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HELICOPTER CONTROLS AND DISPLAYS - FUTURE CONCEPTS

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1. INTRODUCTION

The ingenuity of the helicopter designer in the 'traditional' aerodynamic and mechanical engineering disciplines has provided the military helicopter with an extensive capability to perform a wide range of tasks while carrying a proliferation of weapons and sensor systems.

As a consequence, the helicopter is now beginning to be widely used not only as a general purpose utility vehicle, but as a sophisticated weapons system performing complex missions in all weather conditions.

The design of the vehicle as a total weapons system poses a number of novel problems, in addition to the practical engineering issues normally encountered, which the designer must take into account if the effectiveness of the system is not to be compromised. These problems all address the design of systems to match the capabilities and limitations of the human operators.

These problems are not new. For many years operators of large military and civil systems have recognised that the operator is limited in his capacity to use and process information quickly, efficiently and without error and incorporate appropriate levels of automation in the design of system interfaces.

As the amount of information presented to the helicopter crew increases through the installation of many systems, the helicopter designer must carefully consider how best to match the systems to the tasks which the crew require to perform during the mission.

This paper will briefly trace the development of helicopter cockpits and discuss how the avionics engineer can utilise the many technological advances in control and display techniques to radically improve the cockpit layout and benefit both the user and manufacturer alike.

2. HISTORICAL DEVELOPMENT

Figs. 1 and 2 illustrate the changes which have occured in the cockpit as a result of the evolution of the vehicle. Analysing the numbers of controls and instruments for a range of helicopters and plotting these against the in-service dates produces the general trend shown in Fig. 3. Extrapolating this curve shows that the number of conventional instruments, controls and display heads will eventually reach a level where they may be difficult to install in an instrument panel of reasonable proportions.

In addition to the growth of numbers of instruments, there must be a corresponding increase in the instrument panel space required to contain them and we may presume, a decrease in the outside vision available to the crew.

The conventional instrument panel is also extremely limited when the customer wishes to retrofit an instrument or controller to an existing panel. Many examples can be cited where the controller is situated in an inaccessible position or of a display reducing the outside field of view.

Increasing the instrument packing density by decreasing the physical size of the control or display is not a viable approach due to legibility and operability considerations.

An analysis of the way cockpit space is utilised in typical military helicopters is shown in Table 1. This shows the percentage of space occupied by different functional groups of displays or controllers and their utilisation throughout a mission. The conclusion which can be drawn from this is that considerable areas of panel space are provided for systems such as weapon systems, communication systems, etc. and which are used very infrequently.

3. CREW VISION REQUIREMENTS

The visual requirements of the crew are particularly important in the helicopter especially when operating at low level over land. The pilot derives many cues providing fundamental information regarding speed, height, attitude and navigational data and obviously requires good forward vision to detect obstacles. The co-pilot, or observer also requires a wide, unobstructed field of view when carrying out surveillance or target acquisition tasks. As the vehicle speed increases and height decreases, the outside visual characteristics are of paramount importance due to the increased probability of encountering obstacles and the terrain masking effects which interfere with the navigational and target detection tasks.

The current visual field of view requirements for rotary wing aircraft are shown in Fig. 4, which shows the pilot's visual field in terms of azimuth and elevation angles from the design eye position. Fig. 5 illustrates how current cockpit designs compare with this requirement.

4. CREW WORKLOAD CONSIDERATIONS

As the number of systems, controls and displays present in the cockpit increase, so too will the amount of information which the crew are required to process. Operating at higher speeds means that the time available to process the information decreases and at low altitudes the crew's outside visual scan must be maintained, also influencing the effectiveness with which information can be processed.

The operational requirements imposed by all weather operations compounds this problem further by requiring the crew to operate with such devices as night vision goggles, FLIR or LLTV systems.

5. POTENTIAL SOLUTIONS

The problem facing both the designer and the user is therefore how to incorporate suitable displays into the cockpit such that:

(a) the visual field of view is not reduced

(b) the best possible utilisation can be made of available panel space.

(c) the range of missions which the vehicle can be called upon to perform can be satisfied without major modifications.

(d) future growth potential and flexibility can be provided.

Research and experimental studies have shown that almost all of these requirements can be met by using electronically generated displays in conjunction with multi function controls (Refs. 3, 4).

The operation of such a display system is best explained by an example. Fig. 6 shows a console comprising a display head, multi function switch panel and keyboard. By operating one of the 'mode' switches the display can be commanded to operate in one of a number of different modes. Fig. 7 shows the display format obtained when the COMMS mode control is operated. The display then indicates the range of communication facilities available, i.e. VHF, UHF, HF, etc. To select one of these sets, the switch alongside the legend is operated. New frequencies can be set in via the keyboard or alternatively one of a number of presets can be selected.

Similar modes of operation can be employed when selecting weapons for release.

The total cockpit designed on these principles is shown in Fig. 8. The Display Control Units provided allow the crew to selectively control the displays in either their primary or secondary modes. This facility allows data to be switched from one display to another, e.g. radar or other sensor data can be switched from one crew member to another.

It is obvious that the use of electronic displays not only releases some panel space and eases the immediate packaging problem but that the data can be presented in a form which is more readily interpretable. Because the packaging problem is eased, the remaining system controllers can be more easily identified and the remaining system tasks made simpler.

The displays together with the multi function keys enable the basic information to be modified and restructured to a format which suits the immediate requirements of a particular crew and vehicle. Preset data, advisory and warning data can be recalled virtually instantaneously or displayed automatically.

The general configuration of the avionics system needed to process and display the information is shown in Fig. 9. This shows only one of a number of architectures which are possible, the actual implementation being dependent on the level of integrity required, the type of display being used and the degree of interchangeability required.

The 'electronic' cockpit can therefore offer a potential solution to the existing packaging problem and, if the designer is cognisant of various human interface issues to be considered, the workload in the cockpit can be reduced.

The discussion and figures shown above have implied that the CRT would be used to display the various forms of information. A number of alternative display types are available. These are:

(a) Plasma Panels

The plasma panel consists of a matrix of gas cells, insulated from each other and connected to a controlling electrode. The display elements are neon orange with a peak light intensity of around 60 foot-lanberts and a contrast ratio of 20:1 with the use of suitable filters. The display construction means that the plasma panel can be manufactured as a flat, shallow, virtually transparent panel. AC plasma panels have inherent storage limitations in the display elements and consequently do not require refresh electronics but cannot provide a shades of grey capability. DC plasma panels on the other hand, do not possess memory and must be refreshed and consequently can provide a shades of grey capability.

(b) LED Arrays

The domestic use of light emitting diodes (LED) in watch and calculator displays is well known. Both alphanumeric readouts and LED matrix panels have been considered for cockpit applications. The LED display is attractive because it can be fabricated as a flat panel and as such offers a rugged, reliable display head. The LED display emitter can be manufactured to provide red, green or yellow displays with peak outputs up to 1000 fL. Suitable optical filters can provide contrast ratios of 6:1 while maintaining an output of 200 ft.L.

(c) Liquid Crystal Displays

A display device is fabricated by trapping a suitable liquid crystal between two pre-treated conductive glass plates. One electrode must be transparent while the other may be transparent or reflective; both must be shaped to provide suitable display patterns. The display is positioned such that when there is no potential applied between the electrodes, the crystal material is clear and the individual cell appears black. In the ON condition with a potential difference across the electrodes, the crystal appears white due to the scattering of incident light. This incident light may be natural or artificial.

(d) Electroluminescent Displays

An electroluminescent panel uses a suitable electroluminescent material, such as a zinc sulphide phosphor, doped with manganese and copper. Electrical contact is made to the panel via sets of electrodes on either side of the panel. Applying a voltage between the two electrodes an electric field is established thereby causing the phosphor to emit light.

Experimental a.c. panels have been fabricated, ref. 5, up to 6 x 6 in in size with 20 elements/inch which have brightnesses of up to 40 fL. With suitable contrast enhancement this display is legible in ambients up to 8,000 ft. candles.

Devices such as these all offer the capability to be used as flexible general purpose displays for the management of various cockpit tasks in a similar manner to that described above.

(e) Head up Displays

The head up display has been widely accepted for a number of years in fixed wing aircraft as a standard equipment fit capable of providing a variety of navigational and weapon aiming symbology in "head up" presentation. There may be some scope for considering developments of this technique in helicopters as a means of reducing the instrument panel area by projecting main flight symbology onto a combiner in front of the pilot.

The helmet mounted display offers an alternative method of projecting information to the pilot. With this system the display source, a miniature CRT or matrix panel is mounted on the helmet and the display projected onto a combiner in front of the eye.

From this bewildering choice of displays, the designer must select those which offer the most potential in terms of legibility, reliability, flexibility, size, weight and last but by no means least, cost.

Three main contraints will influence the choice of display; these are:

- Environmental Factors
- Engineering Factors
- Human Factors

6. ENVIRONMENTAL FACTORS

The environmental factors which will influence the design of electronic displays for use in the cockpit are:

- the ambient illumination
- vibration
- acceleration

Any cockpit display must be legible throughout the range of ambient illumination encountered. To be legible, the symbology and alphanumerics must be sufficiently brighter than the immediately surrounding background to ensure that the symbols will stand out. Factors which affect this are the incident illumination on the display, display reflectivity and symbol luminance. Typical absolute values for the ambient illumination which a helicopter pilot may experience vary from 11,000 ft. candles for direct sunlight at midday to 2,000 ft. candles for a clear sky. The illumination incident upon the display face will be further modified by the cockpit geometry, the transmittivity of the canopies and their condition.

For the helicopter with relatively high canopy incidence angles, a transmittivity of 90% will produce maximum illumination levels of 10,000 ft. candles in the cockpit although the presence of various structural items and other crew members may reduce this by 25%.

The effects of overall cockpit geometry are difficult to predict, the available literature shows a surprising lack of data on photometric measurements of instrument panels under typical operational conditions, consequently the designer, before hardening the display requirements specification should evaluate the likely illumination levels in a mock-up.

The presence of vibration in a visual display will adversely affect visual acuity. The extent of the degradation is a function of both the frequency and amplitude of the vibration. Because the actual display is a complex structure composed of various symbols, letters and numbers, the effect of vibration is dependent on the actual task being undertaken, e.g. symbol discrimination or symbol detection.

Acceleration can also have an adverse effect on visual performance, the extent of the degradation being a function of the magnitude of the 'g' force and inherent display parameters such as its luminance.

The individual with 20/20 vision is capable of resolving objects subtending one minute of arc. The degradations caused by variable illumination, vibration and acceleration will all tend to increase the minimum separable acuity figure. Currently research indicates that the designer should be considering a figure of 2.5 minutes of arc separable acuity, this corresponds to 20/8 vision.

7. ENGINEERING FACTORS

Assuming that the display can be designed to satisfy the various environmental contraints, there are a range of engineering factors which must be considered. These address the various installation aspects of size, weight, reliability, maintainability and flexibility which are attendant with any practical engineering problem.

Space precludes a full discussion of all the issues involved and accordingly only the dominant factors will be commented on.

The display head situated in the cockpit is only the 'tip of the iceberg' as far as the overall avionics system is concerned. The remainder of the system is concerned with the processing of raw sensor data, controlling the flow of information and generating the appropriate symbology. Symbol generation can, according to the display type, be a dominant factor in the complexity and cost of some display systems.

The display type chosen will also be influenced by the operational requirements, for example, the number of resolvable elements within the display will be a major factor in determining the type of display required. This can range from 500,000 for a high quality TV display down to 100 for simple analogue displays such as thermometer strips and alphanumeric read-outs, etc. The information refresh rate required will influence the cost and complexity of the system as will the grey scale and colour requirements.

The flexibility of the electronic display technique is provided not only by the display head, but by the ability to use the system to collect and sort data from a variety of information sources, and to display data in a form which can be optimised to suit the particular phase of a mission.

The 'heart' of the system is essentially some form of processor which controls the information flow between sensor and display in accordance with some predetermined programme which can be modified by crew commands.

The main functions of the display processor are:

(a) to ensure the display system is provided with the information necessary to generate the formats required.

(b) to accept modifying commands from the crew

(c) in the event of a display failure to control the system in some reversionary mode.

The display characteristics and the formats required are determined by the operational requirements. From these the characteristics of the display processor can be established.

(a) Display Type

The different display types described above require differing drive arrangements. The displays fall into three main categories:

(i) Single input displays having only one information input connection, e.g. CRTs (ignoring the power supply and deflection connections). This display can also be operated in a cursive mode or raster mode influencing the design of the processor further.

(ii) Fixed format displays, such as alphanumeric readouts, fixed message displays, where the display is controlled by connections to each set of discrete elements.

(iii) Matrix displays where each element is controlled by a series of row and column addresses.

(b) Information Update Rate

The rate at which data and symbology requires to be updated within the processor and on the display will influence both hardware and software design aspects.

(c) System Integrity

The failure survival characteristics required of the system, will dictate the number of systems aspects, both influencing hardware and software design.

8. HUMAN FACTORS

The helicopter human factors field covers a wide range of issues ranging from those design aspects which affect the crew environment, e.g. vibration, to those which consider the human operator as a component in the total system design and which influence design of the various system interfaces and which are the factors with which this paper is concerned.

The mission requirements again provide a starting point for an analysis of the equipment requirements. By performing preliminary simulation studies the rough system requirements can be identified allowing the systems engineer and the human factors engineer to make an early estimate of the required level of automation and of the likely workload which will be experienced. This allows the likely crewing requirements and division of responsibilities to be established.

The engineer must, throughout this iterative design process, be aware of two major potential problems.

Firstly, the electronic display cannot hope to offer anything over conventional instruments if it is merely used to integrate information from many conventional sources. This will not ensure that the electronic display will be any better than a conventional instrument. The variability of formats, symbols and scales can work against the designer by presenting the crew with a proliferation of non-standard data which may be difficult to interpret in a high-stress emergency condition.

Secondly, the designer must be careful not to deprive the crew of primary information through the time-shared nature of display system. It is necessary to display sufficient data such that the relationship between various parameters can be understood. Similarly, the operations which the crew require to perform should not be such as to increase workload markedly. Simulation studies will be to key to recognising the optimum path to take between these extremes.

Finally, the display and its processor offer the capability not only to replace conventional displays in such a way that legibility and interpretability can be improved but to complement and extend the processing ability of the operator. The significant question to be answered is how to best use the system processor and its inherent capability to automate many of the trivial 'housekeeping' tasks to augment the decision making ability of the observer.

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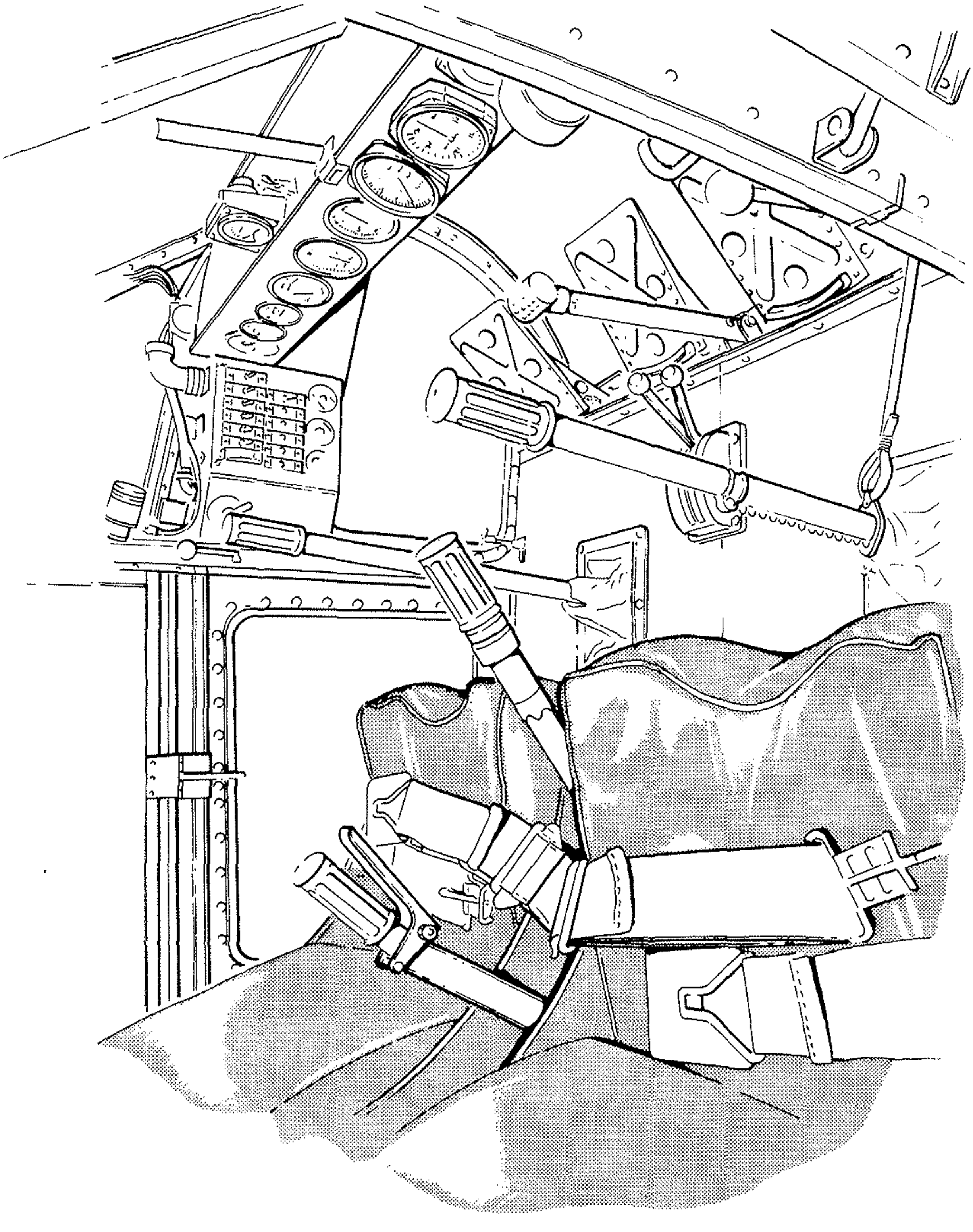


FIG.1 HOVERFLY COCKPIT

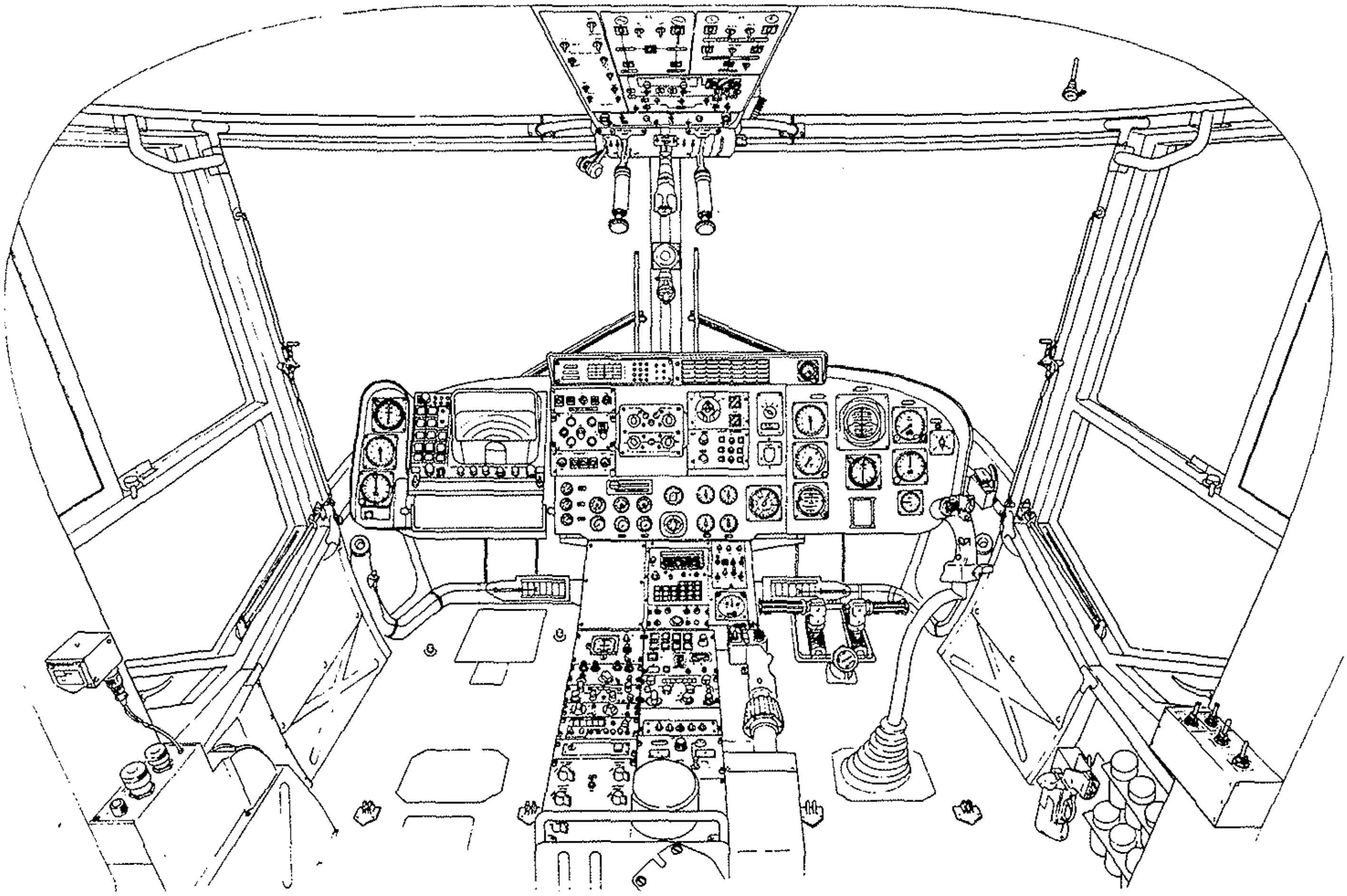


FIG.2 R.N. LYNX COCKPIT

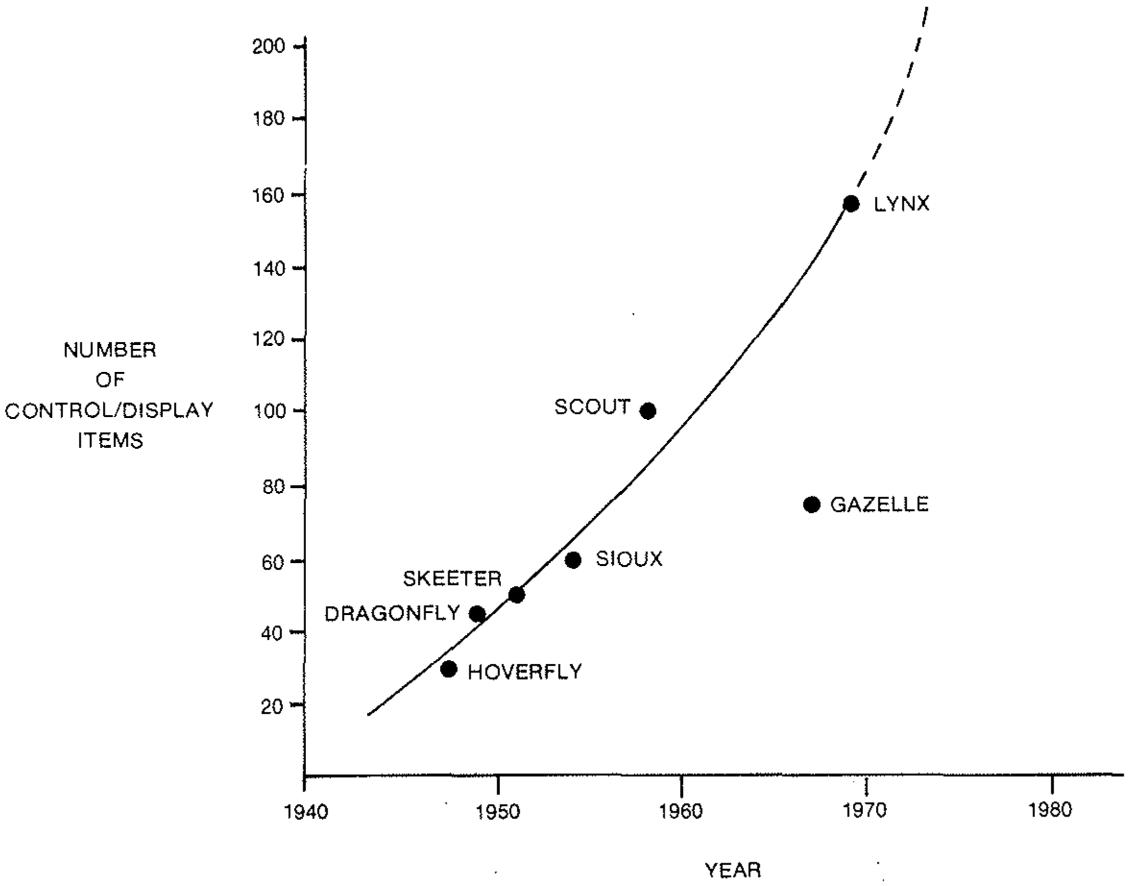


FIG.3 GROWTH OF INSTRUMENTS AND CONTROLS

Aircraft	Decreasing Utilisation			
	Flight Controls and Instruments	Navigation and Communications	Engine and Transmission	Armaments
Dragon	12%	20%	50%	
Skeeter	25%	43%	25%	
Gazelle	20%	33%	38%	5%
Scout	35%	36%	15%	8%
Lynx	30%	25%	15%	20%

TABLE 1 PERCENTAGE OF PANEL AREA OCCUPIED BY VARIOUS INSTRUMENT AND CONTROL GROUPS

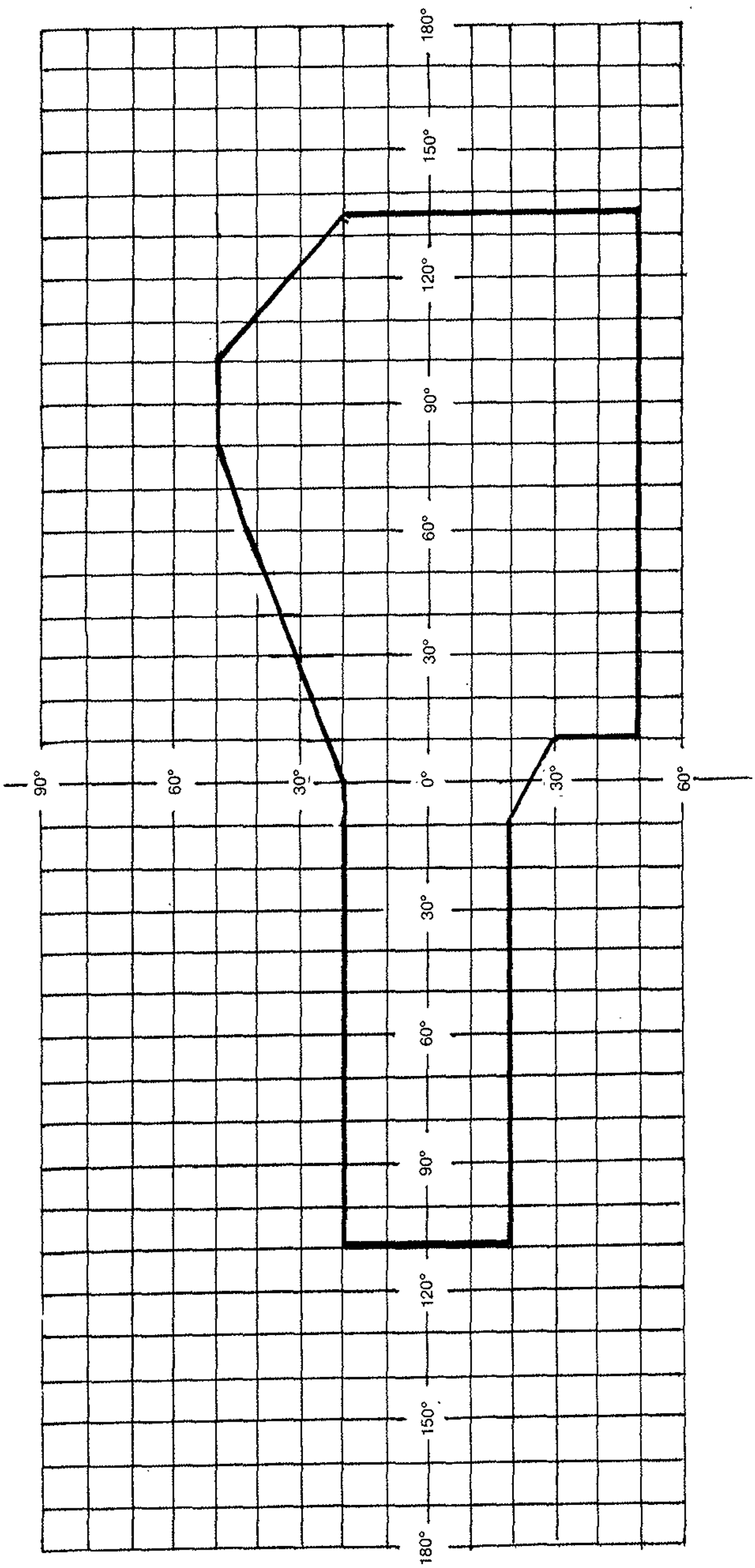


FIG.4 STANAG 3662 REQUIREMENTS FOR PILOTS VISION

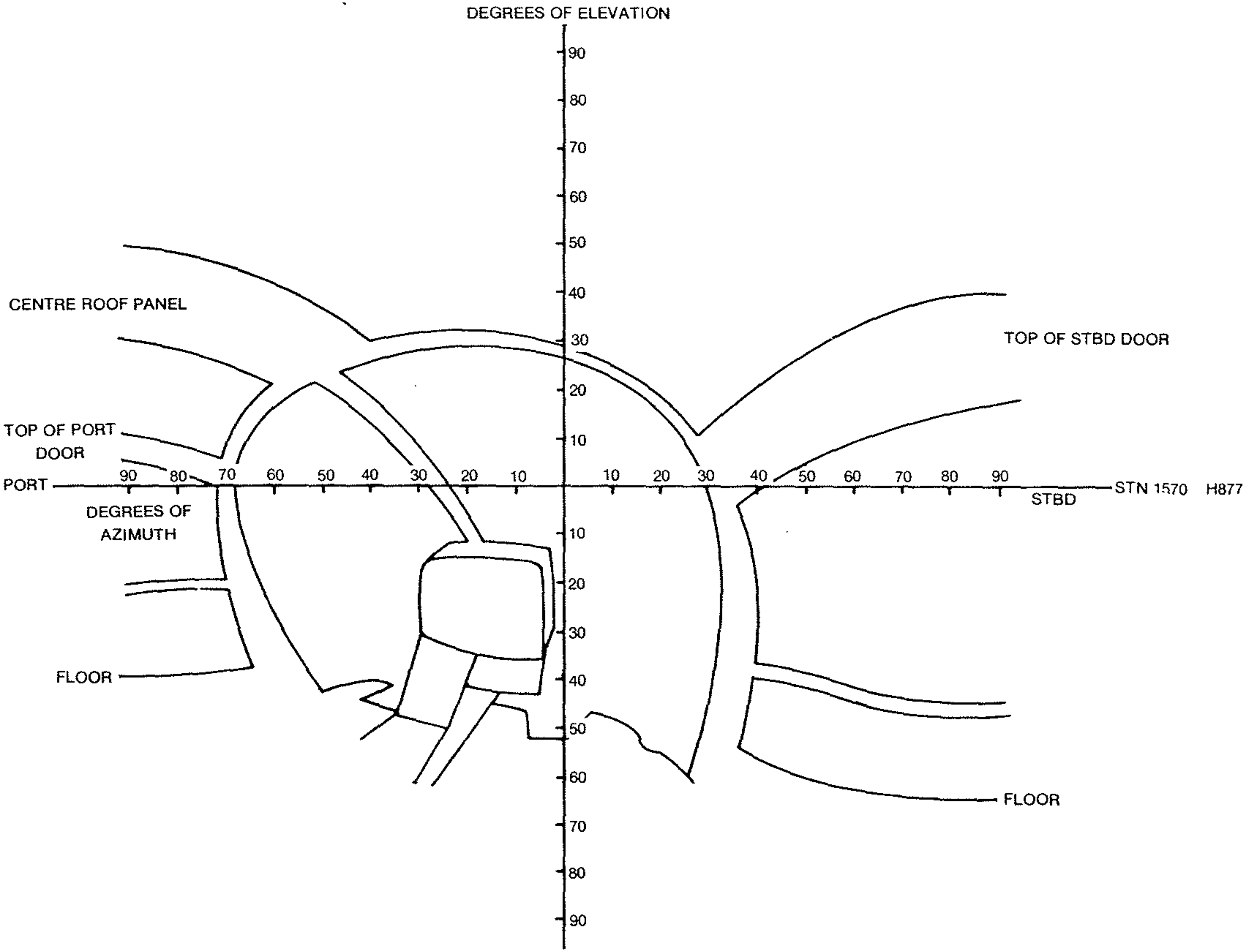


FIG.5 GAZELLE - COCKPIT PILOTS VIEW

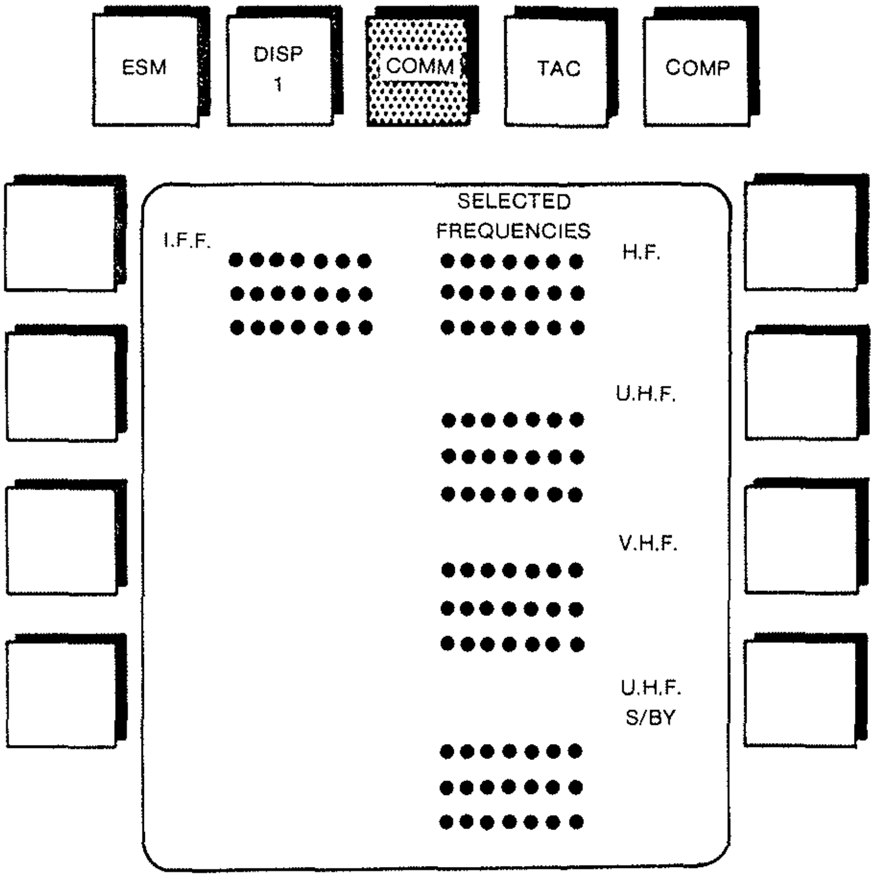


FIG.6. ELECTRONIC COMMS PANEL

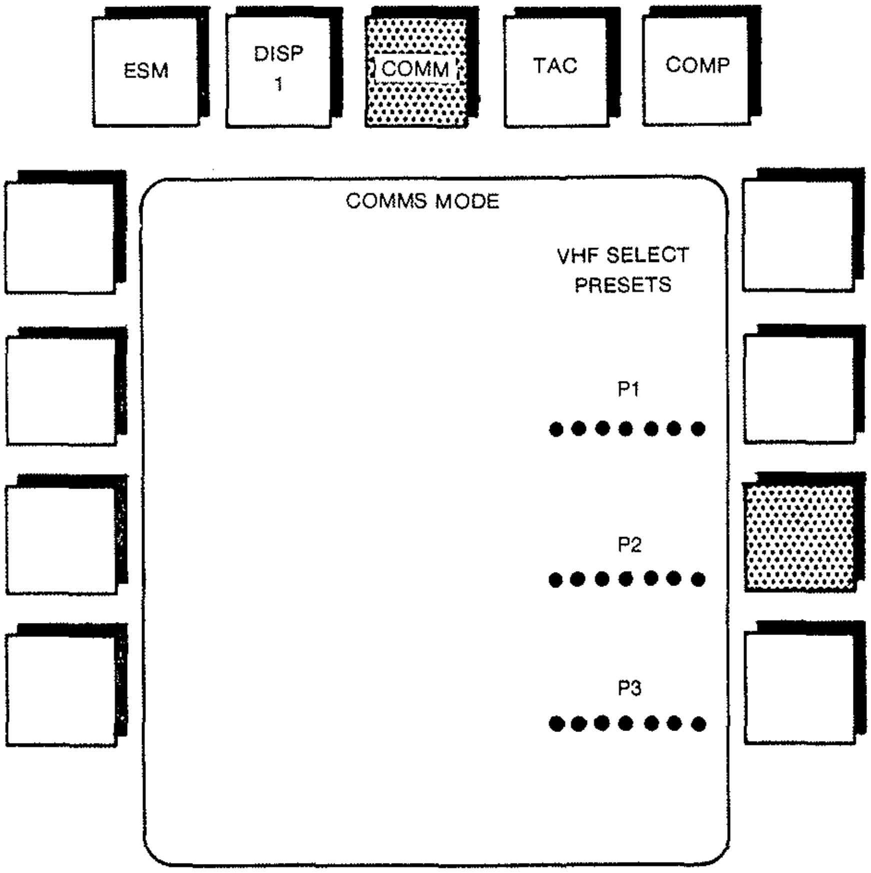


FIG.7. ELECTRONIC COMMS PANEL

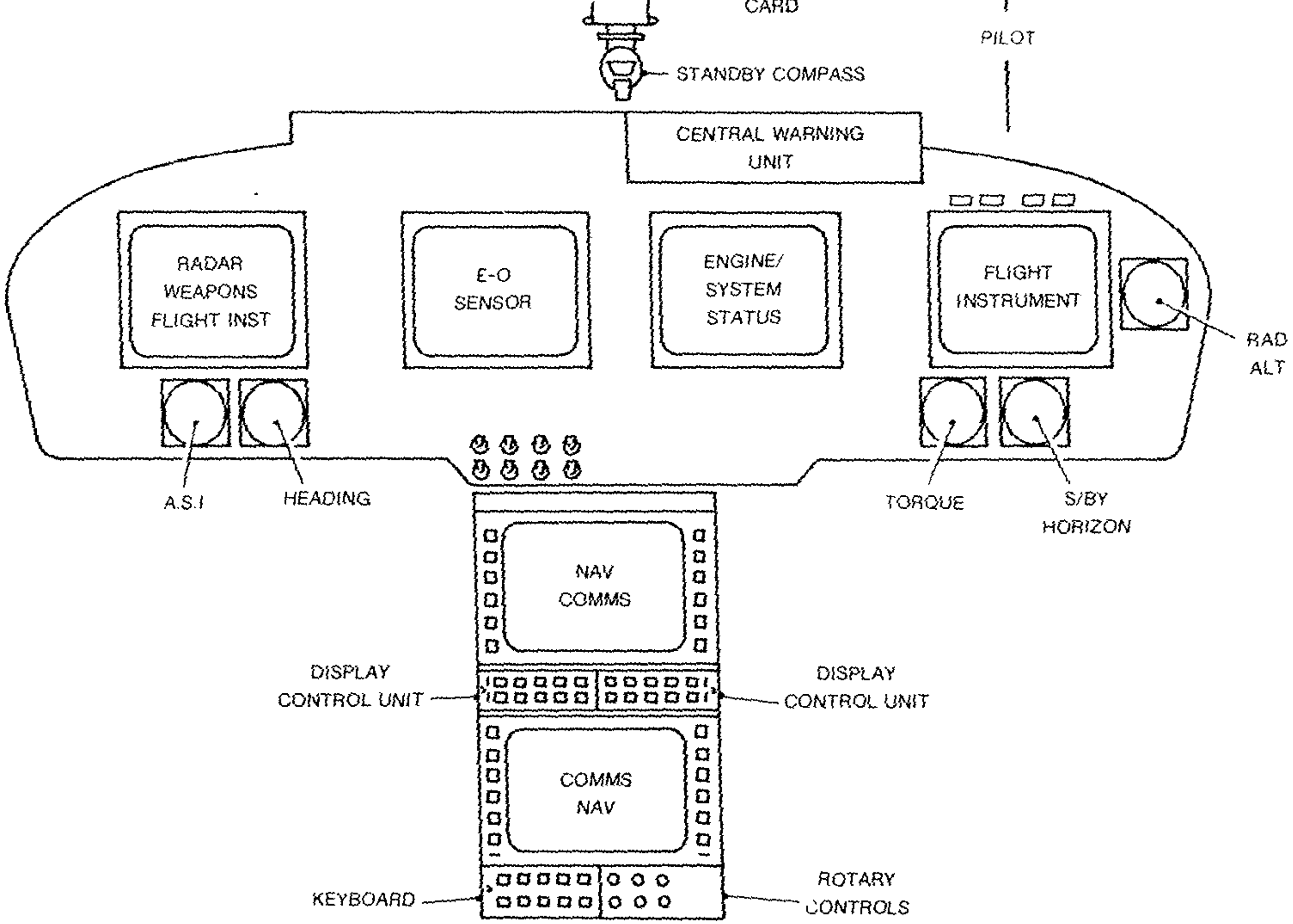
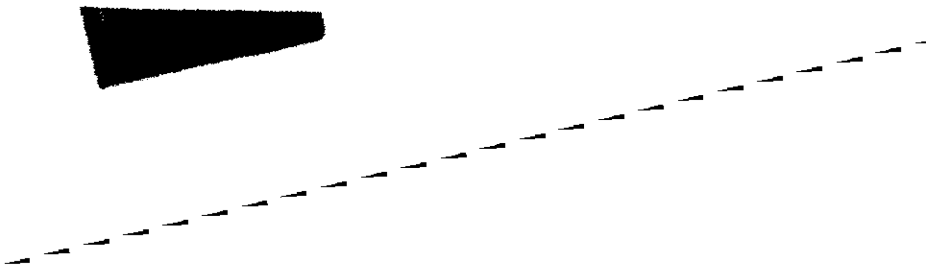


FIG.8 ELECTRONIC COCKPIT



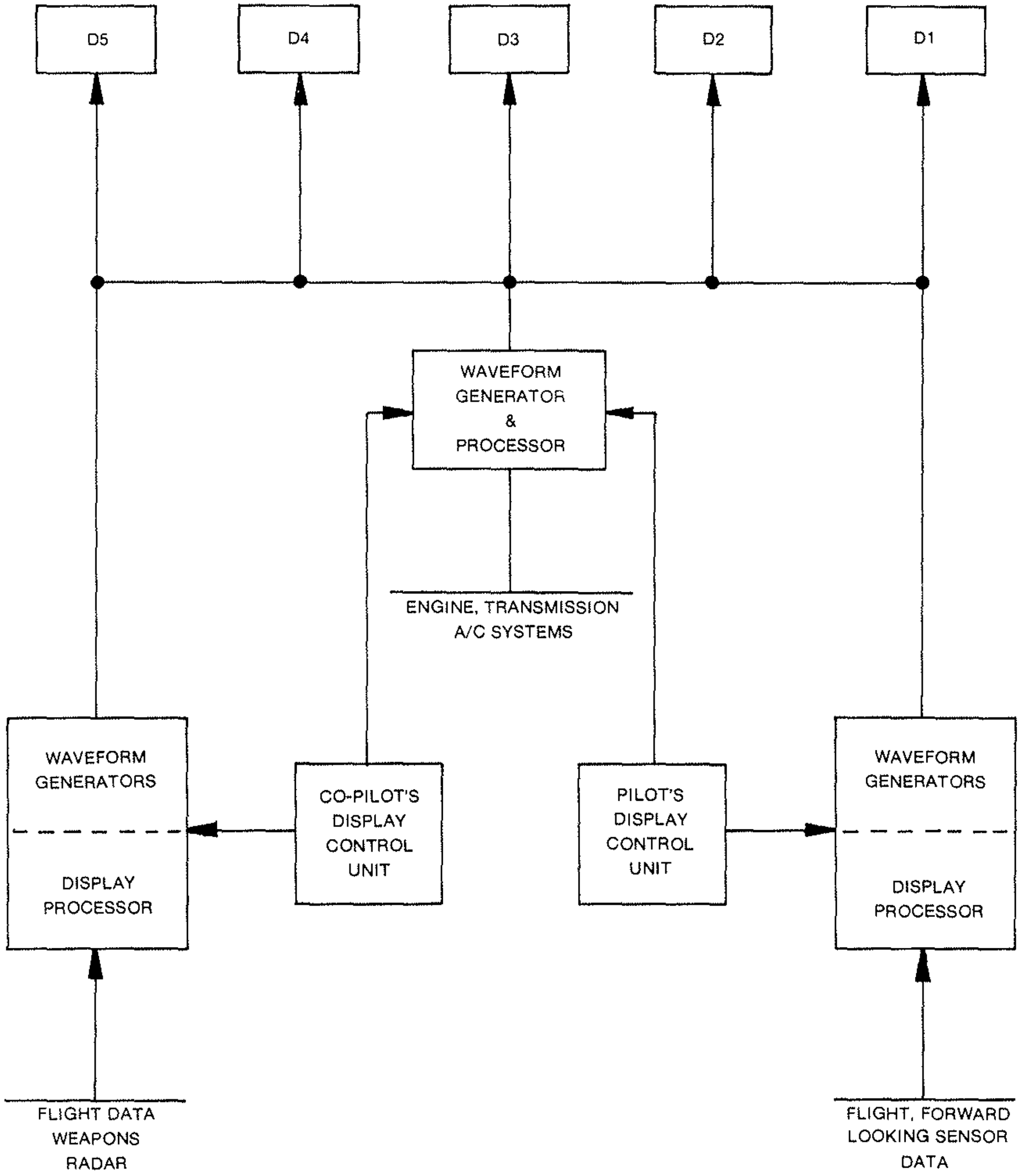


FIG.9. DISPLAY SYSTEM BLOCK DIAGRAM