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CRT DISPLAYS IN MODERN HELICOPTER DATA PRESENTATION

BY

M. R. DUELL

WESTLAND HELICOPTERS LIMITED
YEOVIL, ENGLAND.

TENTH EUROPEAN ROTORCRAFT FORUM

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ABSTRACT

This paper describes the reasons Westland have adopted Electronic Flight Instrument Systems (EFIS) for it's future helicopters, for both civil and military applications.

The benefits to the helicopter user are great. EFIS technology has been adopted by the Air Transport industry, to achieve two-crew certification of transport aircraft, with the presentation of flight, navigation, and engine instrument information on multi-function displays.

The helicopter can utilise EFIS still further by using the multifunction displays to display Torque and Tacho display, Hover display, and search patterns, with consequent reduction in overall pilot workload.

Westland have undertaken studies to assess the means available to provide CRT display of flight infomation, and to achieve the required levels of system reliability and redundancy, by correct design of the EFIS system architecture and interfaces.

The paper concludes that the incorporation of EFIS provides the helicopter user significant benefit in pilot workload and cost of ownership.

CRT Displays in Modern Helicopter Data Presentation.

1.0 Introduction

Westland Helicopters have long used Cathode Ray Tube CRT display technology for the presentation of surveillance Radar and Sonar information in the Military helicopter for Anti-Submarine, and Search and Rescue, roles, performed by helicopters such as Sea King and Lynx.

Improvements in display technology in recent years permit the use of CRT displays as Electronic Flight Instruments (EFIS), with consequent benefit to the helicopter user, in the areas of information presentation and cost of ownership. This paper describes the reason Westland have adopted EFIS for it's future helicopters, for both Civil and Military applications.

The prime motivation behind EFIS development has been the Air Transport industry, with Two-crew certification for aeroplanes such as Boeing 757/767, and Airbus Industrie A310, as the major objective, Primary Flight, Navigation, Engine Instrument, and Crew Advisory functions being presented on multifunction displays.

The reasoning behind EFIS development for helicopters is somewhat different, but the effect is remarkably similar.

Before embarking on the design of helicopters which include EFIS technology as basic to the aircraft, the benefits afforded by the technology have to be clearly identified, in order to justify the adoption of such systems.

In addition, having established the justification for adopting EFIS in the helicopter cockpit, there are a number of ways in which CRT technology could be applied to the presentation of data in the cockpit, each of these must be analysed with respect to the others, as well as assessing the overall benefits of EFIS compared with electromechanical light instrumentation.

2.0 Colour CRT Technology

Westland's fist step in the task to incorporate EFIS in helicopter design has been to identify the benefits to the user. These fall into two categories, those of benefit to the user as aircrew, and those of the user as owner. Offset against these benefits, however, are some disadvantages, and whilst these cannot be completely eliminated, they can, and must, be minimised.

Of great benefit to the helicopter user is any means by which the human element in helicopter accidents can be significantly reduced. The provision of cockpit flight instrumentation in which the presentation of information to the crew contributes to a reduction in pilot workload, will be of such benefit.

The helicopter pilot has a greater amount of what could be termed primary flight information than has the fixed-wing transport pilot. Into this category come torque, rotor speed, and power turbine speed. The flexible nature of the CRT display enables, with careful format definition, the presentation of all this information, together with primary attitude and heading information, in an area of the cockpit equivalent to that covered previously only by electromechanical attitude and heading displays, thus considerably reducing time spent scanning the instrument panel.

Due to the large amount of glass in the helicopter cockpit, when compared with fixed wing transport aircraft, the incidence of direct sunlight onto the flight instruments is potentially higher, with effects such as shadowing of the instruments contributing to higher pilot workload. The elimination of this shadowing, together with the elimination of parallax effects in display viewing, due to the presentation of EFIS information in the plane of the display surface, all contributes to a reduction in pilot workload.

2.1 Summary of the advantages of using CRTs as Flight Instruments.

Flexibility - More efficient display usage, easily modified in flight, suppression of unwanted information and highlighting of high priority data.

A greater amount of information can be presented in a given instrument panel area, than was previously possible, by utilising the multifunction nature of the display, to display information not previously possible on one display, and enabling the aircrew to select display formats appropriate to the particular phase of flight, eg. pre-flight, take-off, cruise, etc..
Furthermore, CRT displays of the fixed-wing EFIS type can be adapted to enable presentation of rotary-wing specific information such as Approach to Hover, dunking sonar cable hover, surveillance search pattern.

Reliability - Use of solid-state technology enables higher MTBFs to be achieved for system components.

Cost of Ownership - Improved failure identification will prevent unnecessary equipment removals.

Lower Mean Time To Repair can be achieved.

Lower cost-of- repair.

Use of multifunction display systems in conjunction with Health Monitoring computers and other Avionic systems with built-in-test (BIT), will enable the presentation of maintainance procedures to ground crew, and failure identification down to LRU and even module level will be possible without removal of equipment from the aircraft, thus reducing the number of unnecessary equipment removals.

2.2 Disadvantages

Weight - The weight penalty of CRT displays, including Symbol Generators and controllers/mode selectors is apparently high. However the effects can be minimised by accomodating a number of flights instruments on one multifunction display surface.

The use of EFIS as an improvement to existing instrumentation cannot be justified unless the certification of the EFIS system can be achieved at a total system weight equivalent to that of the electromechanical instruments being replaced.

Further reduction in the effects of the CRT and Symbol Generator weight can be achieved by the use of digital interfaces, to reduce the size and weight of aircraft looms, in order to achieve a weight equal to or lighter than the system being replaced.

Higher Initial Cost - The initial cost of Display units, Symbol Generators and mode selectors is higher than for electromechanical ADI/HSI alone. Again the effect of higher initial cost can be minimised the incorporation of a number of flight instruments into multifunction displays, and the reduction in time spent wiring the aircraft.

Higher Power Consumption. - For a four tube EFIS with 5" display units an increase in power consumption in the order of 350 Watts is a typical figure.

Westland carefully considered the relative advantages and disadvantages incurred in the use of EFIS in helicopters, with the result that such displays would be of benefit to the helicopter user.

2.3 System Architecture

Conventionally the interface between aircraft sensors and flight instruments has been via various AC and DC analogue signals. This has resulted in a heavy and complex mass of cables and looms in the aircraft. Reduction of this weight is clearly of paramount importance in the helicopter.
Furthermore, because of lack of standardisation among the sensor manufacturers, the scope for modification and adaptation of avionic systems and flight instrumentation has not been easy.
If the correct interface between the aircraft sensors and the display system is chosen, however, both of these disadvantages can be minimised. The widespread adoption of digital methods of data transfer in both civil (ARINC 429),

and military (MIL-STD-1553) aeroplanes is of clear benefit to us. Once the digital standard has been adopted, and accepted, as the method of data tranmission between sensors and the display system, then both sensors and displays can be readily adapted to meet specific requirements.

To maintain or improve currently achieved failure rates (such as presentation of hazardously misleading Pitch and Roll attitude or Heading), a high level of system redundancy must be achieved, thus components such as Display Units, Symbol Generators, etc. must be truly interchangable between ADI and HSI, pilot and co-pilot displays.

For certification of EFIS in the civil helicopter market, it is important that EFIS is certainly no less, and preferably much more, reliable than the electromechanical instruments it replaces. The EFIS system must not become "dispatch critical", in other words, the aircraft must still be fully operable following a failure in the EFIS, and all flight information must be available to the pilot.

2.4 Having concluded that the adoption of CRT technology represents the way ahead for Westland, we now are faced with a choice of optimum sizes and types of display available, consideration must be given to applying the display to the task(s) required of it.

2.5 At this point we should refresh ourselves to the types of colour display which will be available for the purposes envisaged.

1) Shadowmask - Full range of colours available (see Fig.1)

- High display luminance achievable when stroke written, line brightness in excess of 300cd/m2 with Index of Discrimination of 2.0 or greater, readable in direct sunlight (108,000 lux).

2) Beam Penetration (Penetron)

- limited range of colours available when stroke written.

- monochrome when raster driven, with limited colour available if stroke written during frame flyback.

- higher power consumption than shadowmask.

- high display luminance achievable when stroke written (readable in 108,000 lux).

- moderate display luminance when raster-driven, suitable for non-cockpit applications.

3) Beam Indexing

- in its infancy.
- full range of colours available.
- only capable of being raster driven.
- highest power consumption.

2.6 Having looked at the types of display available and the features exhibited by each, let us now consider the tasks, and types of data, which we require to present to the aircrew.

1) Primary Flight Information :-

- o Aircraft Pitch and Roll attitude
- o Pitch ,Roll, and Collective command director information
- o Flight Director mode annunciation
- o Glideslope and Localiser deviation
- o Failure and invalid flags
- o Radar Altitude and Decision Height
- o Aircraft Heading
- o Selected Heading, Selected Course
- o RMI Pointers
- o Deviation and To/From flags,

all ADI and HSI functions, in fact, requiring ideally that the display is capable of being generated in a full range of colours.

2) Power Systems Information

- o Engine temperatures and Pressures
- o Engine Turbine and Gas generator speeds
- o Rotor Speed
- o Engine and Transmission Torque
- o Transmission Temperatures and Pressures
- o Fuel Contents and Flow Rate

Actual parametric values and operating limits must be presented, requiring that the display is at least capable of showing green, amber, and red operating limits.

3) Tactical Situation Displays

- o Targets, colour coded and shape coded,
  e.g. Red - Hostile
  Green - Friendly
  Amber - Unknown

- o Waypoints, shape coded

- o Engagement Zones, Search Patterns, etc,

4) Sensor Video

- o Radar, Sonar, FLIR, etc

Together with our partners at Agusta, Westland considered the alternative types of display available, and concluded that, for the types of display function required, shadowmask displays would be used in the EH101 cockpit, and for all primary flight and power systems information, these displays would be stroke written.

The vibration characteristics of shadowmask tubes has been open to doubt for a considerable time. Increasingly, shadowmask displays are using lightweight, in-line gun assemblies, thus decreasing the effects of colour convergence from vibration susceptibility, and display units of the sizes currently being considered for projects such as EH101 and W30 fall within the helicopter vibration envelope, and have been tested and cleared for installation in vibration isolated racks and panels.

2.7 The conclusion to the first part of this study has been that for the majority of Electronic Flight Instrument, and Mission display applications, shadowmask CRT displays will be used in the helicopter.

3.0 The Application of CRT Displays to the EH101 Helicopter.

The first project to which colour CRTs were considered for application was EH101, in conjunction with our partners at Agusta.

Before illustrating the steps which led to the display system which has been adopted for EH101, let us first consider the instrument panel proposed for it's predecessor, WG34.

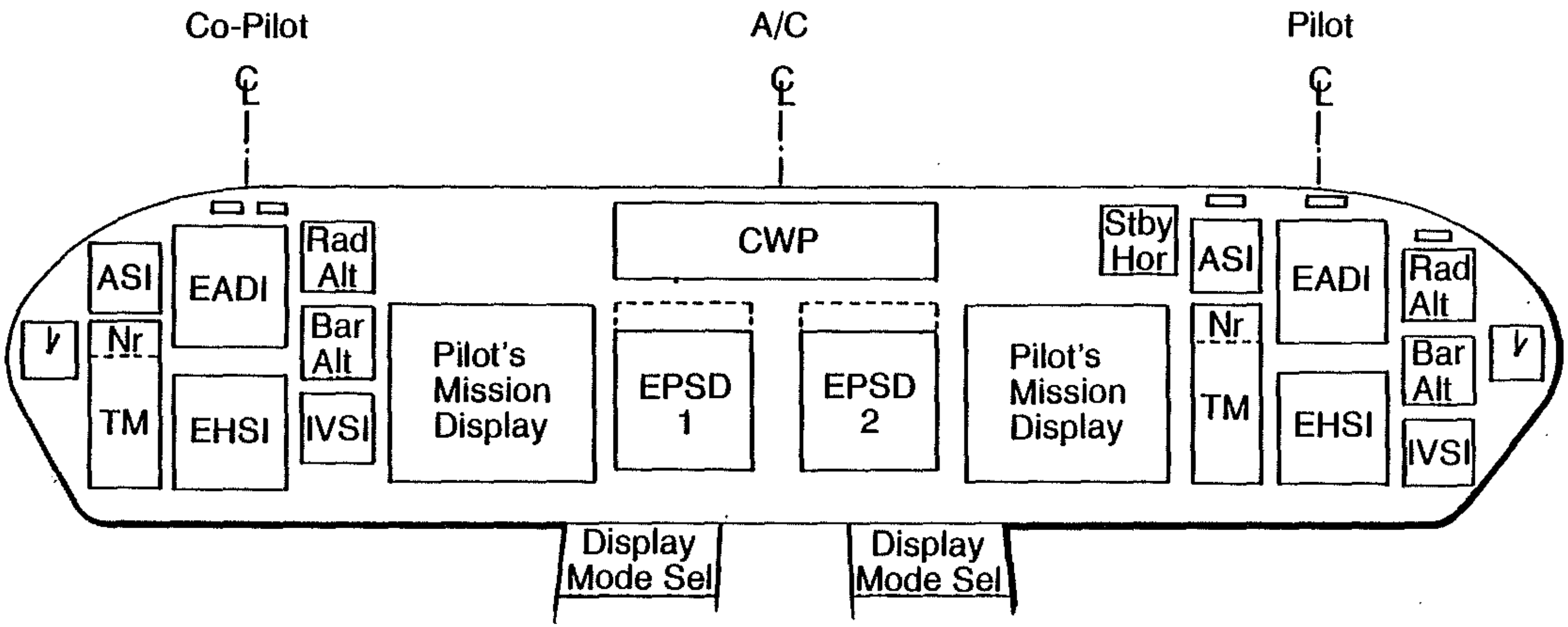


FIG.1. EH101 BASELINE COCKPIT UPDATED TO INCLUDE ELECTRONIC ATTITUDE AND POWER DISPLAYS.

Progressing from this starting point, the first application of colour CRTs would have been the provision of EHSI, the "Baseline" cockpit. This would have served to enhance the performance of the HSI by including Map display format, as well as increasing component reliability. A small cost and weight penalty would have been incurred.

At the time (1981), both Westland and Agusta had perceived a move throughout the industry to move towards the "all-glass" cockpit, both in the Airtransport and Military fixed-wing field, in the USA and in Europe.

In the light of this, and the recognition of the potential benefits for a project as advanced as EH101, the provision of an "all-glass" cockpit became a design objective.

Returning to the Baseline cockpit we see that a comprehensive range of information types are required in the cockpit.

In the design of the "all-glass" EH101 cockpit, several major considerations must be borne in mind.:-

- o Maximum commonality between all variants (RN, MMI, Civil)

- o Provision of sensor video in the cockpit (e.g. Radar)

- o Flexibility in display usage

- o Single - Pilot operation in the Royal Navy role.

To this end, then, the projected EH101 cockpit evolved to include Torque and Torque Margin, Radar Altitude, Vertical Speed, Free Power Turbine, and Rotor Speed display on the primary flight displays, with all Power Systems related parameters and Central Warning System "Cautionary" captions on the centre displays.

Having decided which functions would be displayed on the Electronic Instruments System (EIS), as it now became known, two questions remained.:-

1) How to present the information?

2) How to accumulate, process, and transmit the information?

4.0 Simulation

To answer 1) above Westland, on behalf of the EH101 Project Office, purchased two high resolution shadowmask displays from Smiths Industries, together with display processing units, stimulated by outputs from the EH101 cockpit simulator, and the software necessary to be able to develop display formats on-site at Yeovil. These units were installed at Yeovil in May 1983, and have been used to generate and evaluate the display formats illustrated in Figs 9 & 10.

This work continues at the present time, and these display units will remain in service until the simulator is equipped with display units fully representative of the type finally selected for the EH101 aircraft.

6.0 EH101 Electronic Instrument System

An Electronic Instrument System (EIS) will be provided in the cockpit of the aircraft to display to the aircrew a variety of flight, navigation, power systems, and cautionary information. Six multifunction display units (MFD) will be provided. The display formats on each multifunction display unit will be generated by one of four symbol generators, using data provided by the Aircraft Management System. In addition, in some roles of operation the EIS may use data provided directly from role-specific radio-navigation equipment.
The multifunction display units will be high-brightness, stroke-written, shadowmask cathode ray tube (CRT) display units. The precise content of each display format, and the colour coding used to represent differing types of information will be fully defined during the development of the equipment. However, it is anticipated that the display formats may be generally as defined by figures 5 - 10.

The general layout of the instrument panel and consoles is shown in Fig. 2. Although there are differences between the roles of the aircrew in the two variants, the general hardware layout will be common with the exception of a few, role specific, controller differences.

The primary roles of the aircrew are as follows :-

Single pilot operation, the main task being to successfully complete the flying task of the mission, but also to be able to contribute towards the mission task on an opportunity basis. However, two aircrew stations will be provided in a side-by-side configuration and the aircraft may be flown from either pilot's station.

The instrument panel layout as shown in figure provides the display of primary flight information, including Attitude, Horizontal Situation, Rotor RPM and Torque Margin, Barometric Altitude, Radar Altitude, Airspeed, and Vertical speed, at a location directly in front of each pilot. The traditional layout is largely maintained, with Attitude and HSI information located on the pilot's centre-line.
The display mode selector panels have been located such that they are equally accessible from either pilot station.
The layout has been optimised for single-pilot operation, with all primary and standby flight, navigation, and power systems information located in the starboard half of the instrument panel.

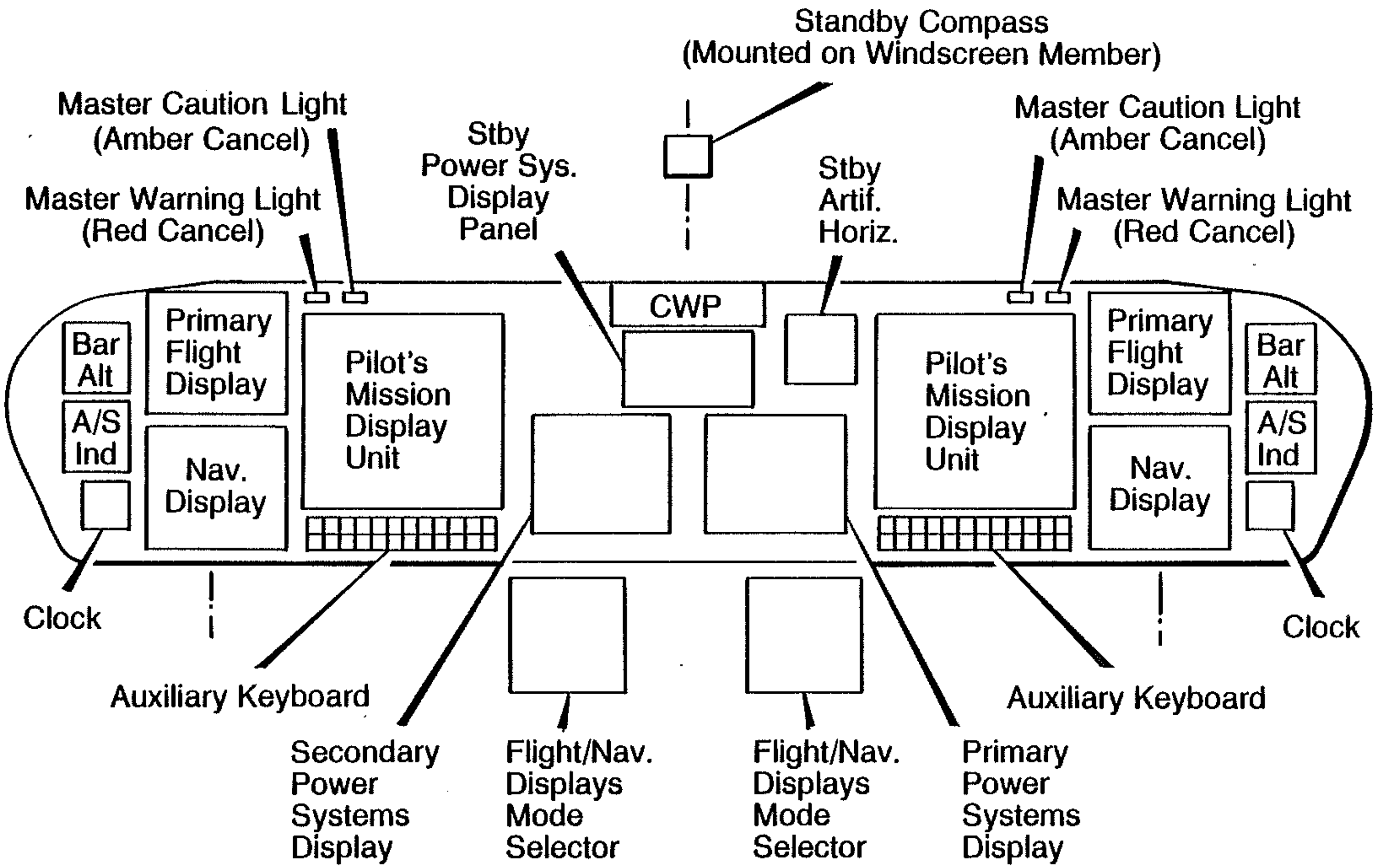


FIG.2. EH101 COCKPIT LAYOUT.

Careful design of the EIS system architecture ensures that the helicopter can be flown successfully from the pilots station only, with complete dual redundancy of all EIS functions on each side of the cockpit.

Figure 3 illstrates the means by which system redundancy is implemented. Symbol generator failure within either the primary flight/navigation or power systems units will not affect display availability since the remaining symbol generator is able to drive all displays.

Loss of critical functions (pitch and roll, heading, engine data) is relegated to a third failure, and is thus extremely improbable.

Assessment of the overall system reliability assumes that each symbol generator is able to drive all the display units, thus cascade failures will not contribute to a reduction in the predicted reliability.

Figure 4 illustrates a mission reliability plot against both cost and weight for typical system architectures of different complexities, the proposed EH101 system is shown to be the optimum in terms of integrity, cost, and weight.

7.0 Westland 30 Series 300 Electronic Flight Instrument System

Concurrent with the "all-glass" cockpit study being undertaken on the EH101 project, Westland has identified another project for the application of EFIS technology, the Westland 30 - 300.

This helicopter is the latest variant in the Westland 30 range, with GE CT7 engines, 5-bladed main rotor, AUW of 16,000 lb, and increased payload/range over the earlier W30 variants.

In terms of avionics, however, initially the -300 will be similar to earlier variants of the Westland 30, with a "conventional" instrument panel, but including EFIS. It is hoped, however, to improve and refine the Avionics/Displays system of the Series 300 throughout the aircrafts production life, taking advantage where possible of the experience gained on the EH101 project. To return to the current -300 system design, here we have what could be termed a "mature" aircraft, with interfaces between avionics and flight instrumentation already defined. To include EFIS on this aircraft involves the replacement of ADI, HSI, Marker beacon, and Navigation Mode selector, with EFIS, comprising co-pilot and pilot EADI and EHSI, with dual redundant symbol generation and display mode selector panels. Westland defined the contents of the display formats, and have selected a supplier to provide a 4-tube EFIS.

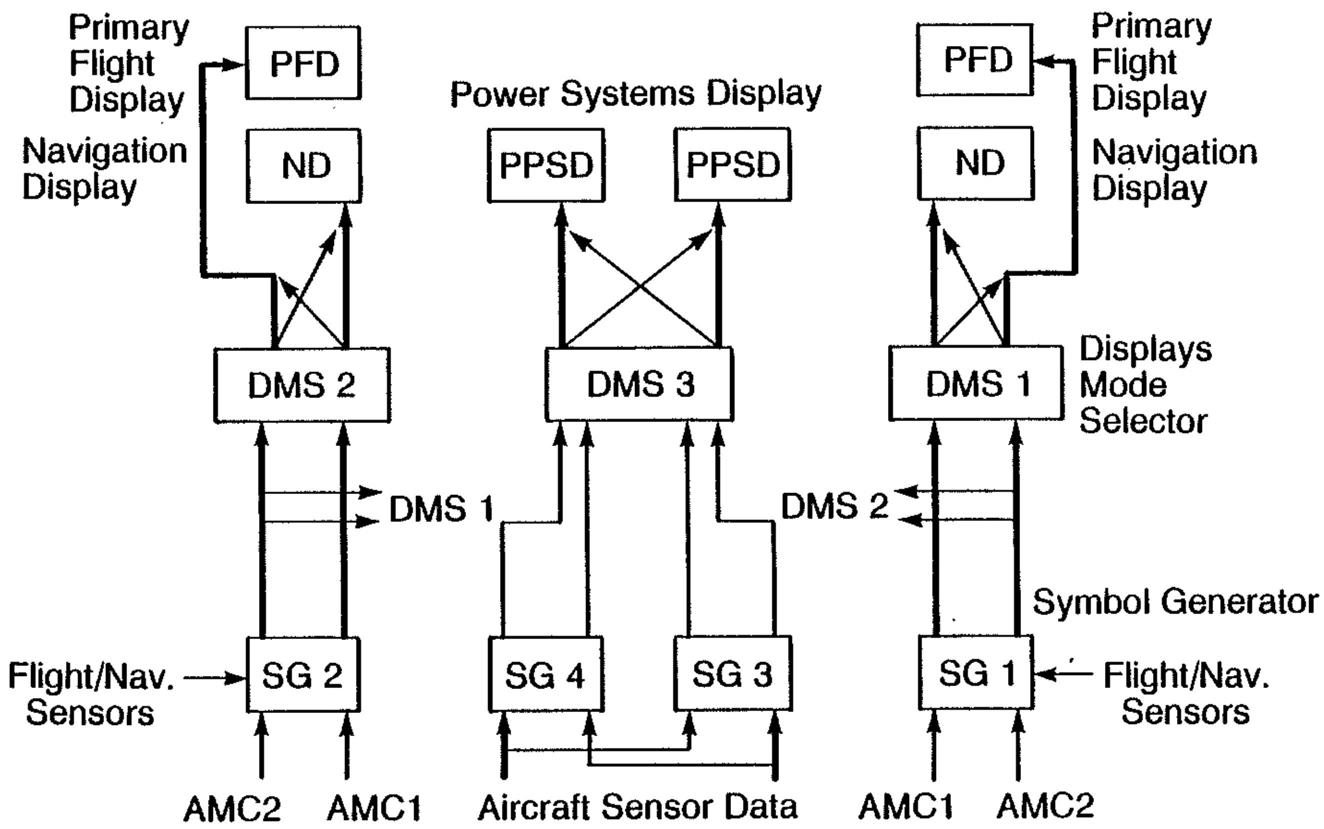
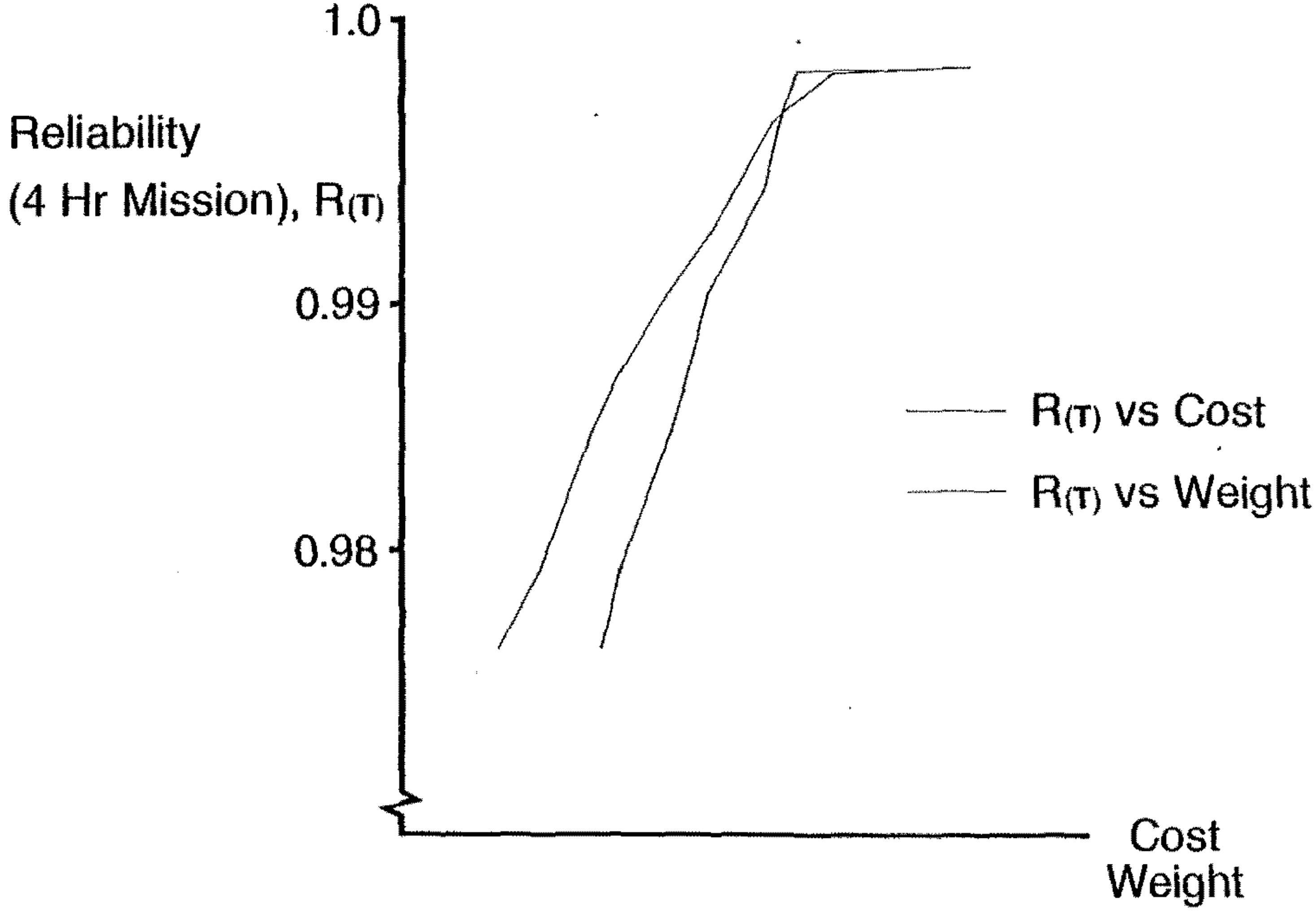


FIG.3. SH101 EIS REDUNDANCY PATHS.

FIGURE 4.



Effect of System Configuration upon Mission Reliability

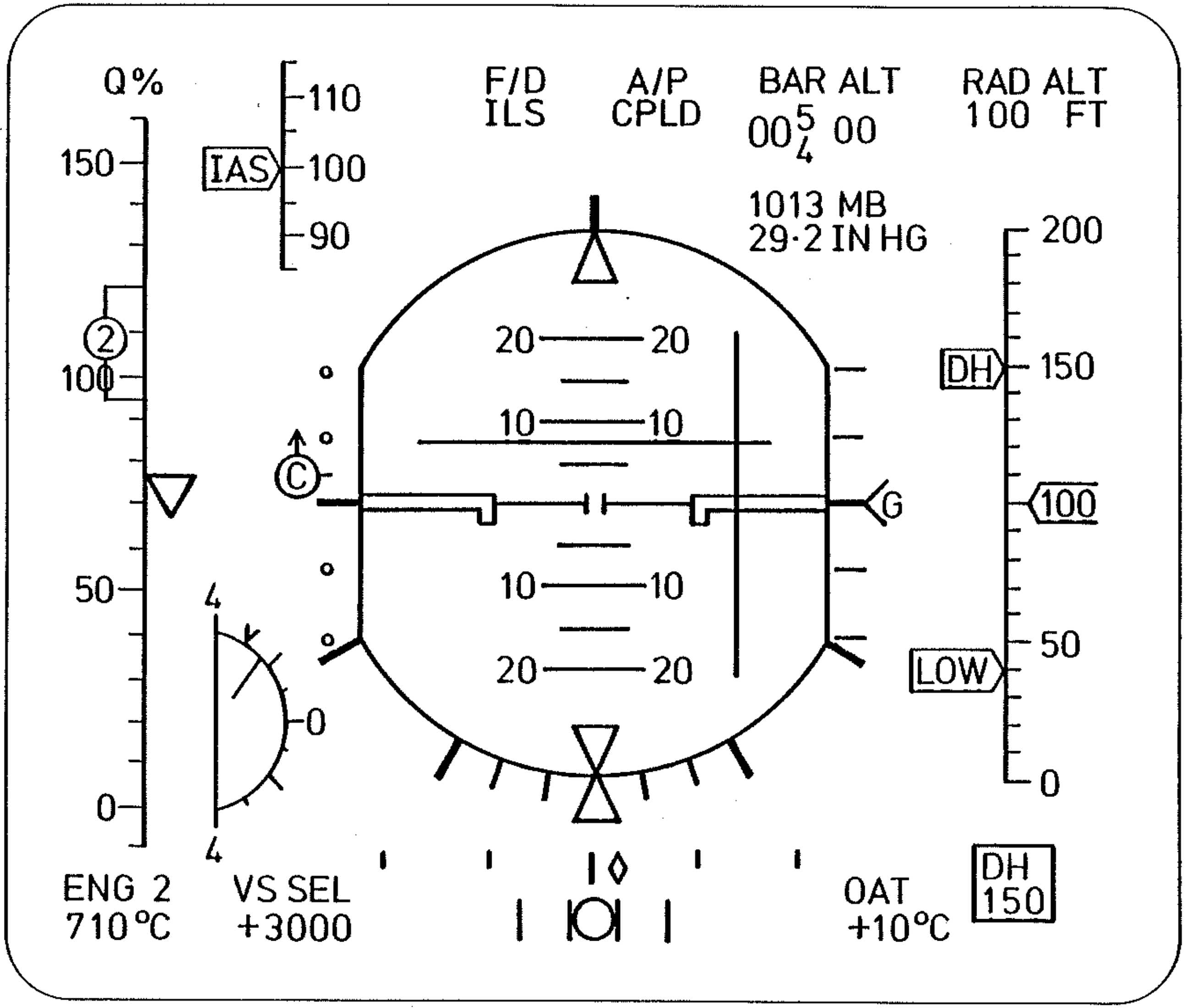


FIGURE 5. PRIMARY FLIGHT DISPLAY.

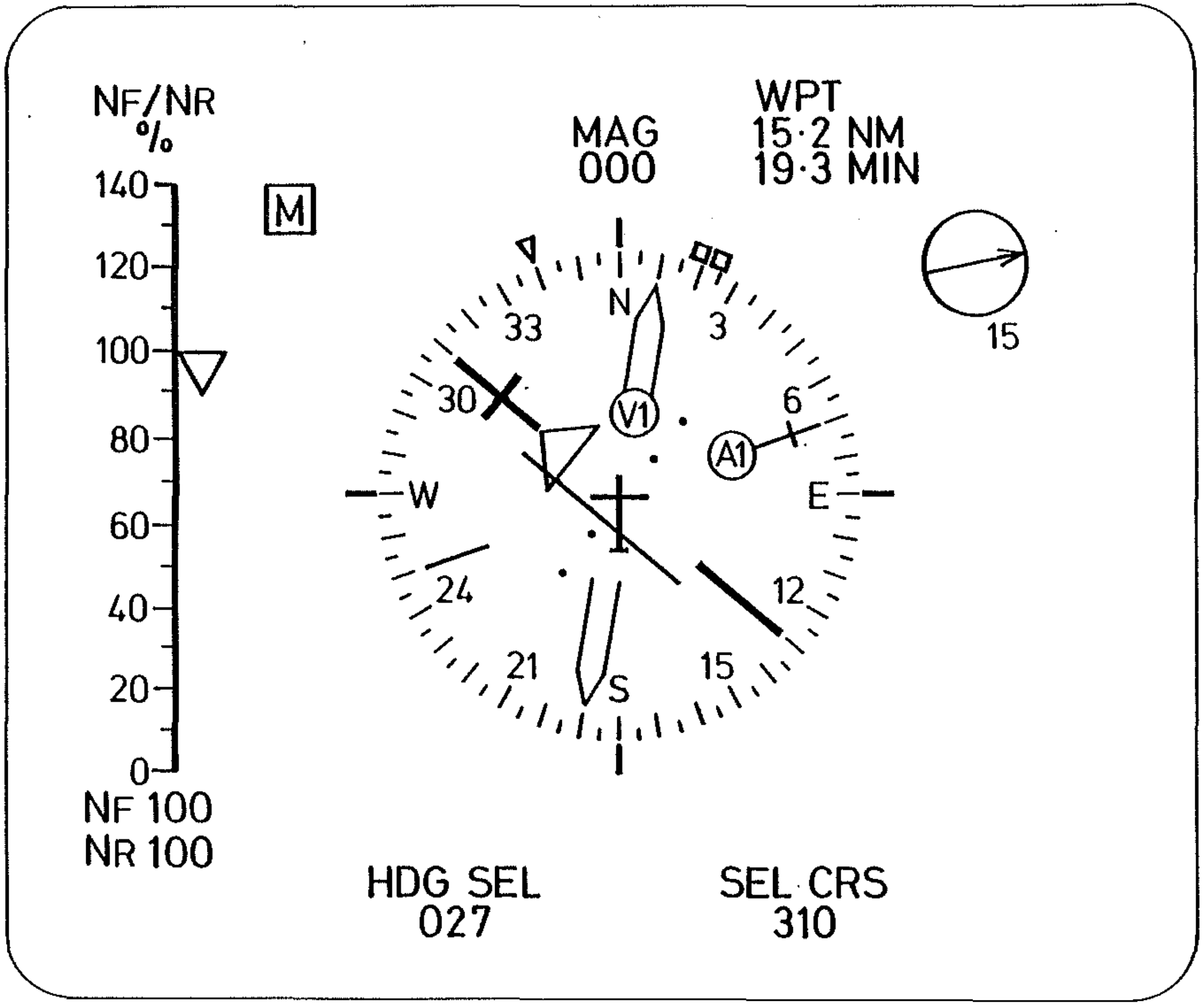


FIGURE 6. COMPASS DISPLAY.

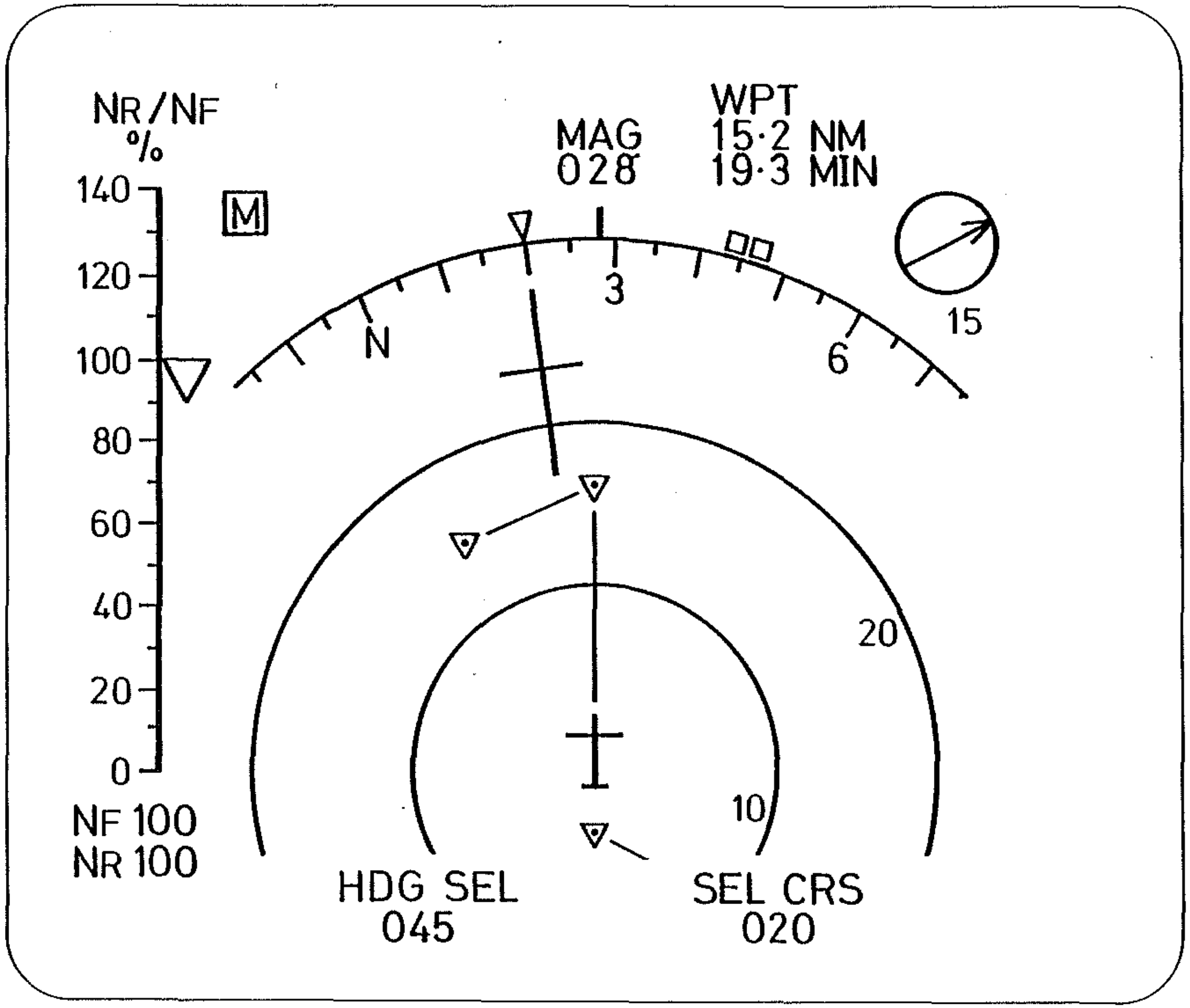


FIGURE 7. MAP DISPLAY.

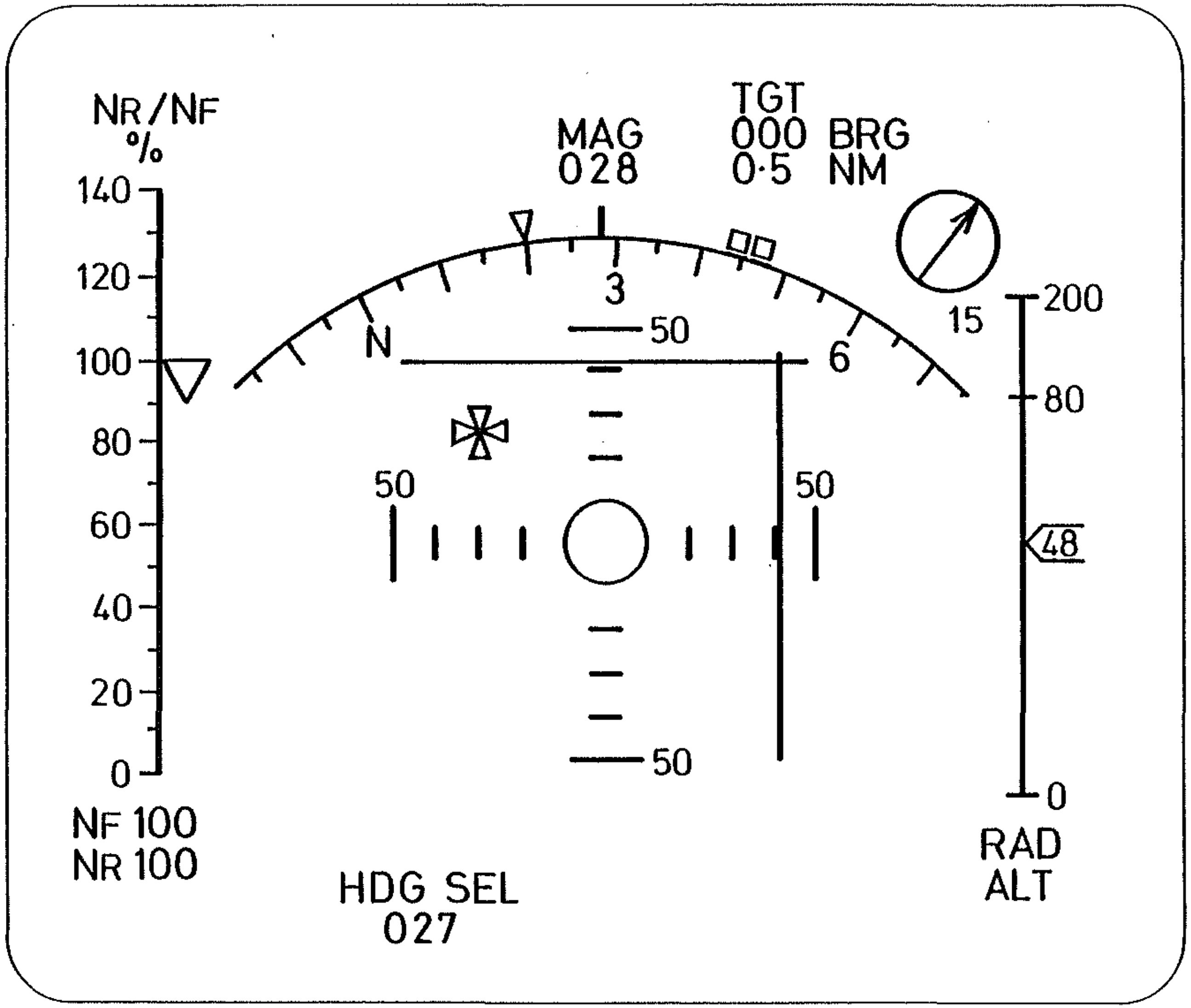


FIGURE 8. HOVER DISPLAY.

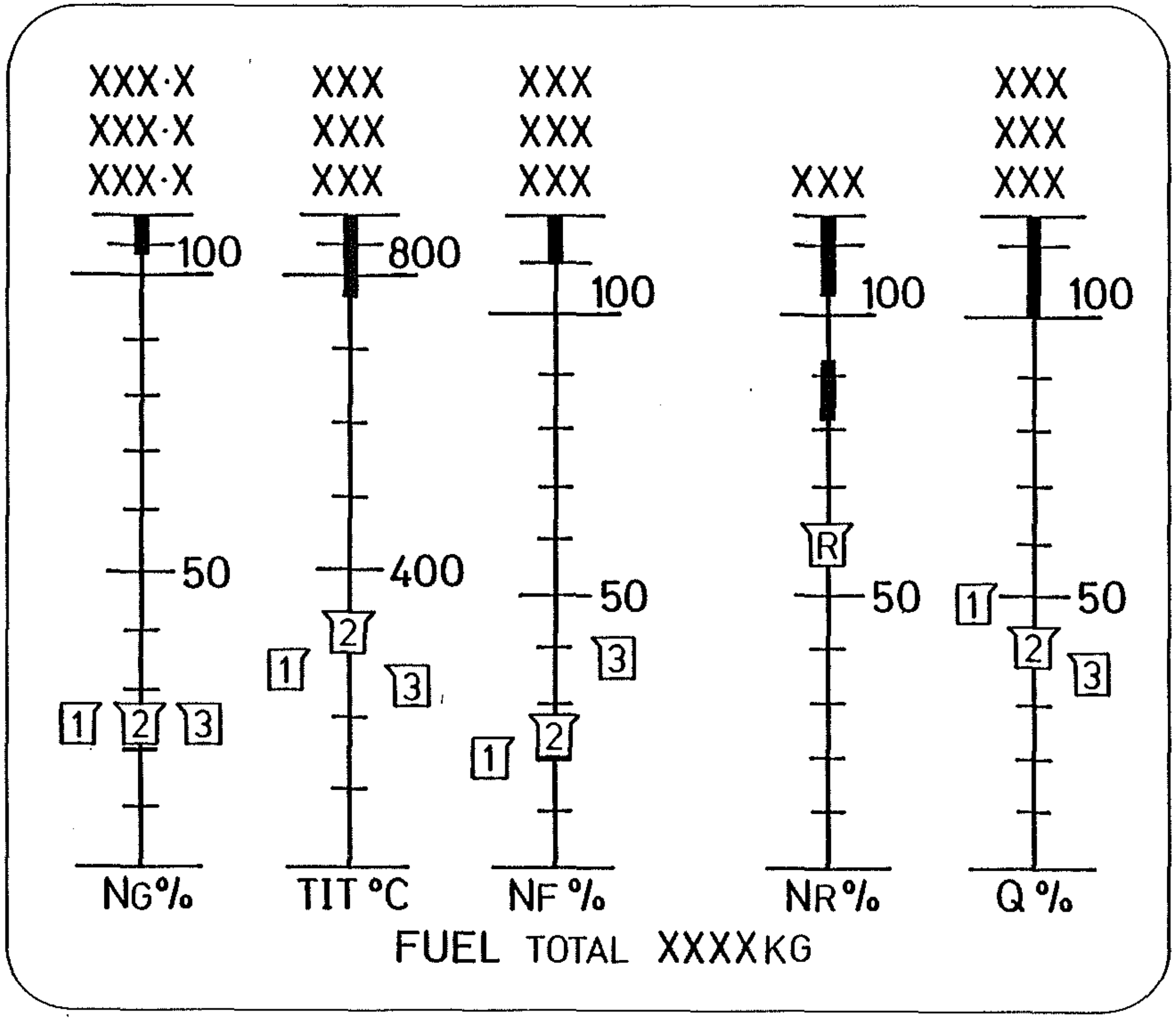


FIGURE 9. PRIMARY POWER SYSTEMS DISPLAY - START CONDITION.

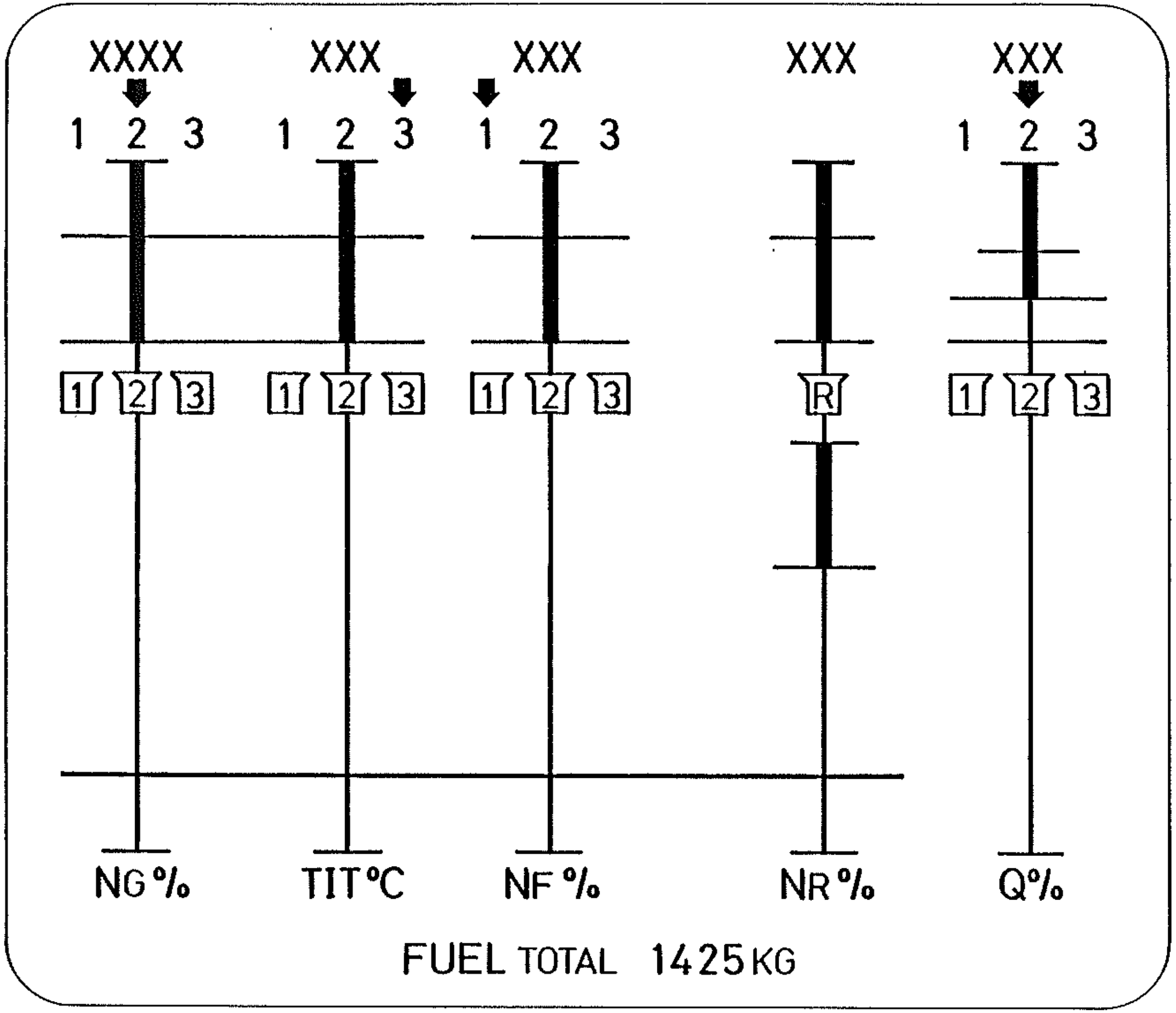


FIGURE 1C. PRIMARY POWER SYSTEMS DISPLAY - CRUISE CONDITION.

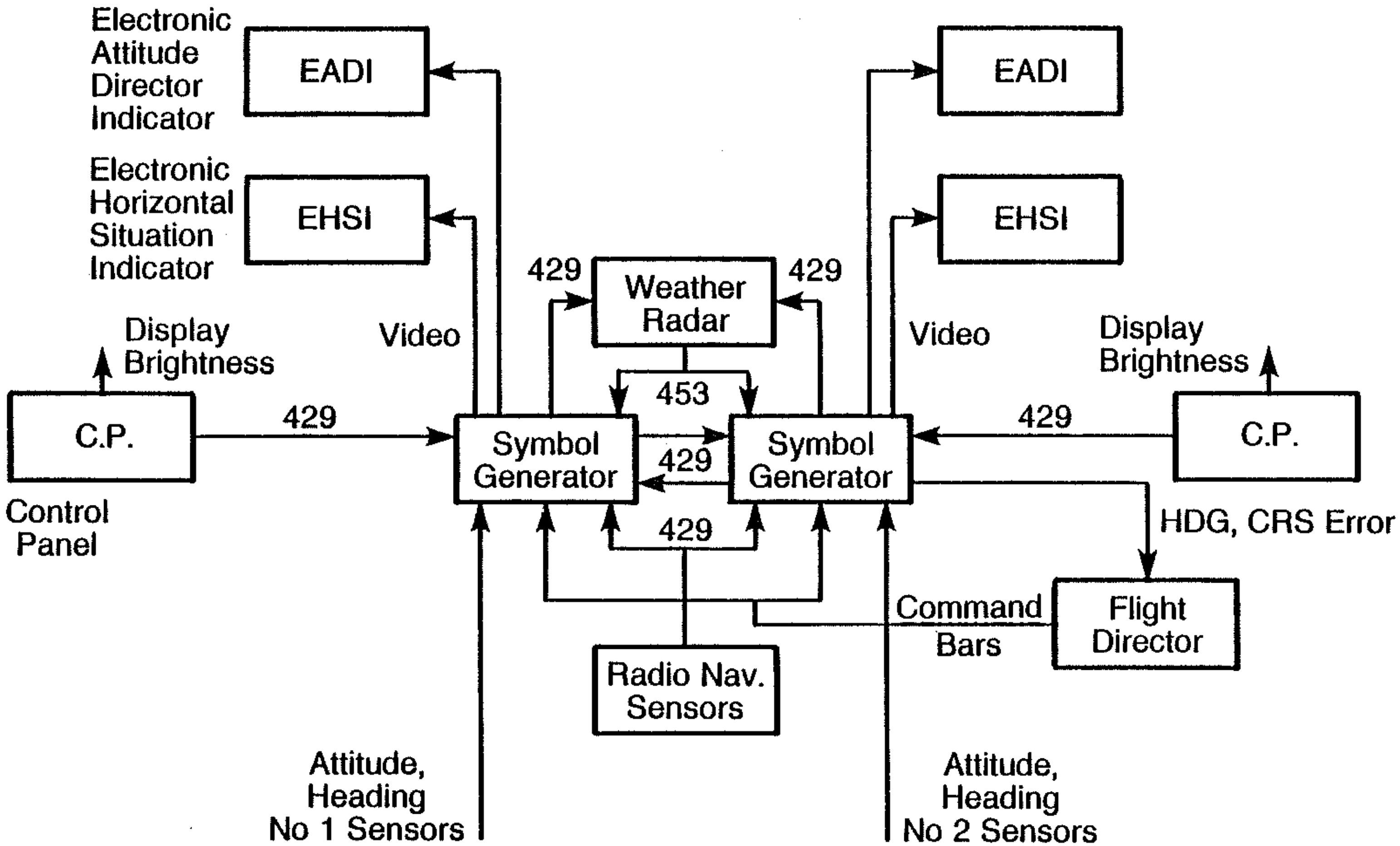


FIGURE 11 - WESTLAND 30 - 300 EFIS.

This is an example, at this stage, of a purely civil application of EFIS, using stroke-written shadowmask displays. However, using the digital interface described earlier (in this case ARINC 429), the EFIS could be adapted to put SAR, or Tactical Situation Displays in stroke-written symbology should the need arise.

8.0 Conculsion

It can be demonstrated clearly that the use of CRT displays in the helicopter cockpit does offer benefits in terms of information availability to the crew, and also in terms of improved cost of ownership.
However, there is room for improvement in terms of the weight of EFIS systems, and this aspect should be addressed in two ways.

- The adoption of technology other than "todays" CRT, eg. colour LCD, flat CRT.
- Changes in the means of data presentation, moving away from analogous representation of electromecanical instruments, and into display formats and methods more appropriate to clear and efficient usage of the display area.

Pilot workload could be reduced still further by adoption of the "quiet cockpit" philosophy, whereby, when all conditions are normal, displayed data is at a minimum, and only abnormal conditions are flagged to the pilots attention. Care must be taken to ensure the integrity of the system, to ensure that the presentation of abnormal or failure conditions does actually occur, when required.