A NEW APPROACH TO AIRBORNE EARLY WARNING

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ABSTRACT

THORN EMI ELECTRONICS (TEE) RADAR DIVISION

Airborne Early Warning (AEW) systems were initially used to protect naval forces from air attack, later systems have been designed to provide surveillance on a grand scale and are consequently very expensive and require large aircraft to accommodate them. This paper presents an argument for a more modest radar system which nevertheless meets the key AEW operational requirements and provides adequate warning of the approach of high speed aircraft.

Experience gained from a long line of airborne radars has established design criteria for a software control, multi-role radar system with advanced electronic counter counter measures. Modern signal processing has allowed size and weight to be reduced so that this high performance radar may be carried by a wide variety of relatively small aircraft. The radar's primary role is AEW and facilities are incorporated for the automatic detection and tracking of airborne targets flying at all heights, including very low level, against any background.

Historical Review

The first recorded military use of an airborne surveillance platform occurred at the Battle of Fleurus in 1794 when J.M.J. Courtell, a French Colonel, observed enemy movements from a hot-air balloon. Balloons were also used to observe gunnery fall of shot in the American Civil War, and gas filled balloons were widely used for observation by both sides in the first European War, 1914-1918.

Airborne Early Warning (AEW) as we understand it today first began with the development in the U.K. of the RDF-2 radar in 1935. This was intended to complement the RDF-1 ground stations used so effectively in the Battle of Britain 1940. Also in 1940 the Plan Position Indicator (PPI) for air radars grew out of the development of the 10cm cavity magnatron which allowed the use of a narrow, scanning, high energy radar beam, and this type of set has been in use ever since. By 1942, airborne PPI radars such as H^2S developed by my Company (then EMI) were used for navigating and bombing for the first time. The first recorded use of a dedicated airborne surveillance platform was in 1944 when the British "White Wellington" provided early detection of air launched V1 missiles. This aircraft also acted as an airborne Ground Control Intercept (GCI) station directing fighters towards the V1s, thus functioning as the first airborne warning and command system, (AWACS).

The need for AEW follows the fact that the principal weakness of any defence system lies in an inability to react effectively to an airborne attack due to insufficient warning time. To remedy this defect, the outer limit of sensor coverage must therefore be extended, particularly against high-speed, low level aircraft which, due to clutter and line of sight considerations, will normally not be apparent to ground radars until too late for defensive action.

Events over the last 10 years affecting countries in the Middle East and the U.K. have underlined the need for substantially increased warning times of hostile air action, this can only be obtained through extending the radar horizon by use of an AEW platform. We in the U.K. learned this lesson in a hard way in 1982 during the Falklands War when the Royal Navy was without AEW cover, having given up this capability three years previously. The vulnerability of the Task Force to long range air and missile attacks forced a rapid re-appraisal of policy and a decision was made to introduce SEA-KING helicopter platforms carrying a novel installation of the THORN EMI Electronics Searchwater maritime radar modified for AEW use. This arrangement has worked extremely well in operational service and is being expanded to enable AEW operations to be conducted from all three Royal Navy aircraft carriers.

Following the success of this naval AEW system, it was considered that there could be a wide application for such a lightweight AEW but capable of overland as well as overwater detection. All early AEW systems had been naval, partially due to the difficulty of detecting low-flying targets over land. More recently, high powered radar systems such as E2C, E3 AWACS and AEW NIMROD have emerged, these systems, designed to meet very demanding requirements are very complex and correspondingly expensive both in initial purchase and running cost. Examination of the operationally essential characteristics of an early warning system shows that there are many circumstances where a more modest radar performance could yield an adequate solution at a much reduced cost. This is an important conclusion for countries where the costs of purchasing and operating one of the major systems could not be undertaken. Further, some countries already deploying a major AEW/AWAC system may find that there are circumstances where a complementary, lesser,system is a sound military and economical concept. Such a system would, however, still have to meet the basic AEW requirements and be able to fulfil all the tasks likely to be placed on an aircraft dedicated to this role.

AEW OPERATIONAL REQUIREMENTS

The AEW aircraft is the sensor for a total air defence system that includes C^3 elements, interceptor aircraft and SAMs. However, in the context of this paper only the AEW aspects are discussed. The basic military requirement for any warning system is that it should provide time for the defences to react to a potential threat. This requirement dictates a certain minimum level of performance in an AEW system in terms of detection range. However, this figure will vary with the speed of the threat, the location of the AEW platform and the position, readiness state and capability of the Air Defence fighters and surface to air missiles. The need to keep the number of AEW aircraft to the minimum, commensurate with the lateral coverage required, will also be a consideration in terms of system range performance. This is illustrated in the diagram at Figure 1 (attached) which shows the defence time plan for an AEW system that detects a typical 500 knot low altitude target at around 100 nautical miles.

The Airborne Threat

Any defence system should be matched to the probable threat. The following air vehicles may not be adequately covered by ground or sea based defence radars and therefore constitute targets for an AEW system.

a. Fighter Ground Attack (FGA)

FGA Aircraft penetrating at low level, 200ft and below, are unlikely to travel at more than 500 knots due to external weapons carriage limitations and fuel consumption considerations. They may on occasion carry air to surface missiles and must be the subject of active defensive action before these can be launched. For a variety of reasons, air to ground missiles are usually line of sight, while air to ship missile range may be considerable. However, in this case, lower clutter levels will ease detection problems.

b. Interceptors

Fighters armed with air to air missiles and dedicated to the destruction of the AEW platform will have a much higher usable performance and may travel at up to 1,000kts. However, at such very high speed, the aircraft will be at some altitude, reducing the clutter problem and extending detection ranges. The threat to the AEW aircraft may well dictate where the AEW patrol line is located, and this is shown graphically in Figure 2 (attached). Clearly, in time of peace, more forward patrol patterns could usefully extend the area under surveillance.

c. Unmanned Aircraft (UMA)

UMAs vary from very small and slow reconnaisance drones to cruise missile type remotely piloted vehicles (RPV) travelling at 500 knots. They can be expected to be of very low radar cross section (RCS) and therefore represent a difficult detection problem for AEW aircraft but an impossible one for ground based radars.

d. Long Range Surface to Air Missiles (LRSAM)

In addition to the threat from interceptors, the AEW aircraft may be at risk from LRSAM. The radar should be capable of detecting such missiles in time to deploy counter-measures.

The philosophy behind AEW system design is that all the above threats must be detected at sufficient range to permit appropriate defence measures to be taken. Also, allowance must be made for the tendency of targets to have increased resistance to detection through the use of ECM and reduced RCS from the application of radar absorbant material on less radar reflective aircraft shapes.

Target Data Handling

Having achieved detection of real, as opposed to spurious, targets, the radar processing equipment must be able to extract information from the received signals so that target velocity, direction and altitude are determined and presented in appropriate format for display and rapid onward transmission from the aircraft to the ground C^3 system. All this target data must also be stored and available for re-call at operator selection, with vectors and other intercept information being automatically calculated when required.

Detection Reliability

AEW system detection reliability must be sufficient to guarantee the maintenance of a very high degree of surveillance integrity at all times. The following factors are fundamental to design concepts:-

Detection of targets at the required range must be achieved regardless of de-grading factors such as heavy background clutter, precipitation and the presence of electronic counter-measures.

Operator workload must be limited to a level where efficiency does not drop off when dealing with complex situations over several hours.

The system should be capable of operating continuously over an extended period using minimum resources.

The AEW platform should have a high degree of survivability, not only in the air but on the ground as well.

MTBF of the aircraft/radar combination should be sufficient to ensure a very high probability of completing an operational mission without failure.

Practicability

The final requirement for an AEW system is that it should be practicable in all senses. Operating costs should be reasonable in relation to overall defence budgets. The manpower, ground operation, maintenance and logistic aspects of the system should be realistic and acceptable in the long term.

BACKGROUND TO THE LIGHTWEIGHT AEW RADAR

Examination of the AEW Operational Requirements by THORN EMI Electronics showed that modern signal processing techniques are mature enough to provide the opportunity for a radar of sufficient performance to perform effectively in the AEW role and yet be sufficiently light and compact to fit relatively small aircraft and middle-weight helicopters. Design of such a radar was therefore started, the philosophy behind the design being that all the AEW requirements should be achieved, but that ultimate range performance and target handling capacity would be limited compared to the very large and complex systems now in service. The Company were fortunate in having the experience of building the Searchwater/LAST AEW for the Royal Navy, and now also for the Spanish Navy, to lean on. However, this radar was designed for use against aircraft and missiles flying over water, the new radar was not only to be more compact and lighter, but was to achieve equivalent or greater performance against targets over a land background and at the same time provide considerably greater operator assistance.

THE LIGHTWEIGHT SOLUTION

In order that the complete surveillance system is economical and easy to maintain, it must be possible for relatively small airframes to carry the radar and associated data link, ESM and self protection equipment. The weight of the THORN-EMI Electronics CP2517 radar allows installation in most twin-engined propeller driven aircraft of 3,500Kg AUW and over.

Airframe selection will depend on the local availability of a suitable aircraft, simplicity of the radar installation and an appropriate speed/indurance performance to ensure that "on task" time is a high proportion of total mission time. Platforms may be unpressurised since the radar horizon range of over 100nms from 10,000ft altitude is matched to the radar's performance against low flying targets over land. Detection at 100nms provides sufficient warning time to enable low level targets to be intercepted by air defence fighters operating from ground alert, see Figure 1. In fact, AEW operation at modest altitudes, with consequent reduction in radar depression angles may serve to increase detection probabilities compared with that obtained from higher altitudes, through a reduction in received clutter and an increase in the period that a low level target will remain in main beam scan.

Cost Comparison

Some idea of the relative costs of an AEW capability are given at Figures 3&4 where the costs per minute of warning time and also per 100 miles of lateral AEW coverage are compared for AWACS, E2C and THORN EMI Electronics Lightweight radar, in this instance installed in an Islander aircraft. The main assumptions behind the comparisons being that the AEW patrol lines are positioned for survival, a minimum warning time of 14 minutes is provided, the threat target is an FGA aircraft of $10m^2$ RCS flying at 200ft over land and at 500 knots. Radar performance and system costs are based on the best available information.

TECHNICAL FEATURES OF THE THORN EMI ELECTRONICS LIGHTWEIGHT AEW RADAR

In order to meet the basic AEW operational requirements, outlined in previous paragraphs, with the THORN EMI Electronics lightweight radar which necessarily uses a relatively small antenna and normally employs only one or two operators, the following technical design features were considered to be essential:-

Travelling Wave Tube Output Amplifier:- for a coherant system which enables:-

1. Pulse Compression:- to provide adequate emitted radiated power
2. Pulse Doppler: to ensure direction of low level targets over a land background.

Auto Acquire and Track While Scan:- to provide a low workload for the operator and ensure that multiple targets can be handled efficiently.

Adaptive Thresholds:- to keep false alarms at a low level while ensuring that all real targets are displayed.

Within Beam Integration:- to maximise detection probabilities in non-coherent modes.

Polarization:- Choice of Vertical, Horizontal or Circular:- to enable the radar presentation to be optimum for all conditions.

Automatic System Optimization of:- scan rate, pulse width, PRF, FFT length and antenna depression angle. This feature is to reduce operator input and provide ECCM resistance.

Modes of Operation

The radar has the following main modes of operation:

- A look-down mode using medium PRF pulse doppler for automatic acquisition and tracking of low flying targets over land or sea.
- A look-up mode employing frequency agility and within beam integration to enhance detection of medium and high flying targets.
- A whole-sky mode using 2-bar scan alternating the previous two modes.

Additional modes provided are:-

- A maritime surveillance mode for detection of surface vessels.
- A Coastal navigation mode.
- Adverse weather warning

MAIN RADAR COMPONENTS

Transmitter and Antenna

The transmitter output stage uses a travelling wave tube (TWT) operating at I-band and producing a mean power of over 500 watts. The selection of a TWT amplifier rather than a magnatron allows the use of pulse compression providing a processed peak power of 11 megawatts, and pulse doppler processing to filter out ground clutter necessary to achieve detection of low flying targets overland.

An aerial maximum dimension of 1.5 metres was necessary so as to keep airframe modification costs low. This decision led to the use of an I-band operating frequency which enables aircraft targets to be resolved to within 1° and keeps attennation due to precipitation to a minimum. The antenna is a horn fed reflector with continuous 360° or variable sector scan capability. The mounting is stabilised in pitch and roll.

Receiver/Exiter

In addition to the receiver, this solid state unit contains the items required to generate a coherant, frequency-agile R.F. source at a power level necessary to drive the transmitter output stage.

Console

The pulse compression sub-system, phase sensitive detectors, signal processing circuits, radar display and controls are all housed in a lightweight console. Up to six additional consoles may be fitted, each containing a digital scan converter to generate the PPI display and provide the last stage of signal processing.

Display

The display is in TV rastor format on a 14 inch colour tube. Control selections are made via the two touch sensitive plasma panels. The example of a display picture at Figure 5 shows target markers and danger zones, both ground and target stabilised. Symbols are shown in different colours according to purpose, extending to the use of separate colours to depict high and low altitude targets. All symbols and alpha-numerics are selected by controls on a plasma panel display page.(Figure6)

Files

Over 100 targets may be stored and updated automatically. On selection any two files may be displayed together with own aircraft data. The computer calculates vectors between display files based on the most direct intercept track.

Navigation

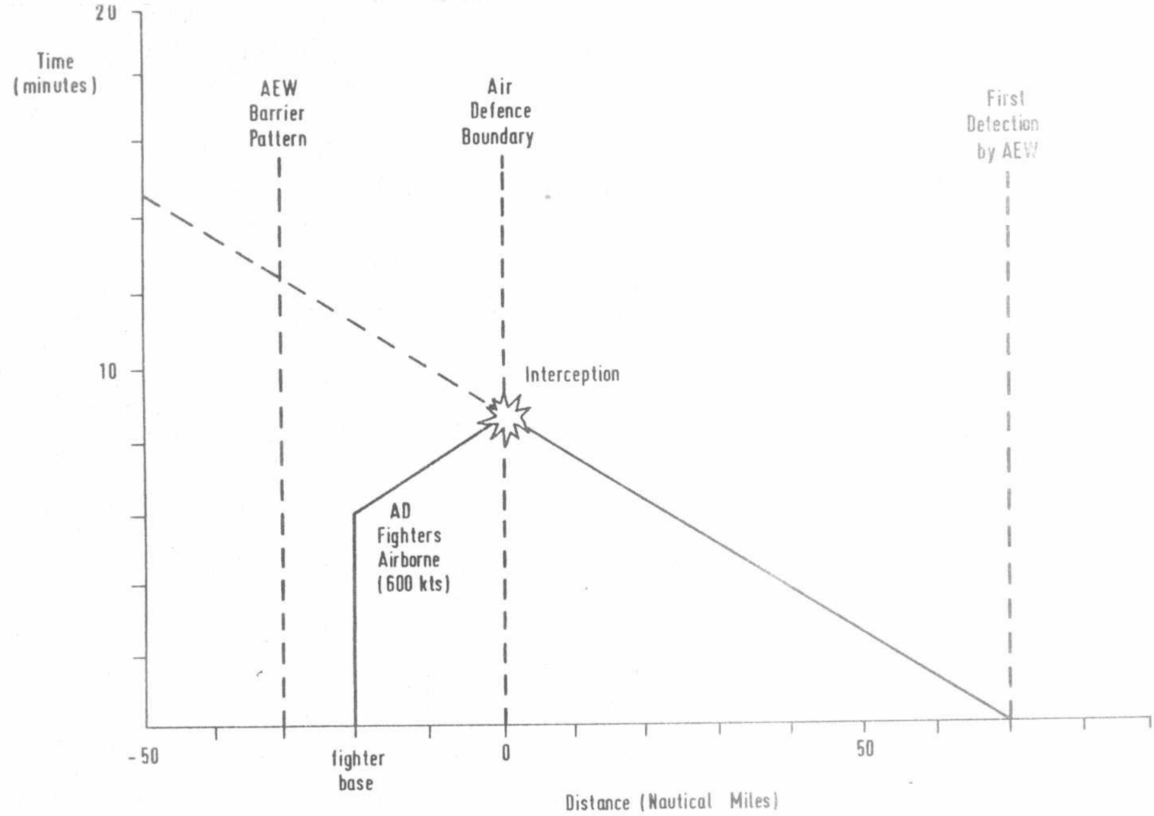
The radar requires the output from a high grade inertial navigation system (INS) or a mix of INS and doppler information.

Controls

Apart from a power switch all other control functions are exercised through touch-sensitive plasma panels. Each of these panels can display 10 different pages, providing the equivalent of several hundred switch selections. These panels may be simply adapted to a variety of functions, they provide total system control of the radar, INS, IFF, Data Link and ESM equipment through a 1553B serial interface. In addition, the panels can also be used to display information.

LIGHTWEIGHT AEW INSTALLATION

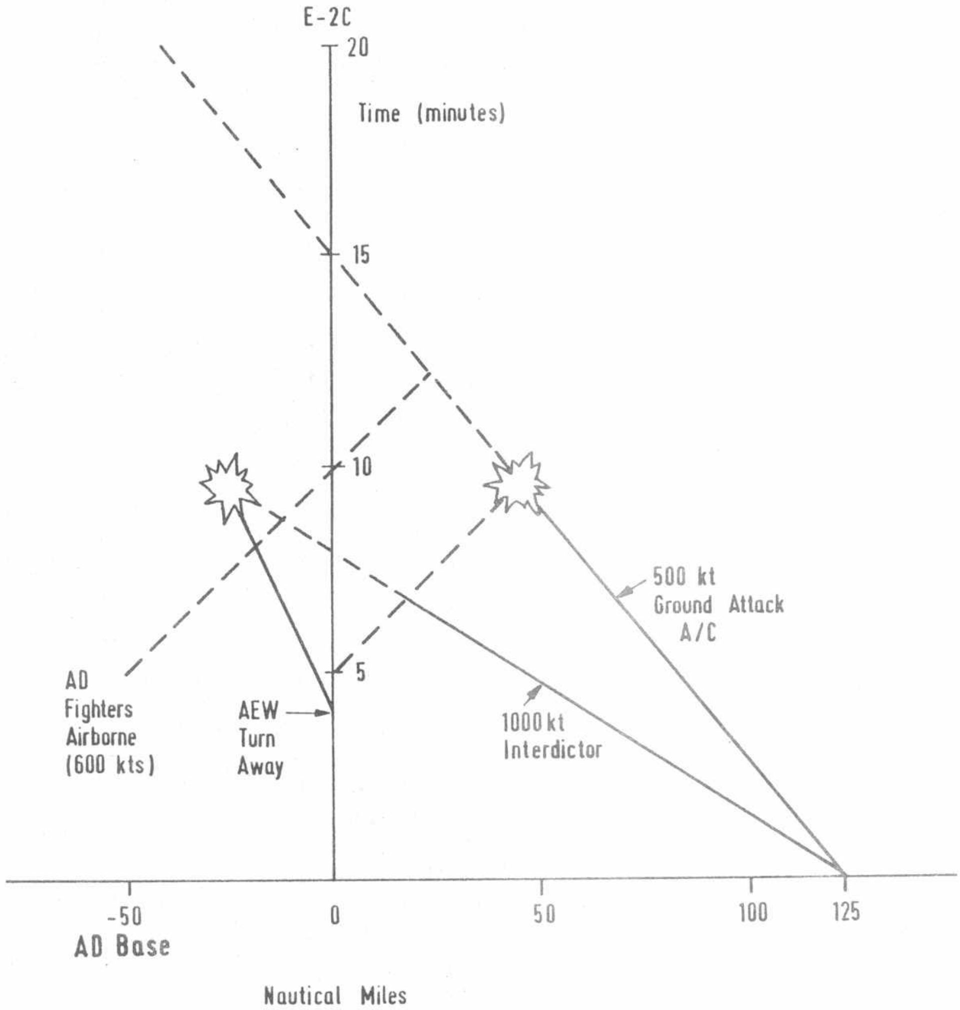
The THORN EMI Electronics AEW is sufficiently compact to allow installation with two operator consoles in a Pilatus Britten-Norman Islander and this aircraft/radar combination will be available for demonstration early in 1986. Installation in a wide variety of other airframes has been examined ranging from the SH60 through Sky Van and CASA 212 up to the C130. All these installations can be achieved for a small fraction of the cost of a major system allowing a serious defence requirement to be met at a more affordable price.



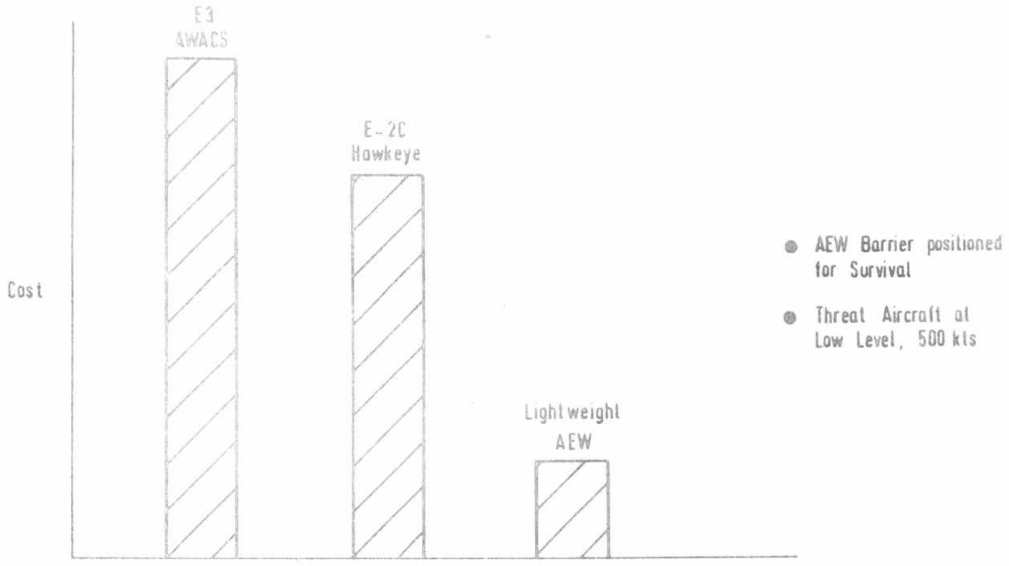
Distance Time Plan – Low Level 500 knot Threat

Tim

Fig.1

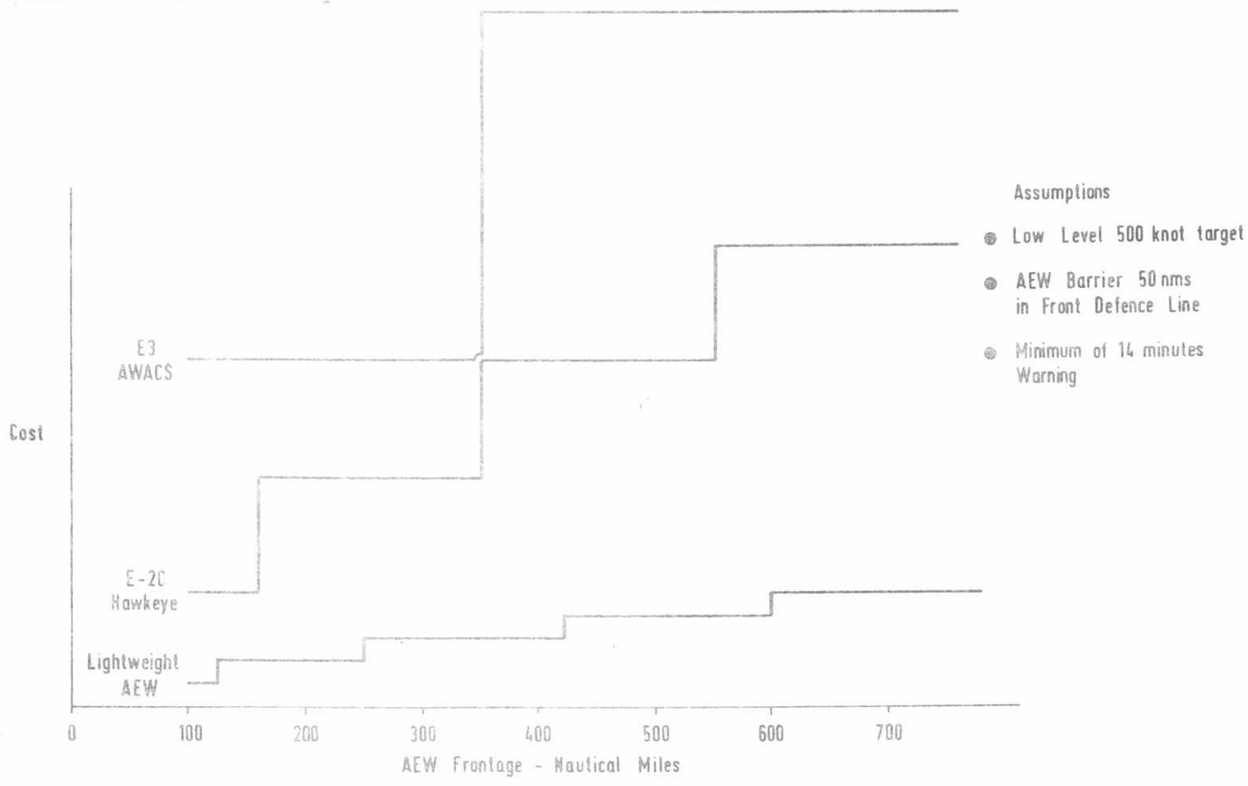


AEW Aircraft Survival



Relative Cost Minute Warning Time (Max)

Fig.3



Relative Cost of AEW Coverage

Fig.4

CP 2517 RADAR DISPLAY

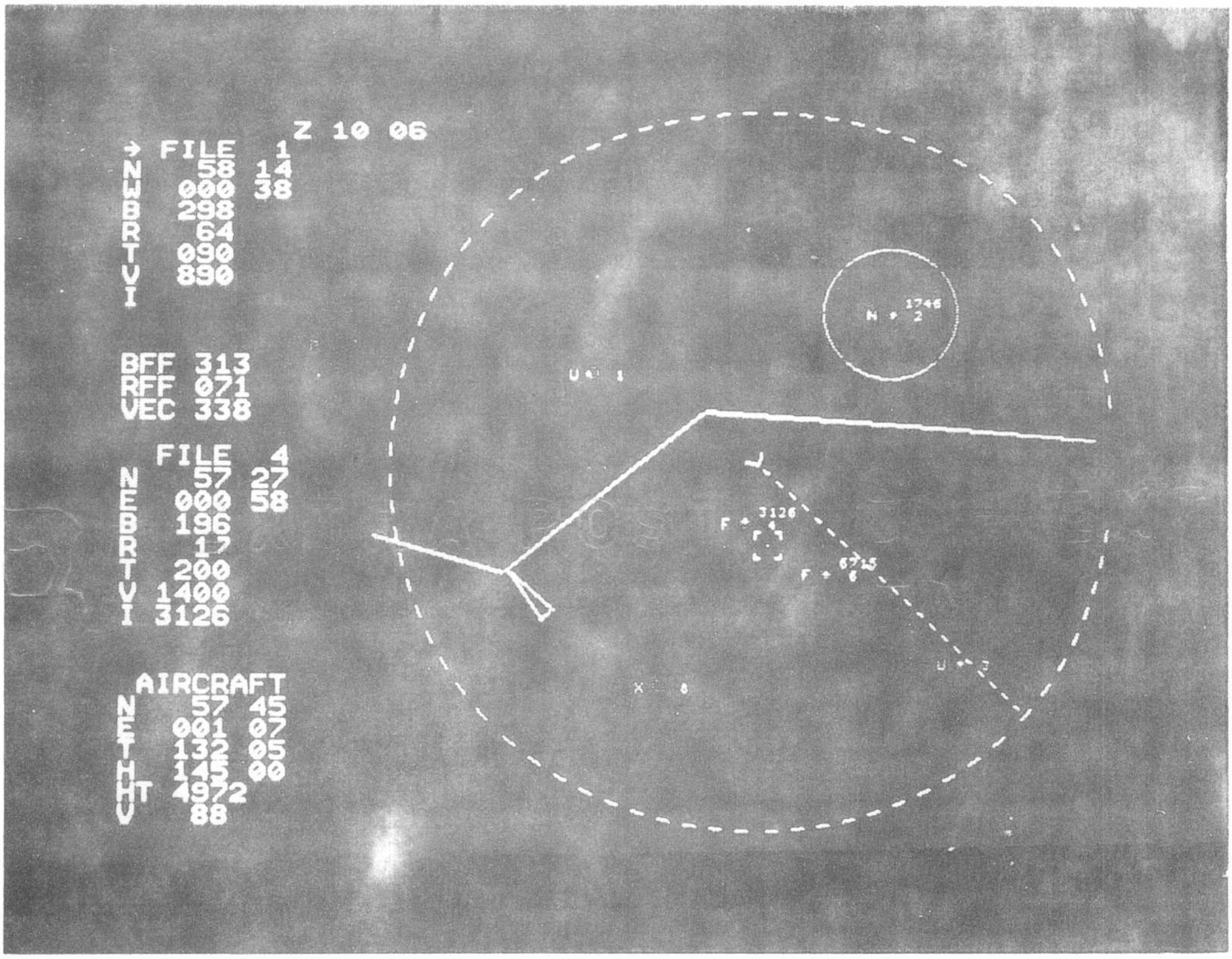


Fig.5

PLASMA CONTROL PANEL

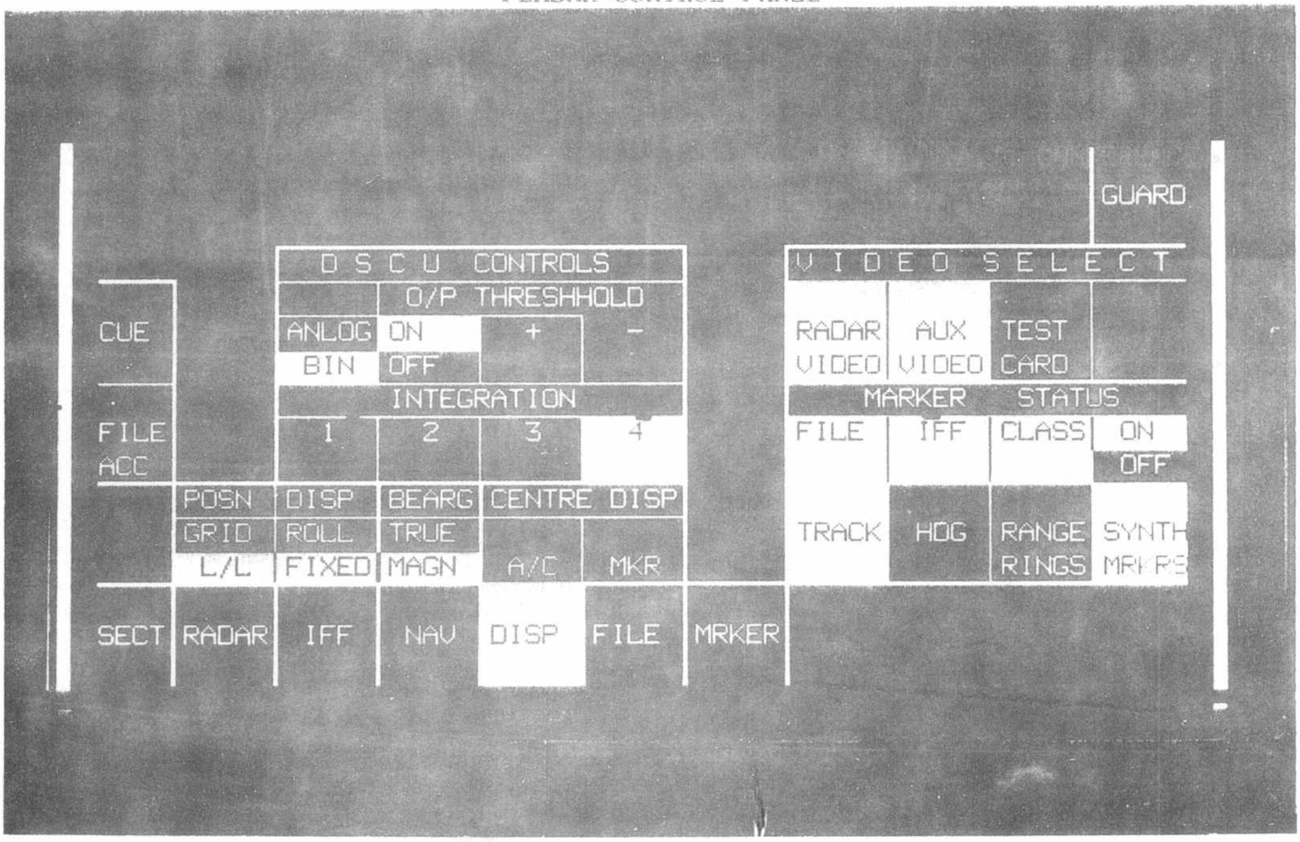


Fig.6