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IMPACT OF SYSTEMS TECHNOLOGY
AND INTEGRATION ON HELICOPTER DESIGN

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Abstract

The improvement of new helicopter systems is related not only to new, modern design of the main components but also to application and integration of advanced systems and system concepts.

After the first and second generation of aviation systems, i.e. use of conventional CNI-systems and their connections and improvements by the use of different augmentation devices, e.g. CSAS or weather radar, in future system concepts essential changes can be observed. These changes can be derived from three factors, the chronological advance in the design of the different system components, new technologies for new systems, e.g. in the field of visionics, and at least the system architecture based on a digital bus connection.

By these means not only an improvement of existing system concepts is possible but also the application of new system-concept philosophy can be achieved. Future helicopter design is to conduct under the knowledge of these tools and due to the wide variety of possibilities with regard to mission tasks as well as reduced workload and improved security.

1. Introduction

A helicopter design depends on a variety of parameters, criteria and requirements. A new design is generated either by a direct order of a customer or due to industrial investigations in the different fields like market trend-studies, application of advanced or new technologies and/or overall efficiency improvements. A complete design includes not only the vehicle design with its main functional groups but also the integration of the systems/equipment concept (see Fig. 1). In the past a new helicopter design was conducted mainly due to the task for a new vehicle. The fact that - especially in the military field - the impact of systems gets an increasing influence in all design areas, gives an impression of the importance of systems technology and integration in the helicopter design.

2. The Systems Role in the Field of Helicopters

The complete helicopter and its integration results in the integration of the two main parts of the total system, the vehicle- and the systems/equipment-part. Figure 2 shows graphical the responsibilities and integration flow for a helicopter. Herein the vehicle integration and its functional subgroups are

- o rotor groups, i.e. main and tail rotor
- o propulsion group, i.e. transmissions, engines, fuel system, drives etc.
- o flight controls
- o airframe incl. landing gear, tail boom, fins and stabilizer and cowlings

as well as the related activities, mainly weight-, performance- and strength-calculations.

Corresponding to the systems/equipment side the following subgroups are to be considered

- o systems analysis
- o avionics
- o flight control system
- o electrical system
- o visionics
- o mission equipment, e.g. armament and ASE in the military field
- o environmental control
- o ilities.

Figure 3 schematically shows the items to be worked out in the various subgroups of the systems/equipment part. As to be seen there exist different tasks and different interface- and interaction-duties in the various subgroups.

In the first generation of system concepts predominantly self-supporting subgroups with practically no interface to each other have been designed and selected. The role of systems was limited to indicate necessary informations about flight conditions and to monitor the essential functional groups of the vehicle. Combined with new tasks, e.g. in the field of navigation and flight control precision navigation, autopiloting, hover hold, the complexity of systems and system architecture increased. Figure 4 shows the role and increase of importance of systems for helicopters. That increase can be interpreted as a reduce of deficiencies in the field of systems in parallel with the requirements for improved mission efficiency and for new mission demands.

3.0 Systems Technology

The task for systems integrated in a helicopter in principle not changed in the course of time. But due to the progress in technology the degree of sophistication, complexity and automation still changes to meet the - to some extent - divergent requirements. Figure 5 shows the interdependence between complexity and automation as well as the man-computer-cooperation [4]. Besides cost and weight aspects the degree of automation and equipment complexity has to be selected with regard to system flexibility and a certain extent of satisfying type of work.

3.1 Advance and Trends in Systems Design

Besides the progress in still introduced systems the use of new developed systems and system components enables the advance in systems design.

In the field of navigation the important characteristics are improvements in autonomous and precise navigation. Today used navigation systems are mainly of the radio navigation type. If no autonomous navigation requirement exists these systems with a high accuracy will be improved in the field of weight, EMI, controls and due to overall system integration aspects.

By means of navigation satellite systems, e.g. GPS, a precise, ground-independent system exists, its general availability will be in the late 80ies. Navigation methods exclusively using on-board equipment are called autonomous, which primary implies the use of an inertial navigation system, i.e. measurement of accelerations. An autonomous navigation can be achieved also by measuring of environmental data, e.g. velocities, reflexions, magnetics, which enables to determine the speed vector of the vehicle. The accuracy of these means is shown schematically in figure 6.

Increased requirements in accuracy and information status, especially in the military application, led to combined navigation systems. Figure 7 shows the black-diagram of an integrated navigational system. Such integrated systems have a high degree of redundancy. That improves the short-time accuracy as well as long-term stability. The difference of a conventional and an advanced navigation system package is shown in figure 8.

In the field of communication systems an essential technology step is not to be seen. Development concentrates on security methods for military applications. Advantages are to be seen in size, weight reduction and improved overall handling and integrational aspects.

The requirement to an adverse or possibly all weather capability especially in NOE-flight conditions implies the use of visual aids. The degree of visibility is influenced by rain, snow, dust, haze, fog as well as due to the degree of lightness, i.e. from a clear full-moon night to a cloudy new-moon night. For these conditions different sensors can produce an artificial visibility. Figure 9 shows some impression of the degree of visibility and transmissibility influence. As it is generally known only some discrete wave-length-ranges practically can be used for sensoring purposes.

A very suitable solution to get an improved visibility is to be seen in using night-vision goggles. Figure 10 shows the HOT night-vision goggles (HOT = Holographic One Tube) developed by Hughes Aircraft using one image intensifier tube and lense and preventing eye-damage by suddenly bright events. The next step for improved visibility includes the use of a stabilized sensor platform, where, dependent on the task, one or several sensor systems can be positioned. The arrangement of this platform on the helicopter depends on a wide variety of operational and technological criteria. One very attractive solution is shown in figure 11. Herein above the rotor of a BO 105 a mast mounted sensor platform is installed including a TV camera, a FLIR system, and laser distance and TV-tracking equipment.

For the performance of these systems, especially the increased range in visibility for the different sensor systems, the most important technology steps are done, e.g. FLIR-detector R & D, IR-image transformation techniques, IR-TV image overlay. Future trends are to be seen for improvements to meet minimization and serialization demands.

In conjunction with these platforms a display device is necessary. Here in principal three possibilities exist, a head-down display, a head-up display or a helmet-mounted display. Figure 12 shows these three types of installation.

Close to the question of type of display the cockpit instrumentation is to consider. Here the technology step and development trend enable basic new cockpit-design philosophies. To illustrate the differences of a conventional and advanced electronic instrumentation for flight control figure 13 shows on the one hand the set of conventional instruments, on the other hand a cathode-ray-tube display both supplying the same informations.

Additionally to flight information monitoring functions have to be integrated in the cockpit area. As an example an engine-condition-monitoring system is shown. Figure 14 gives in an extract engine/transmission parameter signals which have to be sensored. A schematic architecture monitoring the addressed components is also diagrammed in this figure. Similar to parameters requiring a high degree of accuracy and repeatability essential system components with a high demand for a fail-safe or redundant design are of special interest for technology improvements. An essential weight reduction and maintaining the safety features of conventional systems can be achieved for example by a hydraulic design with only one piston but dual hydraulic pressure systems and dual servo valves.

In the field of flight controls in future systems also an essential technology step can be achieved by the introduction of fly-by-wire or fibre-optics systems. Figure 15 shows a comparison of the conventional links of a mechanical flight control and a digital electronic flight control. Two or four shielded cables (depending on redundancy) can replace the mechanical equipment and - depending on the size of helicopter - save an important amount of pounds in addition to eliminating the rigging and maintenance problems with links. The technology for this type of system in helicopter application is in a strong phase of development. Several firms investigate by their own or under governmental direction and foundation fly-by-wire or fly-by-light systems, to demonstrate enhanced capabilities. The interest in the use of fibre-optics is based on the non-interference by EMI (electromagnetic interference) and EMP (electromagnetic pulses) in contrary to fly-by-wire systems. The impact of radiation seems to be tolerable.

3.2 Improvements with New System Concepts

While up to now it was outlined the advance and progress in systems technology itself in this chapter the impact of these improvements and trends on system concepts and integration will be mentioned. There are two types of systems integration to be considered

- o the overall system architecture, i.e. the analysis and lay-out of the total system interoperability
- o the more hardware oriented type of integration, e.g. the possibility of combining different functions in one display unit.

As shown in figure 3 system integration combines the basic system analysis as well as the knowledge of the actions in the different system groups. With these informations it is possible to work out a system architecture.

As to be seen in figure 16 a conventional system architecture, mainly used in today's helicopter, necessitates a big amount of cabling, cross-coupling and adaptions. Besides the weight penalty and mechanical complexity a further disadvantage exists in a poor flexibility to changes, i.e. mainly in adding of additional system components. The latest improvement could be achieved by introduction of integrated multiplex bussystems. The multiplex concept is a practical means of interconnecting digital systems in an organized and structured manner. By multiplexing the necessity of digitalizing of all data is required as well as a strong integrated approach to systems design. Communication between the components is established in a centralized manner not withstanding a distribution of control and computation throughout the system. Figure 17 shows the system architecture using a multiplex concept including the same functions compared to the schematic diagram of a conventional architecture in figure 16.

The significant advantages of multiplex are to be seen in saving weight, offering a high degree of flexibility and reducing crew workload by following characteristics (figure 18)

- o enhanced crew capabilities; the multiplex system allows an integrated approach to control and display with maximum use of human factors principles to reduce operator workload
- o high degree of flexibility; in combination with advanced communication standards an integrated systems design allows additional and/or different mission related equipment to be installed without major aircraft rewiring.
- o increased survivability; the combination of centralized communication and distributed control permits the system to automatically reconfigure and select reversionary modes of operation in case of failures or damage

- o reduced weight; by using a multiplex concept an appreciable wiring weight reduction can be achieved also a weight reduction in the area of instrumentations
- o redundancy; in the basic concept a high degree of redundancy can be achieved by a dual design and with revisionary operation
- o expected improvements in maintenance, reliability.

Applying a multiplex system requires for an effective operation the use of CDUs (Control and Display Unit). The CDU combines a number of functions for which normally a number of different control units have to be used. The CDUs enable the crew to effectively interact with the system and it is the essential tool for the pilot's mode selection, data entry and data display transactions in the multiplex system. In figure 19 a representative control and display unit is shown, already available as hardware. The keys at the rim of the display part allow the crew to select more detailed information of the subject presented already on the screen.

A further example for highly integrated functions is the multifunction display (MFD). It is used for flight guidance and system management. Besides a careful symbology design for the display the MFD is also usable to present TV or FLIR video with or without overlaid symbology. Figure 20 shows a typical CRT multifunction display. The same display may also be projected into a helmet mounted sight and display, thus permitting the pilot to fly the helicopter without looking at his panels.

4. Impact of New Systems Concepts on Helicopter Design

As brought up in the above chapters a remarkable technology step mainly due to micro-electronic technology is to be seen. The consideration and integration of these new tools into a new helicopter design not only depends thereon but also partly on contrary requirements and criteria. Figure 21 schematically shows the selection process for an idealized coordinated design. Besides the technology/development cycle, i.e. the time-shift between ideas and transformation into a demonstrated technology, the application of new systems technology and concepts is limited mainly to cost and time frame requirements.

The impact of new systems and system concepts on helicopter design is obvious for the possibilities of cockpit layout. Figure 22 shows the improved cockpit layout and crew control/display that is made possible by processing all the aircraft and systems sensor information through a digital electronic interface. In comparison a today's cockpit design is shown with its typical variety of instruments - mostly working independent - and resulting the large panel.

The future of "electronic" cockpit will reduce crew's workload and improve the above mentioned features, overall system safety and reliability. As pointed out this can be done only if all related and associated systems are properly designed and coordinated to be compatible.

In addition to the mentioned system improvements advantages exist in the increased freedom of cockpit design, i.e. layout strongly related to human factors and overall vehicle aspects.

Another impact, i.e. improvement, in helicopter design was shown in figure 15 by the use of fly-by-wire of fibre optics. Here especially the interior design is related, i.e. the freedom in cockpit, passenger and cargo compartment design.

Beside the before mentioned advantages the use of a multiplex system gives the desired flexibility of systems integration regarding the helicopter design, i.e.

- o effective location of the different remoted terminal units (RTU)
- o the flexibility in systems change for different missions.

In an example figure 23 outlines the possible location of these units.

5. Conclusion

In this general lecture the advance and trends in systems technology is discussed in a short manner. In the main one can say that in the field of systems and thus system concepts a remarkable process in systems technology, applicable to helicopter design, is to be seen. The essential basis for this development is given by the progress of micro-electronics. This does not influence only the classical CNI-area but also enables the use in further areas of helicopter design, e.g. fly-by-wire or fibre optics systems in a replacement for the classical mechanical linkage or furtheron in a higher harmonic control concept.

Beside these here mentioned system-specific aspects the overall helicopter design also depends on the vehicle design as well as the cost and time frame situation. The interdependence of all these aspects, of operational performance, existing and advanced technologies and cost/time frame impacts a balanced design and thus has to be considered very carefully.

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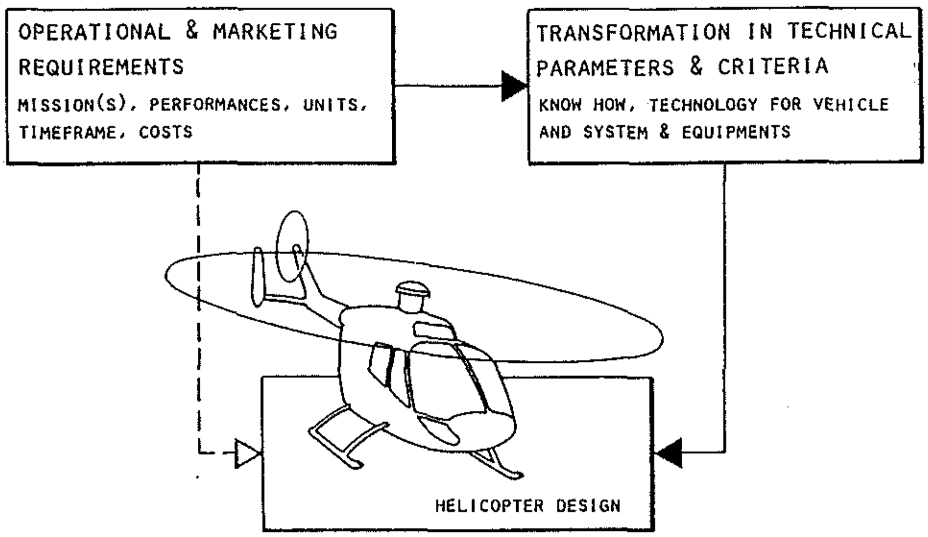

Fig. 1: Impacts on overall helicopter design

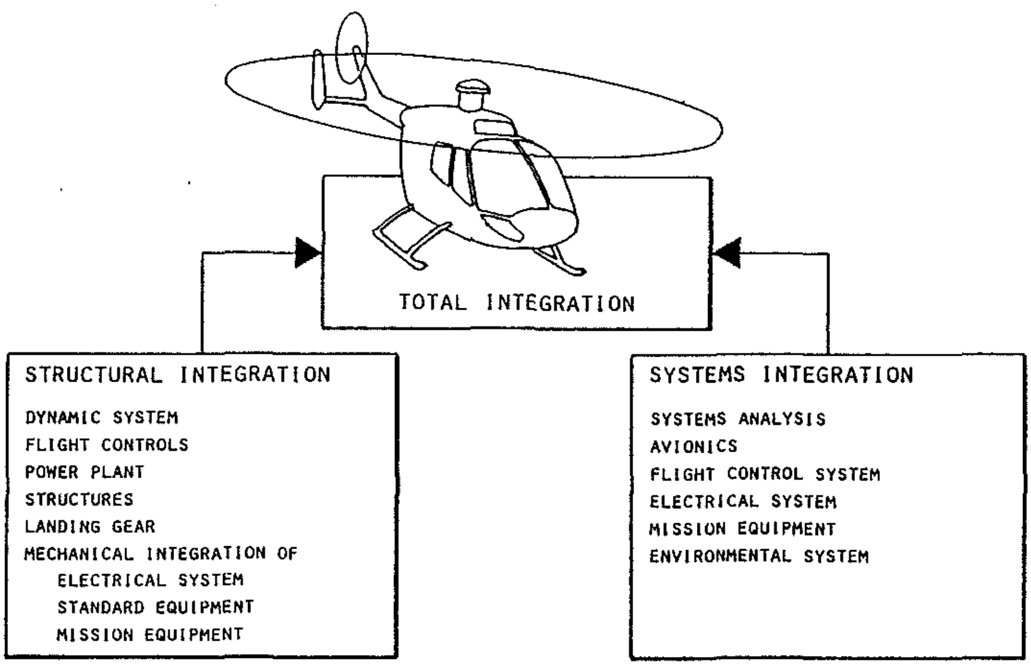

Fig. 2: Integration flow

SYSTEMS INTEGRATION

SYSTEMS ANALYSIS	FLIGHT CONTROL SYSTEM	AVIONICS	ELECTRICAL SYSTEM	MISSION EQUIPMENT	ENVIRONMENTAL SYSTEM
SYSTEMS ARCHITECTURE DISPLAY SYSTEM FLIGHT MANAGEMENT MONITORING AND DIAGNOSTIC FLIGHT TEST SYSTEM EMI SIMULATION HUMAN ENGINEERING RELIABILITY AVAILABILITY MAINTAINABILITY VULNERABILITY	MECHANICAL/HYDRAULIC CONTROLS COMMAND, STABILITY AUGMENTATION SYSTEM AUTOPILOT	NAVIGATION COMMUNICATION DISPLAYS AIR DATA SYSTEM ANTENNAS	DC/AC POWER SUPPLY DISTRIBUTION SYSTEM WIRE HARNESS OPTIONAL SYSTEM (DEICING)	VISIONICS ARMAMENT SYSTEM ASE	HEATING/COOLING VENTILATION DEICING ABC-PROTECTION

Fig. 3: Systems integration subgroups

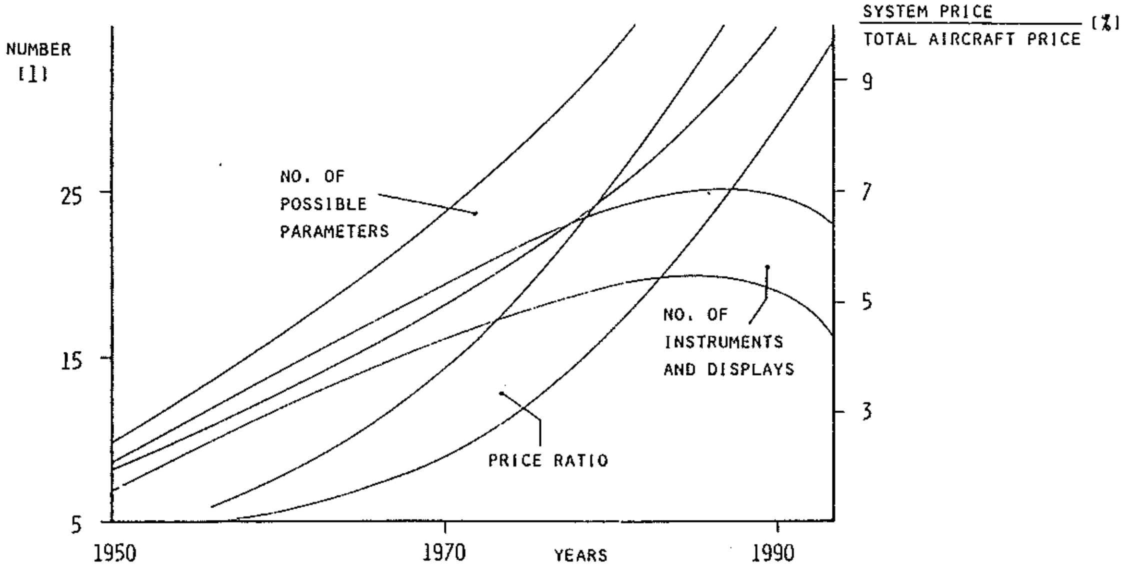

Fig. 4: Role of systems for helicopters

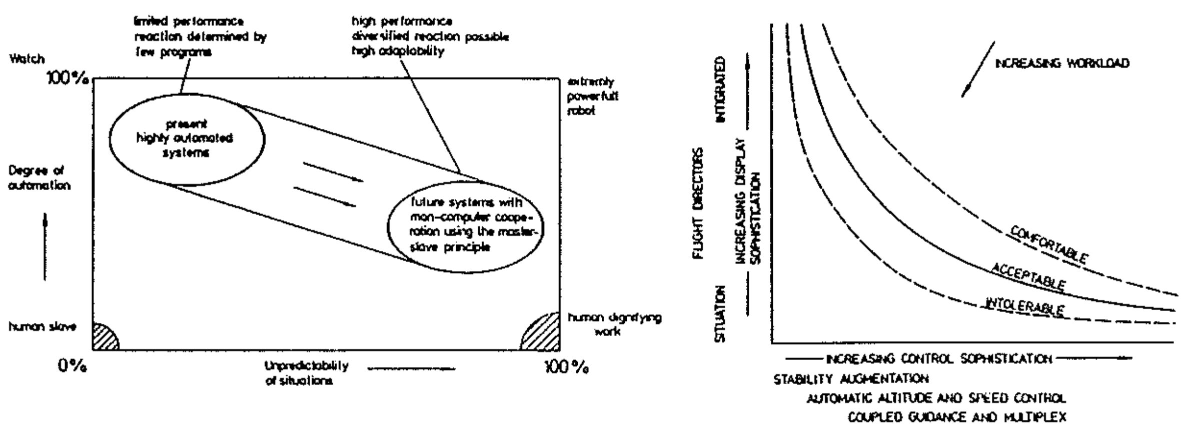

Fig. 5: Interdependence between complexity and automation

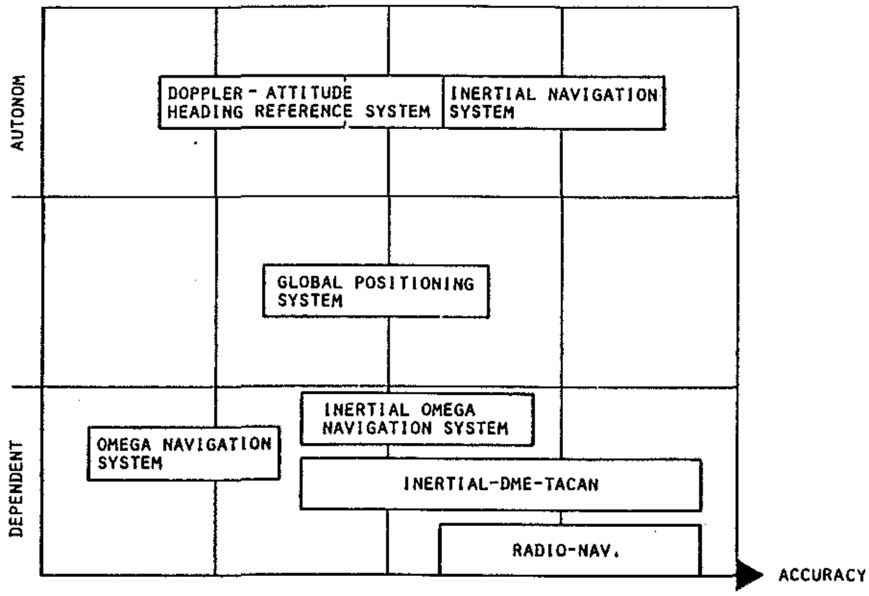

Fig. 6: Characteristic of navigation systems

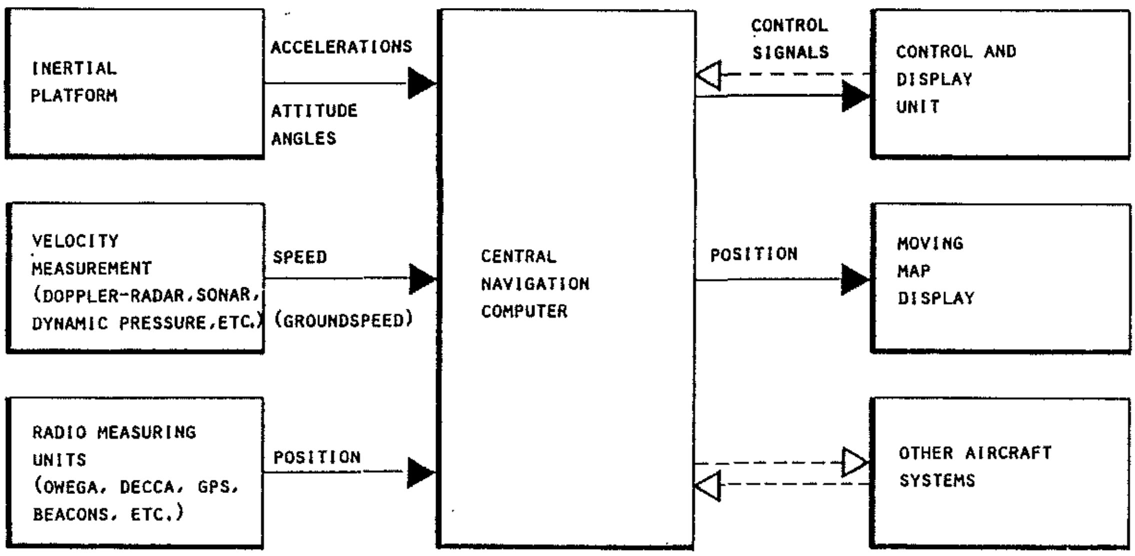

Fig. 7: Integrated navigation system diagram

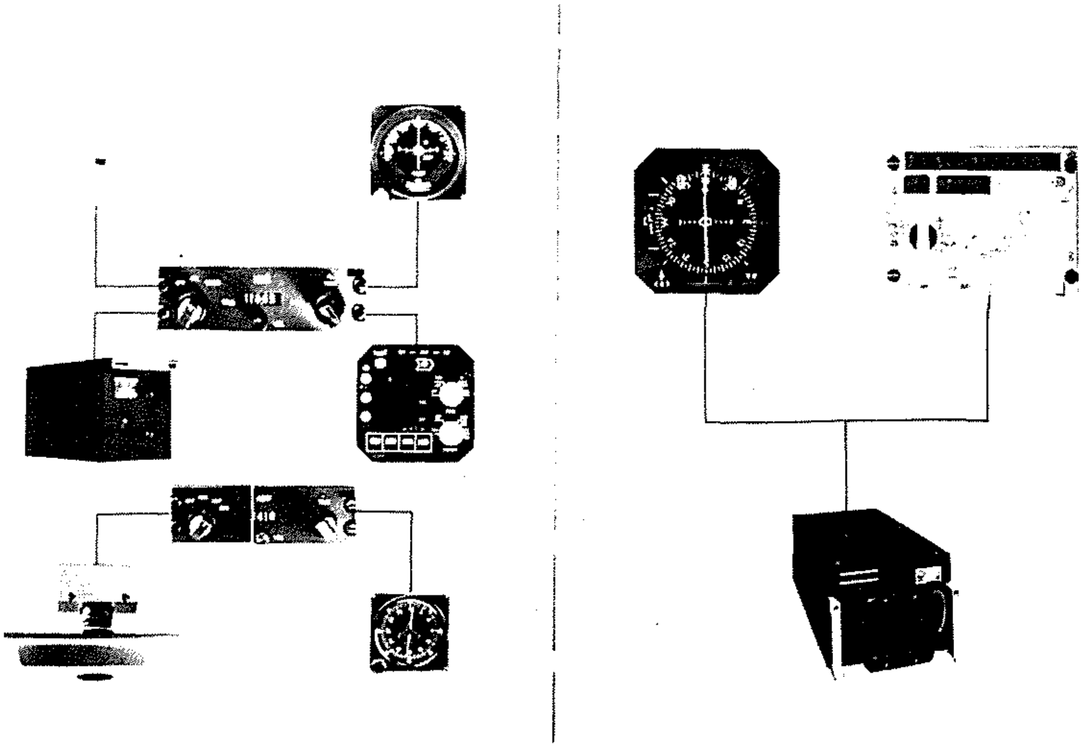

Fig. 8: Comparison conventional - advanced navigation system

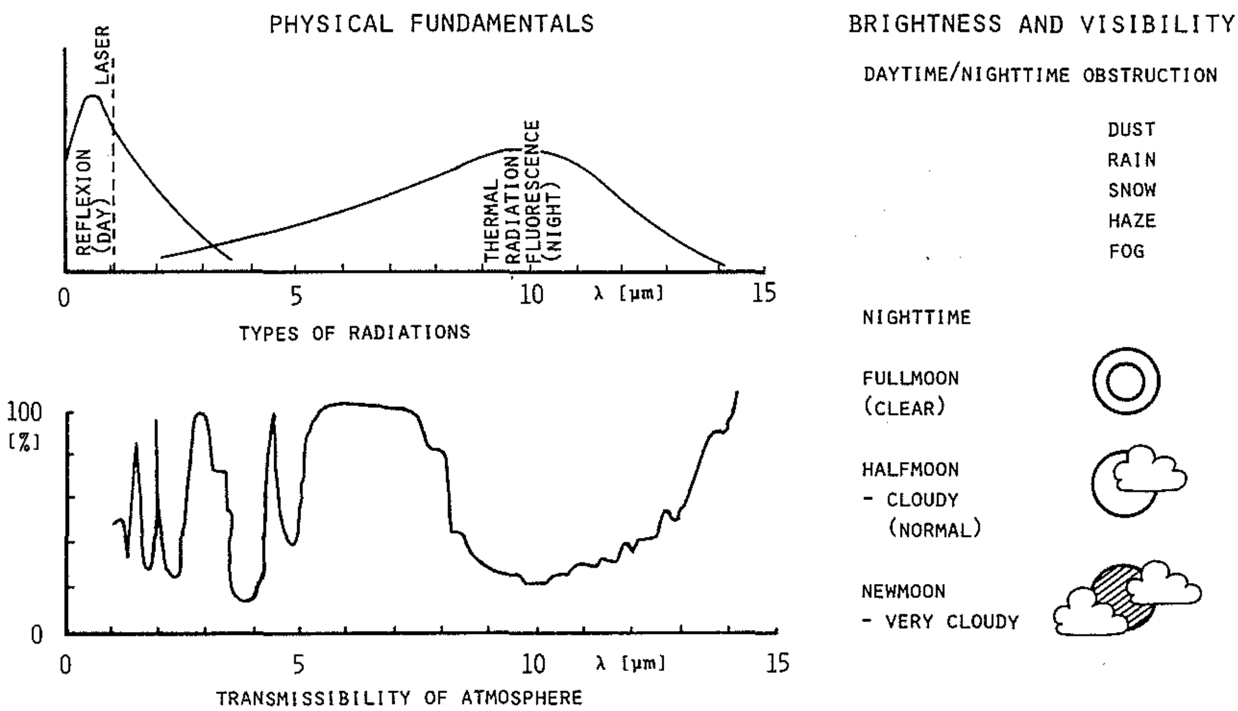

Fig. 9: Visibility and transmissibility

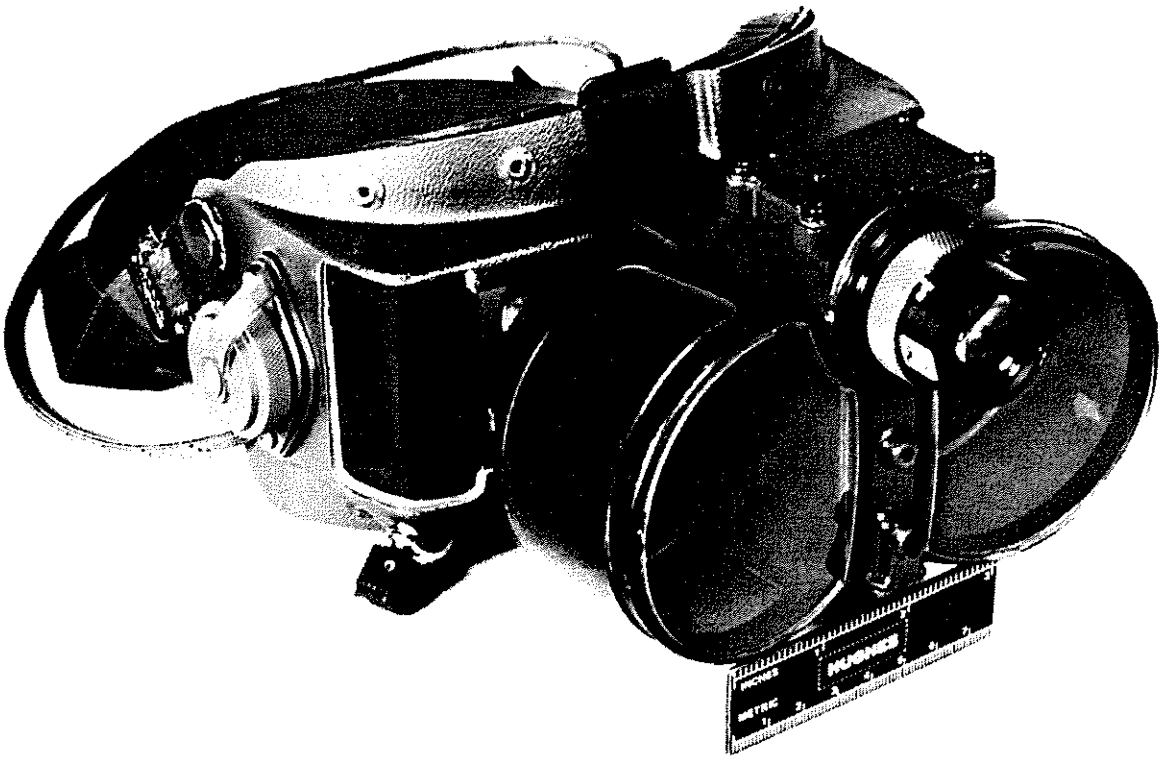

Fig. 10: HOT night-vision-goggles

Fig. 11: Mast-mounted-sight

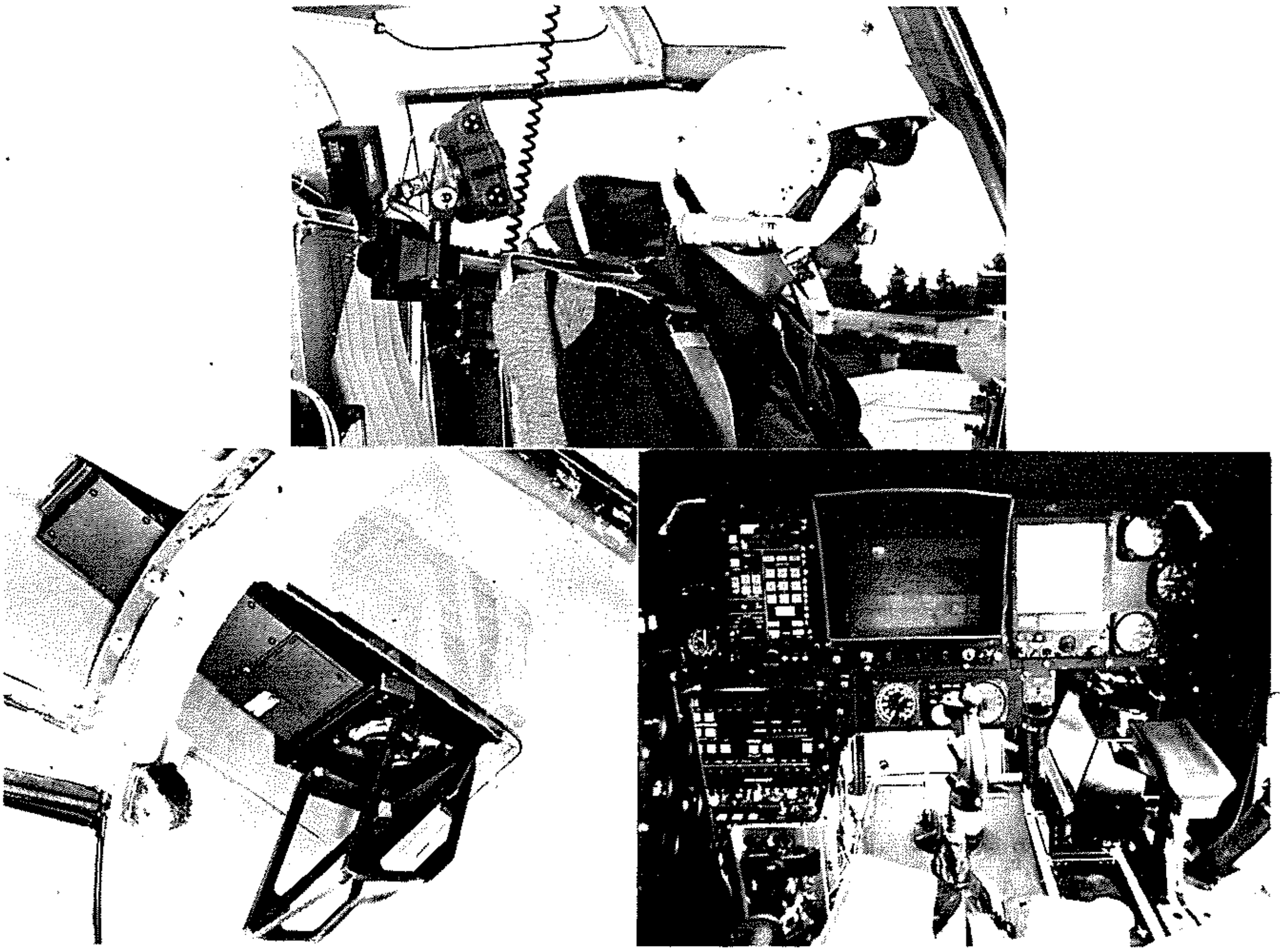

Fig. 12: Display types

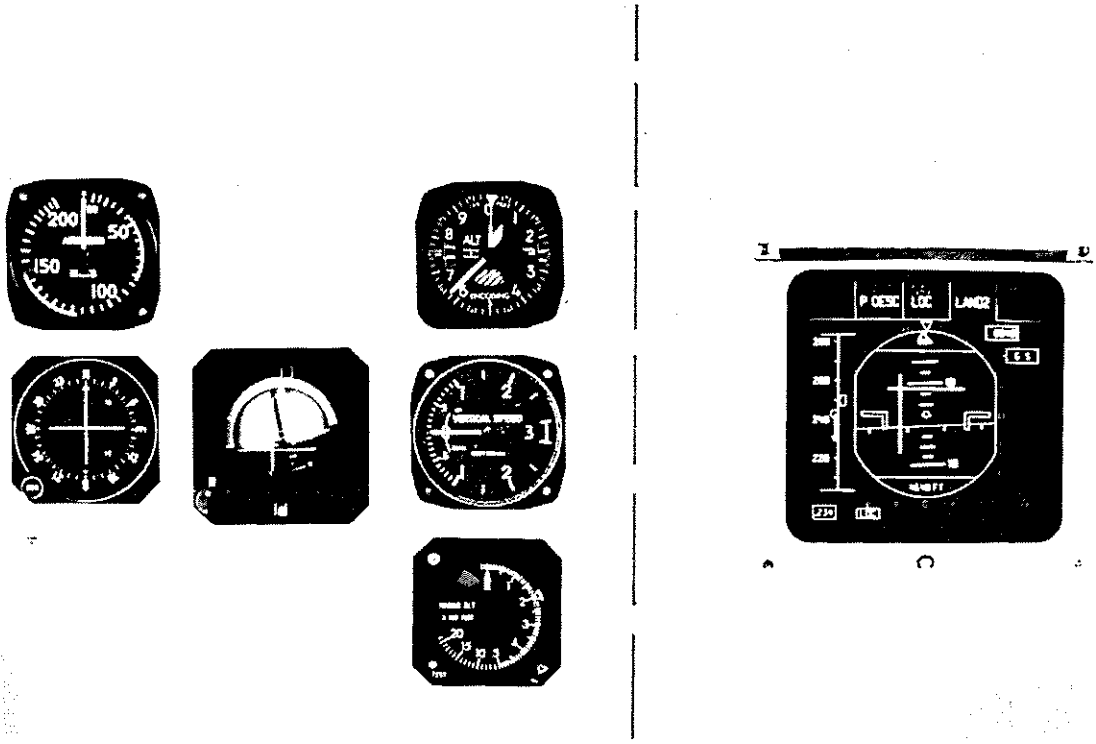

Fig. 13: Comparison conventional instruments - electronic display

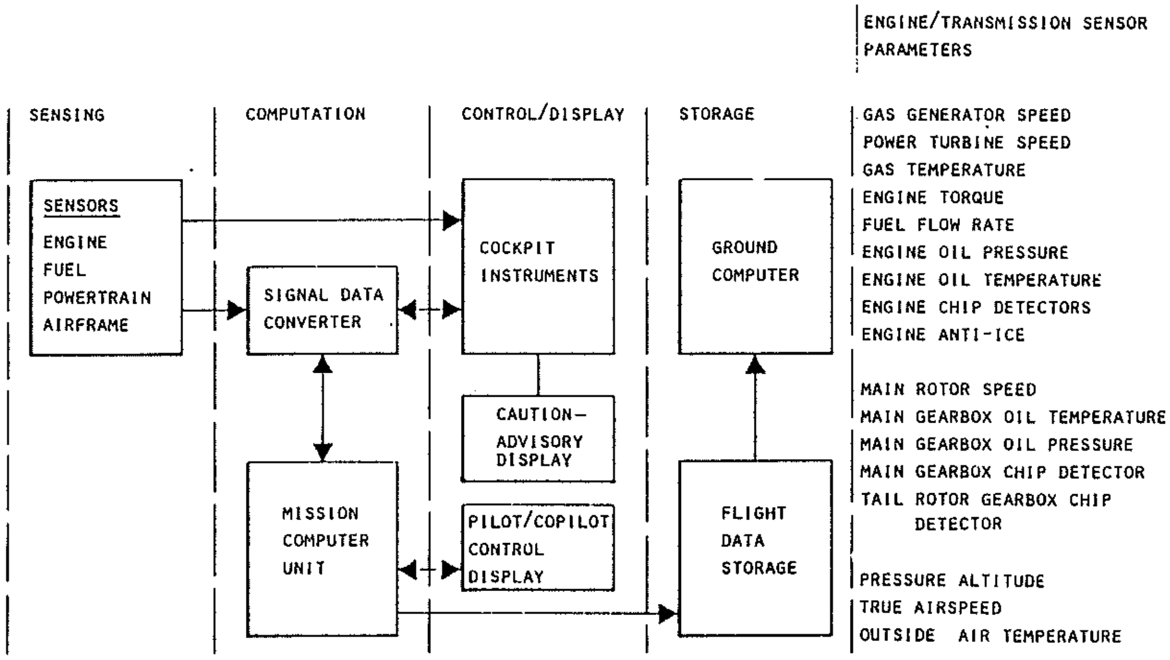

Fig. 14: Monitoring flow diagram

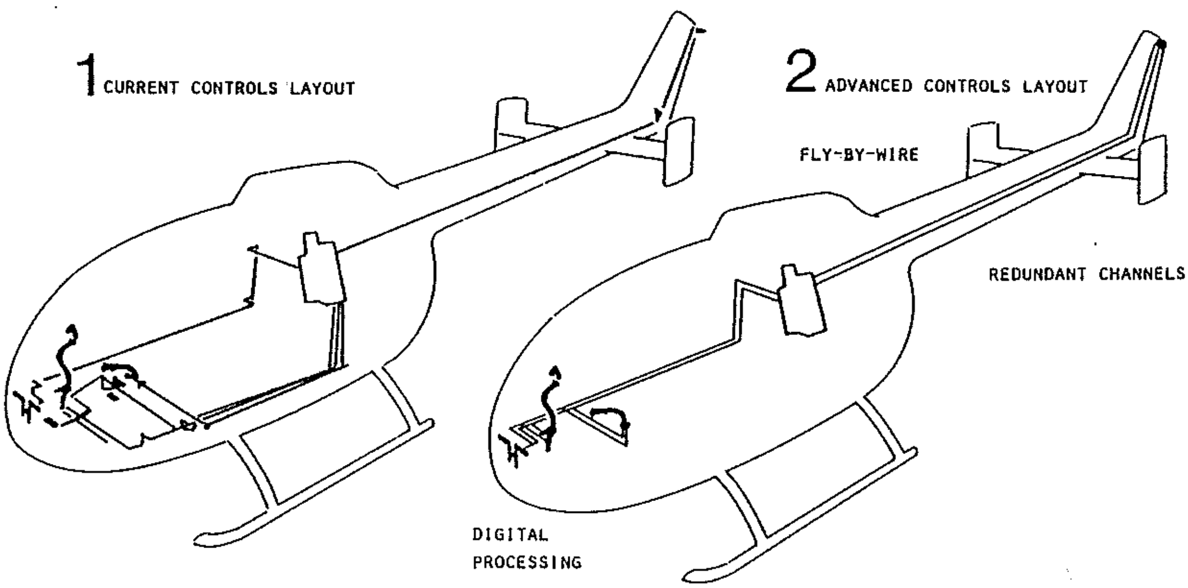

Fig. 15: Comparison mechanical - electronic flight controls

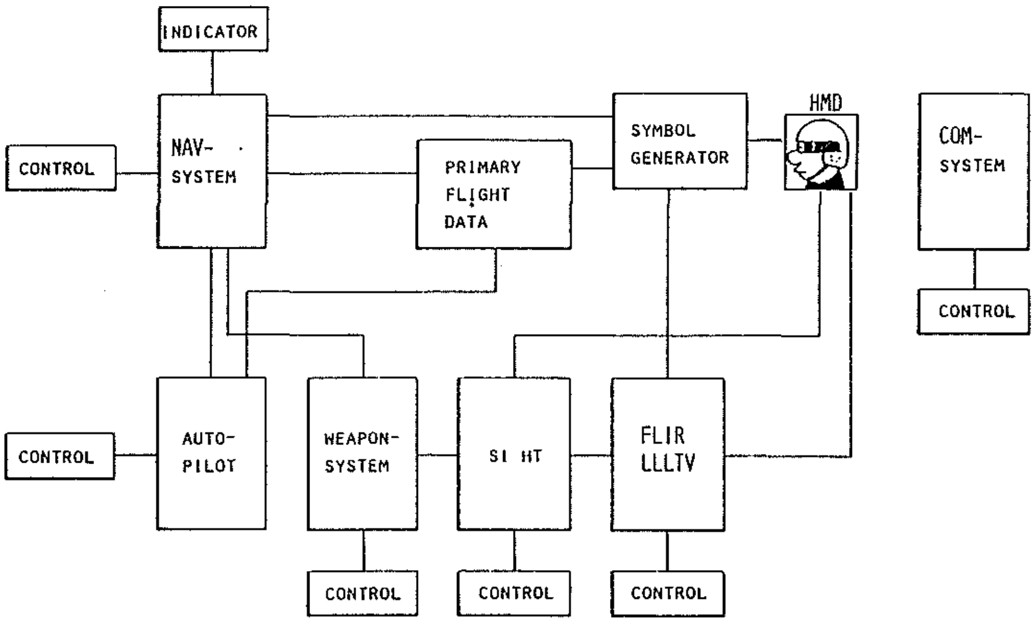

Fig. 16: Conventional system architecture

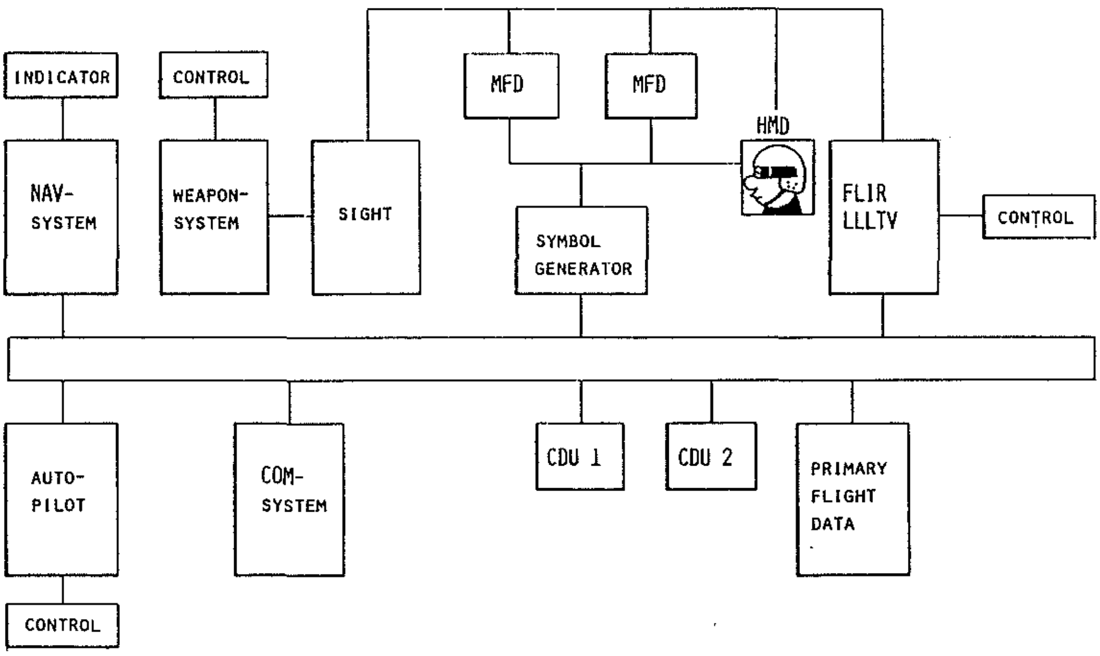

Fig. 17: Multiplex bus system architecture

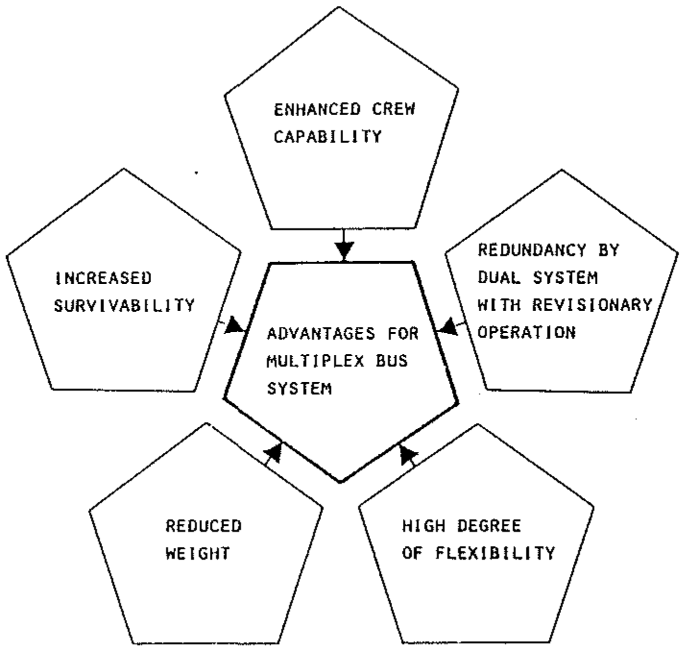

Fig. 18: Characteristics of bus system

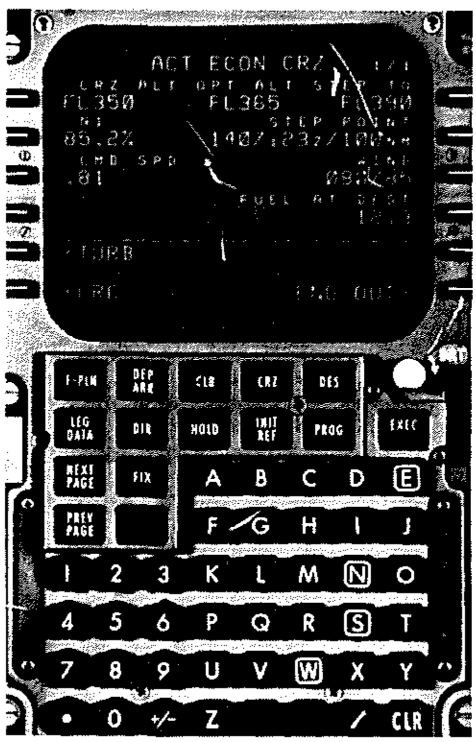

Fig. 19: Control and display unit

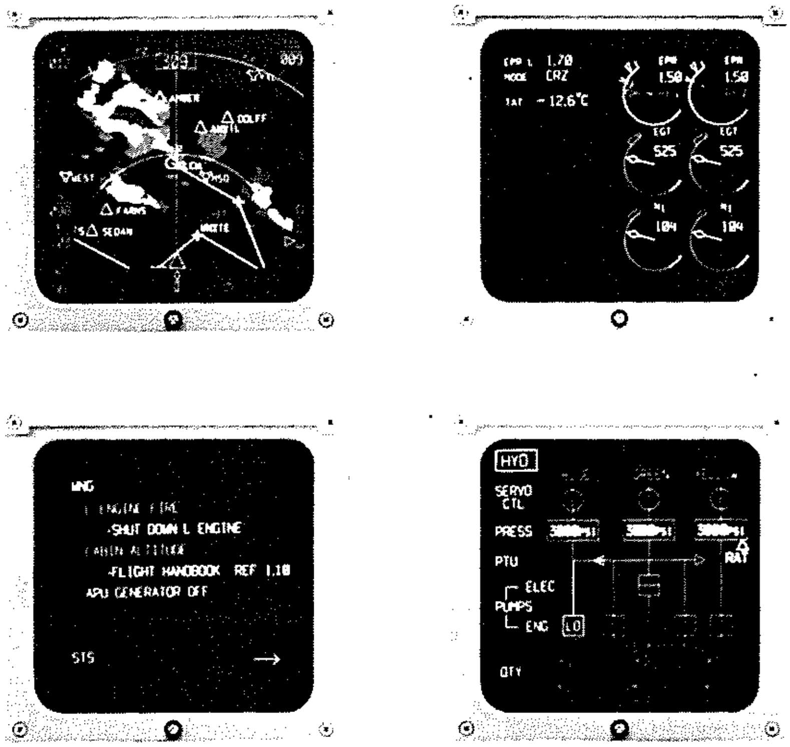

Fig. 20: Multifunction displays

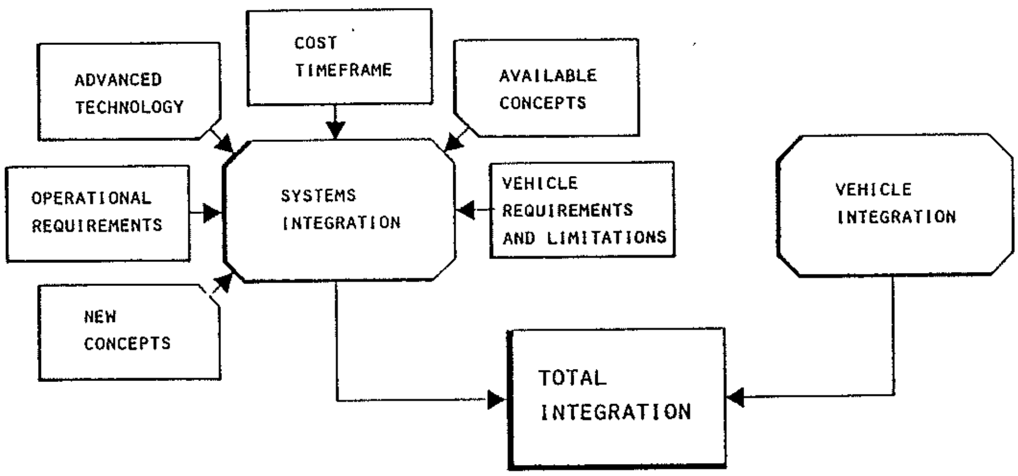

Fig. 21: Design selection process

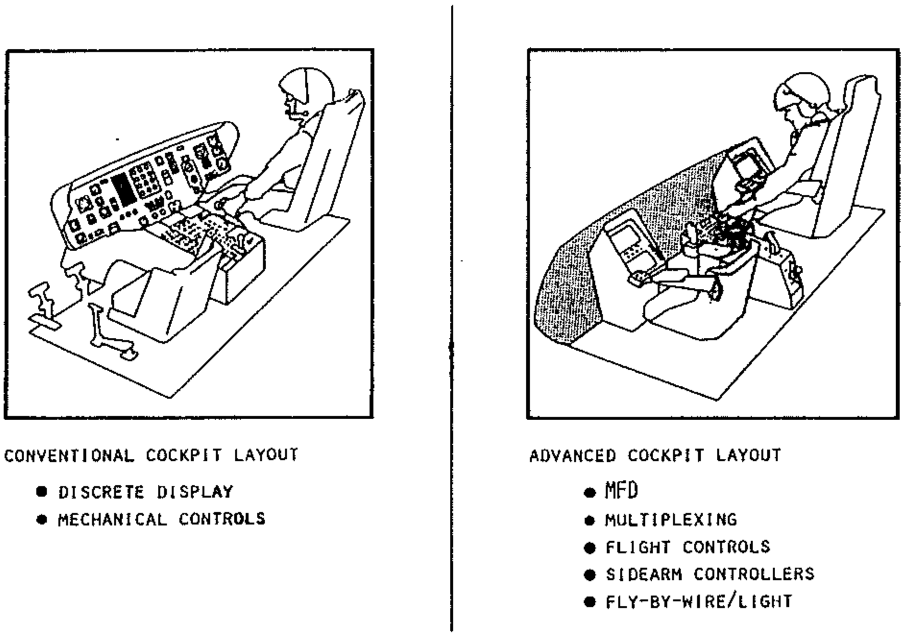

Fig. 22: Todays and future cockpit layout

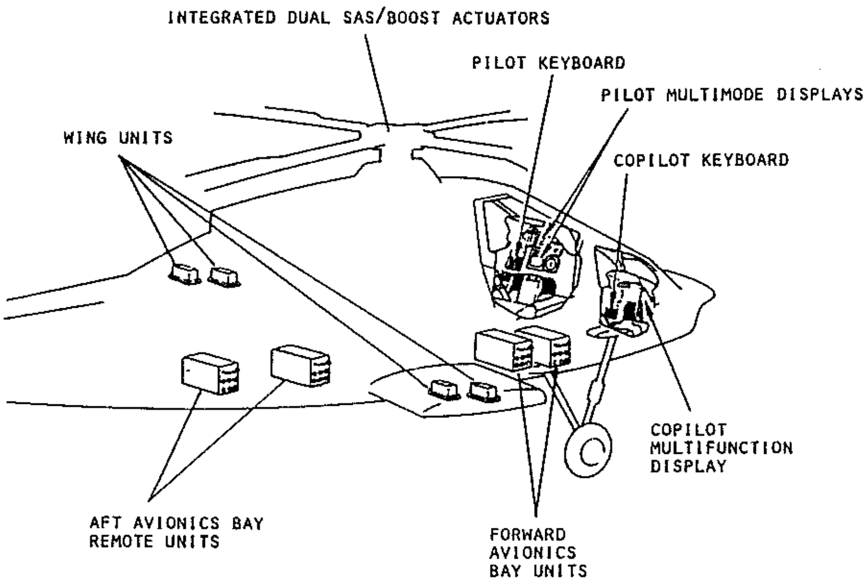

Fig. 23: Remoted terminal units installation