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THE DIGITAL CORE AVIONICS SYSTEM

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ABSTRACT

This paper describes an avionics systems configuration which is applicable to future helicopters. The intention is to use digital technology to create a set of 'standard' building blocks which can be adapted to suit evolving customer requirements.

The benefits which can be obtained by such standardisation are significant. Design, development and production costs can be reduced. Even more significantly, due to the enhanced reliability and maintainability features designed into the system, operating and support costs will also be reduced. The technology used is a two edged sword however, caution must be exercised to ensure that in an attempt to achieve extreme hardware economies, the system does not become complex and inflexible. Fundamental issues such as airworthiness, procurement and management strategies all must be considered prior to the adoption of such an approach. This paper does not attempt to address all these issues. An approach is outlined which, realising considerable economic benefits, recognises a number of unresolved problems still exist which can only be answered by considerable test and development.

1.0 THE HELICOPTER REQUIREMENT

The helicopter places a number of special requirements and constraints on the avionic systems which are required to operate the vehicle and satisfy mission needs. Perhaps the most obvious is that the helicopter is multi-role and multi-variant - traditionally a general purpose 'work horse' has been adapted to suit a variety of roles and applications by equipping the vehicle with a wide range of electrical and avionic systems. The process of customising small batches of vehicles for specialised applications can be major cost element in the design, development and production costs particularly where the commonality between wiring and equipment is low.

In the service environment, the helicopter is normally called upon to operate from very austere sites such as small ships, or battle areas, where support and maintenance facilities are limited. The support and maintenance burden imposed by the crew complex avionic systems fitted to helicopters is a factor causing concern among the user community.

Finally all customers wish to modify and adapt the vehicle at some stage in its life. The avionic system must be designed to accommodate such growth throughout its useful life.

2.0 THE EVOLUTION OF DIGITAL TECHNOLOGY

Today, digital techniques, based on microprocessor technology, are appearing in many applications where computers have never before been used. This offers a tremendous computational power which, if organised in a different manner could realise substantial benefits for both manufacturer and user.

Firstly a reduction of total hardware by using processors to perform more than one function and by using controls and displays in a time shared mode to reduce the proliferation of separate switches, controls and displays. Most approaches to harness this processing power have fallen substantially short of their potential for a number of reasons. Firstly the tradition of separate subsystems, each covered in some manner for the eventuality of a malfunction prevents full use being made of the available processing power, results in incomplete fault coverage and limited utilisation of the available information.

There are reasons why this has been until recently the only viable approach however, stemming principally from a desire to eliminate large scale common mode failures, to limit the damage caused by a failure propogating through the system.

It is possible, using currently available hardware and software techniques to devise system configurations which can overcome many traditional problems and satisfy the basic helicopter requirements.

3.0 DIGITAL CORE CONCEPT

The underlying philosohhy behind the 'core' avionics concept is the creation of a basic system which would be common to a fleet of helicopters and variants and which can be economically adapted to meet differing mission or role requirements. The core system is a distributed system architecture using microprocessors in the interface units for general purpose computing and a standard multiplex data bus to interconnect core system components.

The purpose of the core system is to perform the processing, control and display of the functions associated with basic vehicle operations. The identification of these functions, their interrelationship to the mission and role dependent functions is of prime importance as this determines the amount of flexibility required from the system.

To identify these functions a formal analysis technique based on Softech S.A.D.T. (Structured Analysis and Design Technique) has been utilised at Westland. SADT provides techniques and methods for analysing complex systems in a functional sense, that is "what" the system is supposed to do rather than "how" the system performs the functions.

The results of the functional analysis describe the system totally in terms of data used and generated and the activities which the system is required to perform. This information can then be cross checked and sequenced to provide a model of the system's functional behaviour, which forms a basis of the system's functional specification.

The major system functions which form the basis of the core system are:-

- Flight control
- Navigation
- Communications
- Engine and Transmission control and display
- Lighting and Environmental control
- System maintenance monitor.

The analysis process is intended to identify those functions which are identical in all aircraft variants and those which are customer or variant dependent. This is necessary to establish the overall system size, the 'fixed' functions and the variable functions. Flexibility will be required to permit changes to be made without extensive redesign and rework.

The factors which influence each of the system functions are discussed briefly below.

3.1 FLIGHT CONTROL

The flight control functions include autopilot, autostabiliser, hydraulic power control, flight instrumentation interface. Because of the extremely demanding integrity requirements, with the exception of certain autopilot modes, the majority of these are physically separate from the core processing system. This is not seen as a severe penalty as the basic control laws tend to be fixed and therefore design flexibility is not of prime importance. Autopilot modes can however be role specific and the core system is intended to provide flexibility in this area.

3.2 NAVIGATION

Aside from a very basic navigation fit, this sub-system changes markedly from role to role and significant design flexibility is necessary.

The basic functions contained in the core system are:-

- Computation and display of present position in LAT/LONG or grid coordinates
- Storage and display of waypoints in LAT/LONG or grid
- Range and bearing from present position to any waypoint
- Track and ground speed of any waypoint
- Heading and Time to intercept moving waypoints
- Wind speed and direction.

Further facilities and options can be readily provided by introducing additional hardware and software interfaces. This may be necessary for certain mission roles which demand high accuracies and update rates. Such performance enhancements are relatively easy to accomplish with the core system by allowing the use of data from similar or dissimilar subsystems to reduce systematic

error sources within a given subsystem e.g. Kalman filtering of doppler and inertial derived data from a strap down package can be used to obtain smoothing and prediction.

3.3 COMMUNICATIONS

Considerable flexibility is required to accommodate the wide range of customer defined subsystems. Control of radio and IFF switching, frequency and mode selection is exercised from the control and display units in the cockpit.

3.4 LIGHTING AND ENVIRONMENTAL CONTROL

The system will allow the full control of the range of environmental, lighting and conditioning systems.

3.5 ENGINE AND TRANSMISSION CONTROL AND DISPLAY

As with the flight controls area great care has been taken to isolate the safety critical elements from the core system. The functions performed by the core system include;

- Engine instrumentation display

- Gearbox instrumentation display

- Fuel instrumentation

- Fire extinguishing and detection.

The existence of extensive engine data, air data and other performance parameters enables accurate aircraft performance parameters to be displayed to the crew. In addition 'synthesised' data such as low airspeed, computed from cyclic pitch and other aircraft parameters or power and current weight.

3.6 SYSTEM MAINTENANCE MONITOR

This subsystem which provides built test for the core components and related systems and on condition monitoring of a number of mechanical subsystems. The functions of the condition monitor are to perform the exceedance monitoring, low cycle fatigue and fault detection processing. Data is stored for retrieval either in memory or on tape and is available to ground crew for subsequent processing.

Logistic and support costs for existing systems traditionally run in excess of 60% of the total cost of ownership. The nature of, and the facilities contained within the core system are seen as major steps in reducing life cycle costs. Not only is the intrinsic reliability of the system improved by reducing wire and hardware but the use of the onboard system for test and diagnostics at factory and first line obviates the need for sophisticated, costly test equipment, improves fault detection and isolation and reduces the occurence of maintenance induced faults.

3.7 COCKPIT CONTROLS AND DISPLAYS

This provides the crew with the means of controlling the range of subsystems contained within the core system and of receiving information from them. There is at the current time considerable debate concerning how best to display and control information in the cockpits of future helicopters. While it is possible to design an all-electronic cockpit it is questionable whether this is adequate for rotary wing applications. It may be better for the cockpit to be a mixture of dedicated instruments and controls with integrated CRTs and their associated controls used only for a range of tasks.

Despite this the processing power of the core system can do much to assist the aircrew by automating simple, routine tasks and by providing better processed information which is readily assimilated by the crew.

4.0 SYSTEM ARCHITECTURE

It is impossible to predict or anticipate the range of customer defined equipments and functions which a system may have to accommodate at some point in its life. The core system relies on the use of a very modular and flexible configuration which permits the rapid and economic reconfiguration of the basic functions. The core system is shown in Fig. 1.0. This shows a centralised 'core' interfacing to a number of subsystems by means of dedicated links. The interface units are distributed geographically throughout the aircraft and act as 'data concentrators' by passing data from one region to another via the multiplex data bus.

The nature of the changes and modifications which the system has to cope with may vary considerably. The core system copes with:-

(a) Small changes e.g. the additional of a switch, or display, or change of display format. In the conventional system the ability to introduce this class of modification is constrained by say panel space, requires loom changes, wiring modifications etc. The core system allows this change to be carried out by means of a software change. The implications are that while the design costs of this may be the same for the core system as they are for the conventional system, no physical changes are required with the core system. This has considerable significance both in development, manufacture and in subsequent service maintenance and support.

(b) The second class of change to be considered is that concerned with the additional of a small subsystem e.g. a radio, a navigation sensor such as GPS, weapon subsystem etc. For helicopter applications, this is the most significant in that each variant of the airframe requires a unique customer defined radio, navigation and weapon system. The core concept permits a much greater degree of standardisation and commonality to be introduced into the airframe. Changes will be accommodated by reprogramming the CDU to provide the display/control facilities required by the new subsystem and the subsystem would be interfaced to the multiplex system by changing a card in the appropriate interface unit. By careful design, physical changes to the helicopter system can be minimised.

(c) Large subsystems. It is expected that throughout the course of its service life, the system must cope with the addition of new sensors, weapons etc. this together with a demand for additional processing to meet these requirements. Ideally this should be possible with minimal disturbance to the core system. The core concept permits this in two ways. Firstly, the basic multiplex system can be expanded or secondly, the additional processing can be included as part of a subsystem.

The flight controls sub-system is shown, for safety reasons, physically separate from the main core system although an interface is provided to interconnect sensor data and maintenance data into the core system.

The control and display subsystem may be realised using interactive control and display units (CDU). Two control panels are shown, one for each crew member. The CDUs consist of a display surface, option keys and a keyboard and provide the means of controlling the subsystems interfaced to the core system. The reduction in the proliferation of switches and controls is seen as a major step in improving cockpit design and reducing crew workload.

Control of the multiplex data bus is also distributed, which means that any of the remote terminals can control the transmission of data from one region to another. The penalty of adding bus control functions to each terminal is offset by the ability to decentralise the function thus adding to versatility of the system.

The flexibility and versatility of this approach can only be realised by ensuring that the modularity embraces both hardware and software.

The latter is a particularly critical area to be addressed as the design and structure of software has a major effect on the system cost. Historically software has been blamed for the cost overruns, schedule slippage and poor performance of computer based projects. To overcome this it is necessary to have clear software development standards, well defined standard programming languages and software management policies.

The use of a high level language is necessary to achieve good programmer productivity and the desired flexibility and maintainability. The choice of the language depends on its availability, support, the ability to produce error free programmes. A number of 'new' languages may be more attractive in one or other of these categories but do not have the necessary level of support which is required. The UK Ministry of Defence standard language (CORAL 66) is well established and will remain so for the foreseeable future. Ada is relatively new and considerable development is required before this can be offered as a replacement for CORAL.

Associated with the standard language is the use of MASCOT (Modular Approach to Software Construction Operation and Test) developed by Royal Signals and Radar Establishment.

MASCOT provides:

- A formalism for design which is processor and language independent.

- A method for design, implementation and test of operational software

- A basis for documentation

- A 'kernel' which either interfaces with a host operating system or runs on a bus machine. The kernel is the means of providing machine independance in program.

The expression of the software system as a network has a number of advantages. It provides a static view of the software design which provides for excellent visibility by designer, management and customer alike. The network diagram defines the software modules, their purpose and their inter relations in an unambiguous manner. In this manner the activities which comprise the various subsystems defined in the functional analysis can be defined and detailed. The software interfaces between subsystems are readily identified and controlled and consequently customer invoked changes and requirements can be readily accommodated.

The combination of modular hardware and software arranged in this manner is regarded as an essential feature of new helicopter systems. Trade-off studies have shown that benefits exist and can be achieved by adopting these designs.

There are a number of unresolved questions which limit the scope of application of this concept – particularly where flight critical software is concerned for not only must reliability be achieved, it must be seen to be achieved and before flight critical functions can be integrated, analysis techniques must be provided which will provide the necessary confidence in the design.

5. CONCLUSIONS

It is evident that digital technology allows us to realise integrated digital multiplex systems which can offer considerable benefits in terms of reducing cost and weight.

The key issue in achieving these benefits is to ensure that the system is inherently modular and can be adapted readily for different applications. Modularity must exist in both hardware and software.

The integration of flight critical and non flight critical systems in a common system gives cause for concern – techniques are emerging for proving the design of complex software systems but until these are well understood by the manufacturer and user, it will probably be necessary to ensure integrity by classical and physical separation.

VEHICLE SYSTEMS

DOPPLER SYSTEM
RADAR SYSTEM
ADF & DME SYSTEM

MISSION SYSTEMS

E.S.M.
E.C.M.
WEAPONS INTERFACE

VEHICLE SYSTEMS

NAVIGATION SENSORS
U/VHF & HF RADIOS
TACTICAL RADIOS

CORE SYSTEM
INTERFACE

CDU 1

CDU 2

NOSE
INTERFACE
UNIT

AFT
INTERFACE
UNIT

COCKPIT
INTERFACE
UNIT

CABIN ROOF
INTERFACE
UNIT

VEHICLE SYSTEMS

COCKPIT INSTRUMENTATION
DEDICATED INSTRUMENTS
FLIGHT MONITORING

MISSION SYSTEMS

TACTICAL NAVIGATION
WEAPONS CONTROL
MISSION PLANNING

VEHICLE SYSTEMS

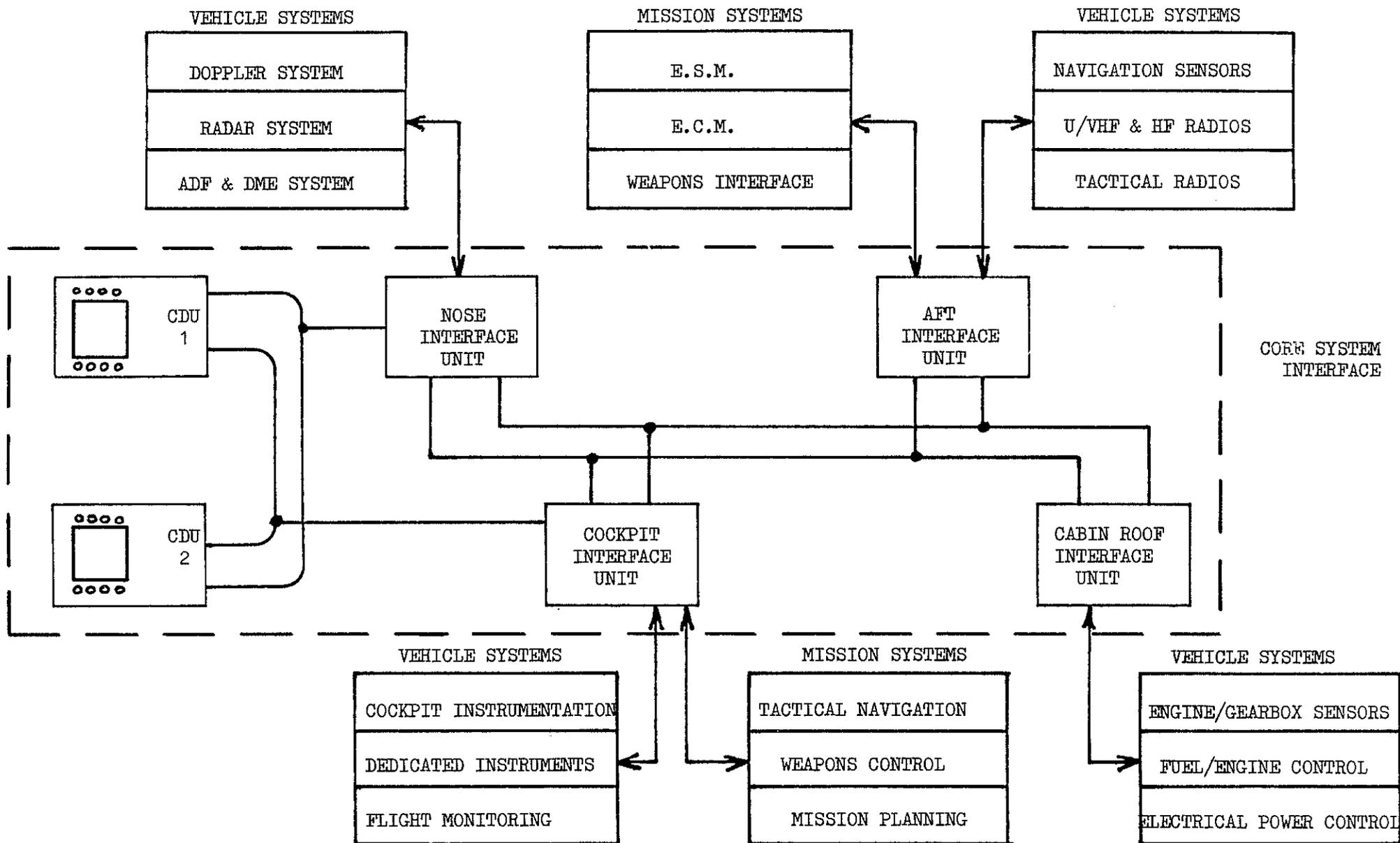| ENGINE/GEARBOX SENSORS |
| --- |
| FUEL/ENGINE CONTROL |
| ELECTRICAL POWER CONTROL |

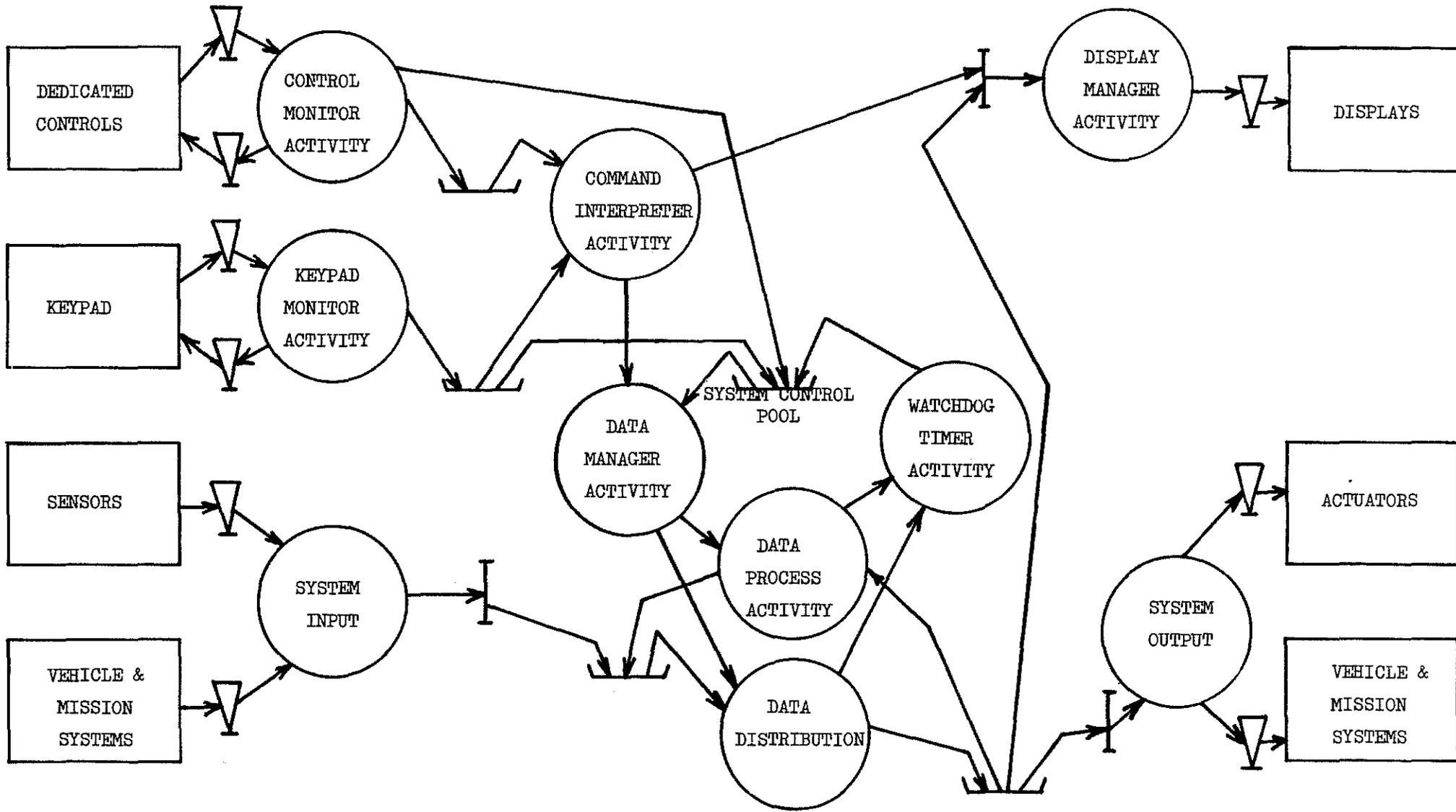FIGURE 1.0   A TYPICAL CORE CONFIGURATION FOR A MEDIUM SIZE COMBAT HELICOPTER

FIGURE 2.0 AN EXAMPLE OF A DCAS MASCOT DIAGRAM.