that of the maritime aircraft, particularly since the destabilising bomb-doors-open condition no longer occurs. Test pilots report that the Nimrod AEW.3 has even better 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 Loral 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 fin 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 Ferranti FIN1012 inertial navigation platforms are fitted to provide extremely accurate heading, position

Heading *The first British Aerospace Nimrod AEW.3 airborne early warning aircraft displays its pneumatic lines, first hinted at* **below** *when the Comet radar trials aircraft was unveiled*



and attitude information.

Accurate knowledge of aircraft heading and position is essential to the tracking and reporting of targets, and the central navigation system supplies this information to the central computer. In return, the mission avionics supply data on targets of interest to the flight crew, such as relief aircraft. The navigation system uses the same multi-function keyboard concept as the mission system avionics and provides for operator decision-making at all levels.

In addition to the cooling system detailed below for the mission avionics, there is a separate system for those avionics essential to the aircraft, such as communications and navigation, cooled by cabin air sucked through the equipment then dumped overboard.

Nimrod AEW is a flying radar station. There are three main methods of target detection and classification; radar, identification friend or foe (IFF) interrogation and electronic support measures. There is also a datalink to give Nimrod access to target information from other sources and to transfer AEW data to other users. Together with the data handling, data presentation and communications equipment these make up the AEW mission system avionics developed by Marconi Avionics.

The pulse-Doppler radar can isolate moving targets from spurious, non-moving, ground reflections at ranges out to the radar horizon. A single transmitter mounted inside the Nimrod—no mean achievement—feeds the two scanners in sequence, giving full 360° coverage. Lightweight Marconi Avionics-developed wide-band, twisted-cassegrain antennas are used to give improved resolution. The antenna shape produces a narrow beamwidth, and therefore good target resolution, and low sidelobes. The latter confers good resistance to electronic countermeasures as the radar can be interrupted only on the bearing of the jamming source and not through the sidelobes. Dual horns produce twin pencil beams by which target height can be measured.

The radar has two modes of operation; high pulse-repetition frequency (PRF) for tracking of fast-moving,

Disposing of unwanted heat

HEAT generated by the mission avionics presents a significant problem for Nimrod engineers. Electronics generate large amounts of unwanted heat and, when densely packed, can prove difficult to cool. Nimrod 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 impracticable. A fluid with greater heat-transport capacity than air 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 tens of kilovolts occur between adjacent stages of the output travelling-wave tubes (TWTs). This fluid is, however, too heavy and expensive, about £270 a gallon, for extensive use and is also a very searching leak seeker. For general use where heat densities are high, water-glycol with additives is used, to cool the TWT body and the dummy load for example.

Some components are immersed in water-glycol while others are cooled indirectly by cold plates (metal-to-liquid heat exchangers). Many components have quite low heat densities and would be uneconomical to cool by liquid, so air is used. Two closed-loop cabin systems draw air through the equipment then force it through water-glycol-cooled heat exchangers before returning it in a cool loop.

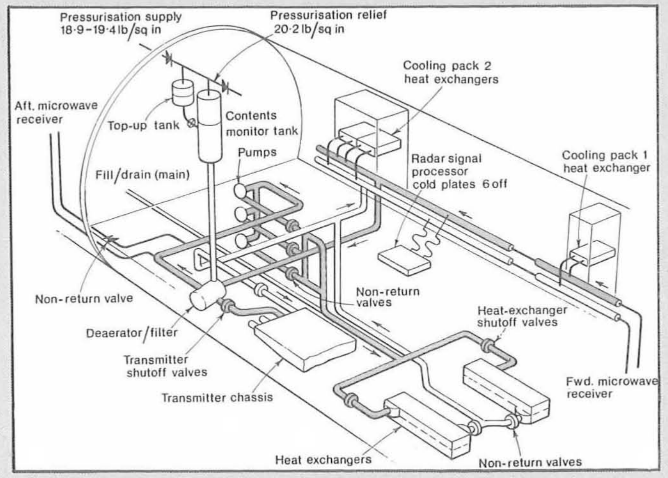
The fluid cooling systems are, however, only heat transfer systems, and the unwanted energy still has to be dissipated. External radiators would be prohibitively large and would generate undue drag. The biggest potential low-drag radiator is the wing itself, and the AEW cooling system takes heat from the fluorocarbon and water-glycol and transfers it to the wing fuel from whence the heat is dissipated to the air. The fluid/fuel heat transfer takes place in two deceptively small heat exchangers mounted in the pannier bay.

Fluorocarbon and water-glycol are supplied to separate sections of each heat exchanger through two pumping systems. About 30 per cent of the total heat is transported by the fluorocarbon and the remaining 70 per cent by water-glycol. Fuel from both wings is supplied equally to both heat exchangers and each wing dissipates half the heat load. If a failure occurs, one exchanger can transfer the total heat load equally to both wings or both exchangers can transfer the total heat load to one wing, depending on the defect.

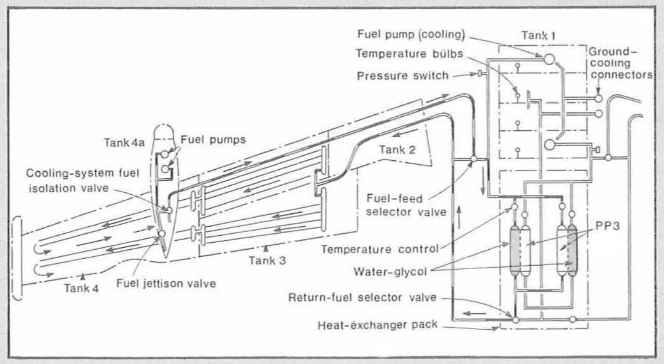
Fuel is drawn from the nacelle tanks, passed through the contraflow heat exchangers and pumped back along the wing through existing top-hat stringers. When the fuel reaches the wingtips it is dumped into the outboard tank where it is cooled by convective heat transfer to the wing skins. Fuel to top up the nacelle tanks is drawn from the inboard, coolest end of the outboard tank. A number of safeguards are provided: the transfer fluids are maintained at a higher pressure than the fuel so that a rupture within the heat exchanger does not allow fuel to enter the avionics cooling loops and so the pressure cabin; and the two halves of each heat exchanger are kept separate to avoid fuel transfer from one side to the other.

To prevent a coolant leak contaminating the fuel—very unlikely considering the vast difference in capacities—and to prevent an avionics malfunction through inadequate cooling, a sensitive contents loss-monitoring system is fitted. Because the liquids expand considerably with temperature a simple visual check is not sufficient. Instead, probes measure the liquid temperature and the appropriate volume is calculated for each cooling loop and automatically compared with the actual volume. A level error of two pints triggers a warning on the flight-engineer's panel. The engineer can attempt to locate the leak by isolating any of the cooling systems and can reset the coolant level by transferring additional fluid from top-up tanks.

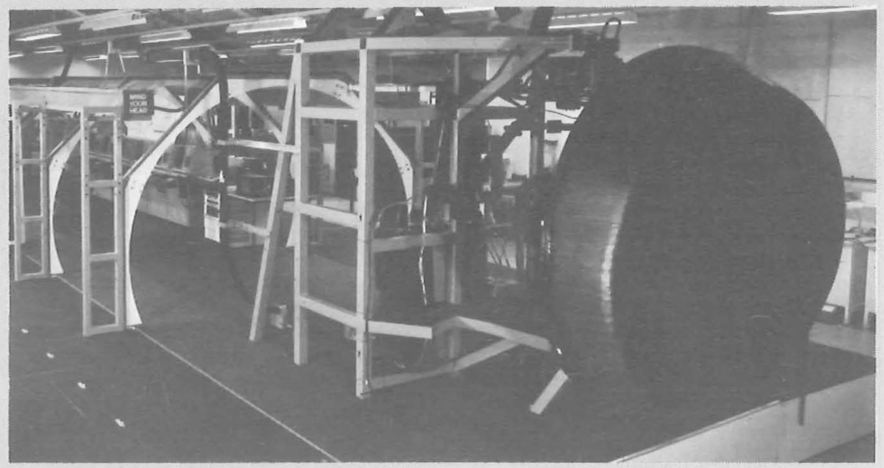
Standard Nimrod fuel scheduling ensures that the outboard wing tanks are the last to empty—a feature incorporated to provide the maximum effective wing bending relief for as long into the mission as possible—so the "radiators" remain effective to the end of the flight. If, however, the aircraft is parked and exposed to direct sunlight for any length of time, the wing acts as a solar panel and the fuel heats up. If the mission avionics are switched on for ground-running or preflight checks, cooling is provided by fuel from the pannier and wing centre-section tanks which are shielded from the sun by the upper fuselage. This fuel acts only as a heat sink of limited capacity. For prolonged ground running a cooling trolley can be attached. Once airborne the wing fuel is recirculated to lower its temperature before being pumped through the heat exchangers.



Left *Water-glycol avionics cooling* **Below** *Fluid/fuel heat transfer*



Software philosophy—distributed processing



PAST development programmes involving extensive software (computer programming) tasks have often run into problems for two main reasons: too much dependence on large central computers; and continually changing software specifications. The 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, can result in a virtually unmaintainable system. Marconi Avionics' AEW software philosophy is based on distributed processing using microprocessors, and structured development using prototype stages.

The central computer's main task is the automatic initiation and maintainance of target tracks. Returns are monitored over a number of scans then automatically recognised as new targets and displayed to the operator or rejected as false alarms. If necessary, a new track is initiated automatically. This relieves the operator of the tedious task of graphically plotting raw returns and drawing up 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, as a safeguard against overloading the operator, the ability to select minimum/maximum altitude, speed or sector display criteria is supplied.

There are three microprocessors in each of the operator consoles, two in the range/azimuth plan position indicator (PPI) and one in the tabular display alongside. The processors act on a database dumped in the console memory by the central computer. Only the tabular display processor can act directly on the central-computer database. Plots and tracks are displayed on the PPI. Symbols indicate the source of target information, building up to a double-pointed rectangle when radar, IFF, ESM and datalink information is available. A rolling ball cursor is used to designate targets for removal or in-depth examination.

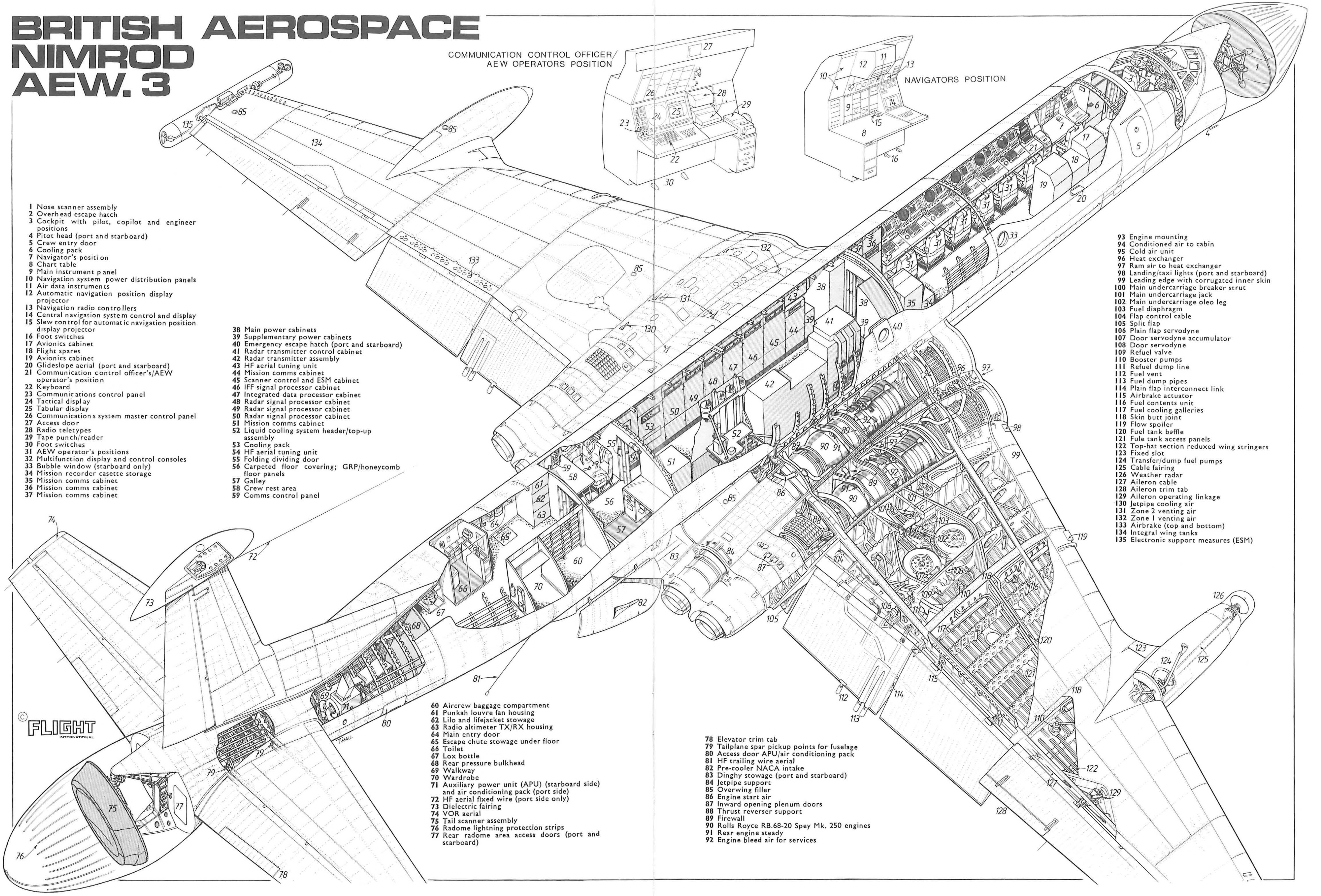
Below the tabular display are six blank "hierarchy" keys, the functions of which are displayed along the lower edge of the screen. The functions change with every key operation. In this way the operator is able to delve deeper and deeper into the database in search of target information. For example, target speed, height, direction, range/bearing (or latitude/longitude), ESM classification, datalink classification, return strength, IFF 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 450 possible operator functions and the interface is the result of two years development work by Marconi Avionics.

To avoid continual modification of the software specification as experience is gained, Marconi Avionics, with the approval of the Ministry of Defence, has drawn up a rigid programme of prototype stages, each successive model having a later design freezing date. There are four main stages: running the initial software on commercial computers; running prototype programmes on the actual computers to be used; running the complete system with inputs from the outside world; and the service model. Marconi ran the first prototype in 1974, even before the Nimrod AEW was officially announced. This system developed the criteria for tracking a single target and, using this building brick, produced software capable of tracking multiple targets.

The two-year definition of the second prototype, completed in 1976, looked like producing an overlarge system until Marconi Avionics and the RAF agreed on a more practical interpretation of the requirement which allowed the volume to be reduced. This was run on a ground model of the actual hardware. By the time it came to defining the service software, Marconi Avionics had a specification thick enough to deter unnecessary changes. The Royal Air Force has never before had an aircraft of Nimrod AEW's capabilities and plans to get the aircraft into service as soon as possible. From operational feedback a final software version incorporating service experience will be developed.

Above *The mission system avionics rig at Marconi Avionics' Radlett plant is complete with fore and aft scanners. The forward aerial is raised relative to its position in the aircraft.* **Left** *AEW operators at their positions in the rig*

BRITISH AEROSPACE NIMROD AEW. 3



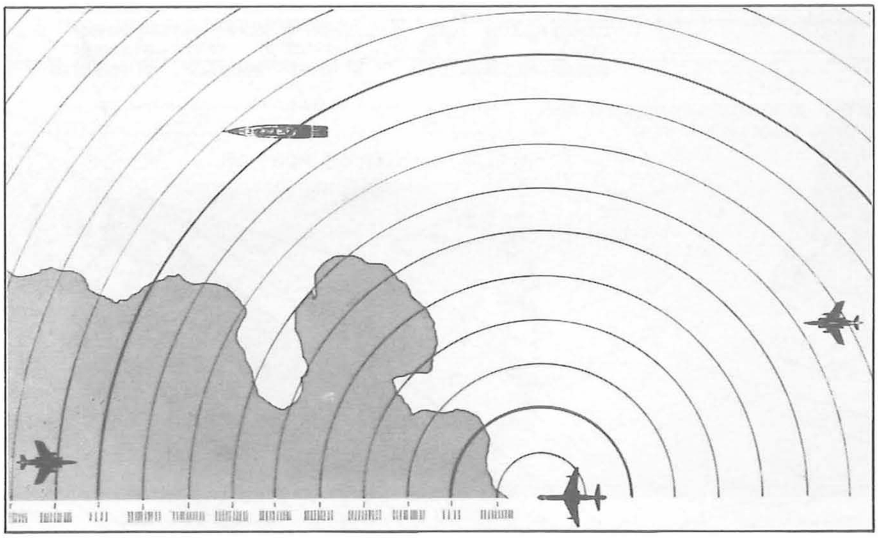
1 Nose scanner assembly
2 Overhead escape hatch
3 Cockpit with pilot, copilot and engineer positions
4 Pitot head (port and starboard)
5 Crew entry door
6 Cooling pack
7 Navigator's position
8 Chart table
9 Main instrument panel
10 Navigation system power distribution panels
11 Air data instruments
12 Automatic navigation position display projector
13 Navigation radio controllers
14 Central navigation system control and display
15 Slew control for automatic navigation position display projector
16 Foot switches
17 Avionics cabinet
18 Flight spares
19 Avionics cabinet
20 Glideslope aerial (port and starboard)
21 Communication control officer's/AEW operator's position
22 Keyboard
23 Communications control panel
24 Tactical display
25 Tabular display
26 Communications system master control panel
27 Access door
28 Radio teletypes
29 Tape punch/reader
30 Foot switches
31 AEW operator's positions
32 Multifunction display and control consoles
33 Bubble window (starboard only)
34 Mission recorder casette storage
35 Mission comms cabinet
36 Mission comms cabinet
37 Mission comms cabinet

38 Main power cabinets
39 Supplementary power cabinets
40 Emergency escape hatch (port and starboard)
41 Radar transmitter control cabinet
42 Radar transmitter assembly
43 HF aerial tuning unit
44 Mission comms cabinet
45 Scanner control and ESM cabinet
46 IFF signal processor cabinet
47 Integrated data processor cabinet
48 Radar signal processor cabinet
49 Radar signal processor cabinet
50 Radar signal processor cabinet
51 Mission comms cabinet
52 Liquid cooling system header/top-up assembly
53 Cooling pack
54 HF aerial tuning unit
55 Folding dividing door
56 Carpeted floor covering; GRP/honeycomb floor panels
57 Galley
58 Crew rest area
59 Comms control panel

60 Aircrew baggage compartment
61 Punkah louvre fan housing
62 Lilo and lifejacket stowage
63 Radio altimeter TX/RX housing
64 Main entry door
65 Escape chute stowage under floor
66 Toilet
67 Lox bottle
68 Rear pressure bulkhead
69 Walkway
70 Wardrobe
71 Auxiliary power unit (APU) (starboard side) and air conditioning pack (port side)
72 HF aerial fixed wire (port side only)
73 Dielectric fairing
74 VOR aerial
75 Tail scanner assembly
76 Radome lightning protection strips
77 Rear radome area access doors (port and starboard)

78 Elevator trim tab
79 Tailplane spar pickup points for fuselage
80 Access door APU/air conditioning pack
81 HF trailing wire aerial
82 Pre-cooler NACA intake
83 Dinghy stowage (port and starboard)
84 Jetpipe support
85 Overwing filler
86 Engine start air
87 Inward opening plenum doors
88 Thrust reverser support
89 Firewall
90 Rolls Royce RB.68-20 Spey Mk. 250 engines
91 Rear engine steady
92 Engine bleed air for services

93 Engine mounting
94 Conditioned air to cabin
95 Cold air unit
96 Heat exchanger
97 Ram air to heat exchanger
98 Landing/taxi lights (port and starboard)
99 Leading edge with corrugated inner skin
100 Main undercarriage breaker strut
101 Main undercarriage jack
102 Main undercarriage oleo leg
103 Fuel diaphragm
104 Flap control cable
105 Split flap
106 Plain flap servodyne
107 Door servodyne accumulator
108 Door servodyne
109 Refuel valve
110 Booster pumps
111 Refuel dump line
112 Fuel vent
113 Fuel dump pipes
114 Plain flap interconnect link
115 Airbrake actuator
116 Fuel contents unit
117 Fuel cooling galleries
118 Skin butt joint
119 Flow spoiler
120 Fuel tank baffle
121 Fule tank access panels
122 Top-hat section reduxed wing stringers
123 Fixed slot
124 Transfer/dump fuel pumps
125 Cable fairing
126 Weather radar
127 Aileron cable
128 Aileron trim tab
129 Aileron operating linkage
130 Jetpipe cooling air
131 Zone 2 venting air
132 Zone 1 venting air
133 Airbrake (top and bottom)
134 Integral wing tanks
135 Electronic support measures (ESM)



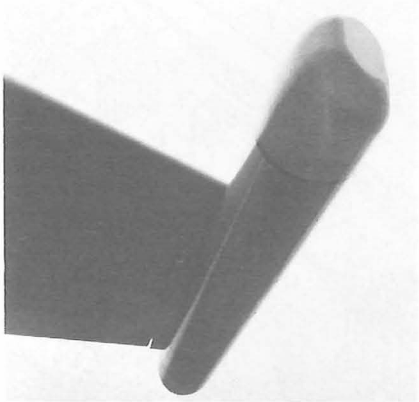
low-flying aircraft and low PRF for periodic updating of ship positions. The modes are interleaved—the occasional high-PRF scan is stolen for a low-PRF sweep. The radar is also frequency agile and incorporates electronic counter-countermeasures features. IFF interrogation is through the same aerial as 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 AEW.3 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 overland use, providing Nato with a balanced force.



Top *High and low pulse-repetition frequencies are interleaved to detect aircraft and ships.* **Above right** *The wingtip electronic support measures pod.* **Below** *British Aerospace builds the radomes*

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 AEW.3s, 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 AEW.3. 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.

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