A PRACTICAL APPROACH TO THE INCORPORATION OF TECHNICAL ADVANCES IN AVIONICS

ICAS-82-3.1.2

J. D. Bannister and D. Roughton

British Aerospace P.L.C.
Aircraft Group
Kingston/Brough Division
BROUGH
North Humberside

ABSTRACT

This paper describes a programme to design, develop and construct an Avionic System Demonstrator Rig for the next generation of Tactical Combat Aircraft. The programme is being carried out by British Aerospace with the prime objective of reducing the development risks associated with the rapid advance of technology.

The approach has been via the development of an Advanced Cockpit with the objective of reducing the pilot workload of a single seat aircraft. The cockpit design depends on the use of multi-purpose displays and an integrated approach to system control. The availability of digital serial time division multiplexed data transmission - the data bus - has allowed the design of a fully integrated system with the pilots needs foremost in mind. The system architecture is based on a multibus hierarchy and embraces traditionally independent systems: Flight and engine control systems, Mission and weapon delivery systems, Fuel and hydraulic control systems. A complete aircraft system is represented on the rig. In the design process the need to recognise the differing integrity levels between different parts of the system manifests itself in the system architecture.

The development is based on an evolutionary approach with a series of readily identifiable intermediate stages. This allows the maximum benefit to be derived from technology advances but is particularly demanding on the configuration control techniques used.

1. INTRODUCTION

Current developments in avionic systems reflect the very rapid advances made in the miniaturisation of electronic components over the last twenty years and particularly the advent of Large Scale Integrated (LSI) and Very Large Scale Integrated (VLSI) circuitry during the 1970's. Throughout the 1960's the electronic explosion was driven by military and aerospace needs for reduced size and weight and hence investment in integrated circuit development. However the application of large scale integration to commercial markets throughout the 1970's and the slowness to exploit the electronic technology developments for military uses has reduced the market share of military applications for semi-conductors to less than 10%. Certainly there has been no dramatic reduction in avionic costs. The reasons are not difficult to find and reside in a variety of technical, economic and political pressures:

- increasingly demanding operational requirements
- increased complexity of military equipment
- unique operating environmental constraints: temperature, vibration, radiation
- relatively long project cycle time
- relatively low number of production units

Hence the consequence has been low volume, high risk, custom built, high cost, production of LSI components for military uses.

Nevertheless, steps are being taken to ensure that the application of VLSI to the military field is more effective than was the case for LSI. Significant investment by the U.S. Government in a programme to stimulate the development and exploitation of very high speed integrated circuits (VHSIC) and due for completion in 1986 should put military users back leading technology advances.

Considered from the view point of the military user and designer, the availability of the desired electronic component at the desired cost and with the desired support is one aspect of a compromise in which severe operational requirements and high risk products are others. It is necessary for the aerospace industry to respond to these pressures by establishing cost effective development programmes with the aim of reducing the risk of immature equipment. The converse problem is the need to avoid the use of devices and equipments which are nearing obsolescence as they are incorporated for the first time in final products. We are involved with products which can go from concept to operation in anything from 5 to 15 years. Essentially we require to understand the nature of the technology that we are applying, and we need to bring an innovative approach to the development, procurement and production of the new technology products.

2. THE DATA BUS

From the view point of the Avionic Systems designer the immediate impact of LSI and VLSI has been the advent of the microprocessor, reducing the size, weight and cost of processing. The microprocessor has had far reaching effects on the "Avionic Process" from the design and development, to the manufacture and testing, to the in-service use and maintenance.

In particular the traditional avionic system which consisted of several sensors each connected separately to a central computer for its data distribution and main processing capability and each with its own dedicated pilot display and controls has been replaced by a system with shared communication and displays but sensor-dedicated processors. The widespread use of microprocessors has lead to the distribution of processing throughout the system and the association of the processing function with the various sensors. This in turn has lead to the need for an effective communication network between the sub-systems. The more complex the system, the bigger the problem which arises from wiring to remote sensors, actuators and electronics all interconnected using dedicated links.

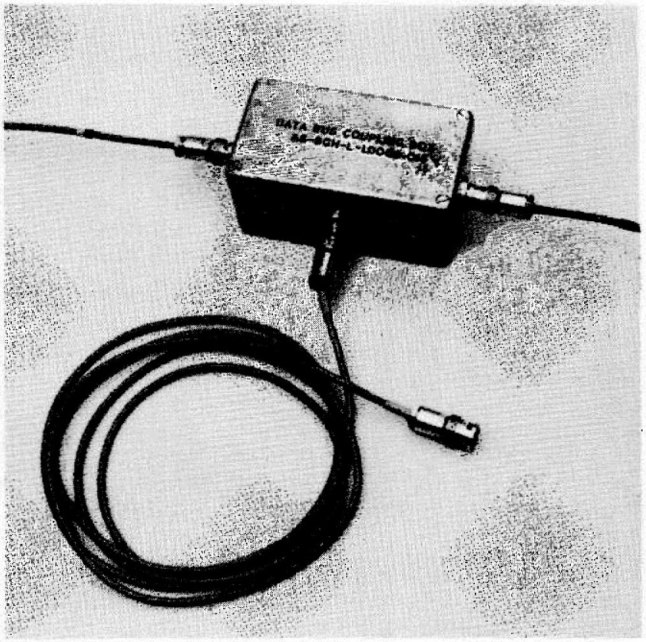

Fig.1 DATA BUS

Hence the result is the development of a digital serial time division muliplexed data transmission standard:- MIL-STD-1553B. It is now theoretically possible to connect up to 31 sub-systems to a common transmission line. This consists of a shielded, twisted conductor pair and forms the data bus (fig.1). Potentially significant weight savings in wiring alone are available from the use of the data bus. Figure 2 shows a wiring nightmare which is all too familiar.

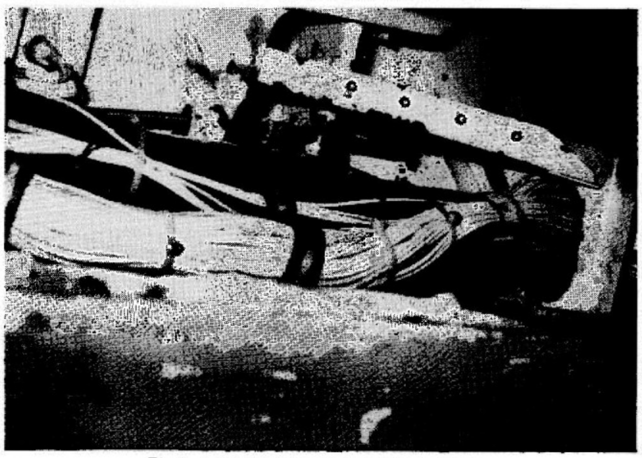

Fig.2 TRADITIONAL WIRING LOOM

Potential benefits which may be derived from the use of data bus come under the headings

- effective sub-system inter-communication
- total system integration
- graceful degradation of the system
- weight savings
- standardisation of interfaces
- improved maintenance procedures
- eased system modification

Total system integration allows significant benefits to be achieved in several parts of the system. It is possible by considering multifunction displays to address the overall issue of the display of information to the pilot and to achieve a systematic re-organisation of the cockpit displays. Similarly it becomes possible to position the subsystem controls in locations in the cockpit which are ergonomically convenient to the pilot.

Traditionally independent systems such as the general services, can now be integrated and the control of the fuel and hydraulic sub-systems rationalised. It has been shown that on a small single engined tactical combat aircraft weight savings of up to 15% are possible. It is believed that substantial improvements in survivability, reliability and maintainability are also available. In the long term these savings should result in a substantial reduction in life cycle costs.

However, there are several unknowns associated with the use of the data bus. These include

- the effects of transmission delays as data is required to await a time-slot on the data bus.
- the inherent limitations on the amount of traffic on the bus
- the possiblity of common mode failures
- identification of those links that cannot sensibly use the data bus

These are the sort of problem that justify the existence of the current programme which is being carried out by British Aerospace and funded by the Ministry of Defence.

3. THE SYSTEM

The intention has been to develop as a ground rig a total system for a tactical combat aircraft with several objectives in mind.

1. To reduce the risks associated with the application of new technology.
2. To understand the real problems associated with a system based on data buses and particularly using MIL-STD-1553B.
3. To address the task of constructing a totally integrated system involving, in addition to the traditional weapons systems, control of general services systems such as fuel, hydraulics etc.

4. To provide a facility allowing system and sub-system future development.
5. To demonstrate system acceptability to the pilot.

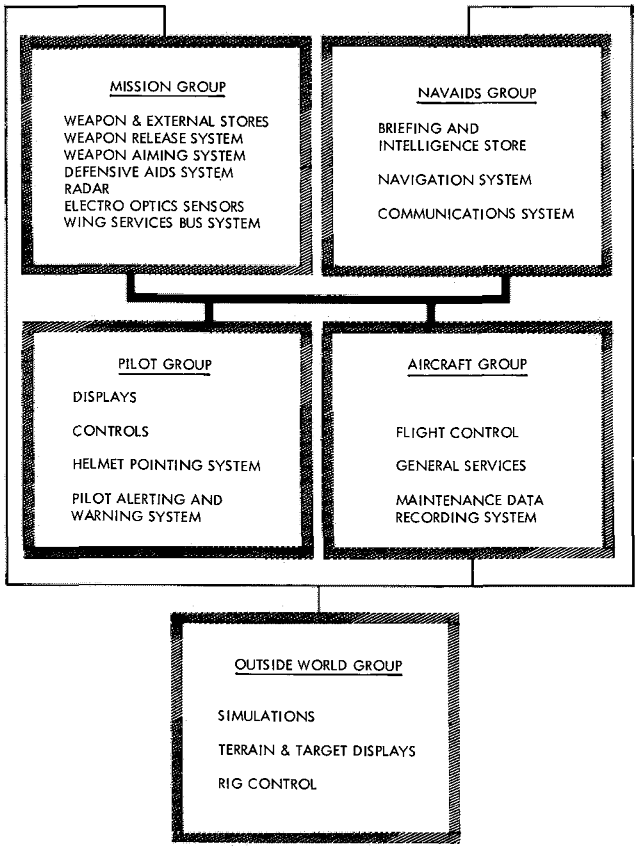

Fig.3 RIG FUNCTIONAL GROUPS

Functionally the system has been split into four groups (fig.3): Mission group, Aircraft group, Navaids group and the Pilot group with the requirement for a ground rig to add an "Outside World Group" to provide the necessary stimulation.

3.1. The Pilot Group

The Pilot group embraces what is normally considered to be the cockpit controls and displays facilities and in this particular architecture also contains the executive control for the avionics system.

3.1.1. The Cockpit (fig.4). The cockpit design and development has been approached from two complementary directions: ergonomic and systems.

In the first instance it has been assumed that the cockpit design should reflect the belief that the effectiveness of the total system is dependent on the pilot's ability to carry out the mission operational requirement which for the tactical combat aircraft is the delivery of its weapons payload. Hence the cockpit layout has been drawn up to simplify the pilots task particularly in the high stress combat situation.

The total rationale for the current cockpit layout has been described elsewhere (1). However, some of the essential features are covered here to allow an understanding of some of the decisions taken in what is inevitably a compromise and controversial design situation.

Rationalisation of the displays configuration has been attempted. The display philosophy adopted assumes a full CRT suite of four displays including the Head-Up Display and the intention is to provide the pilot with a reduced subset of the total system information which could be made available to him. Clearly there is a limit to the quantity of information which can be absorbed by the pilot at a particular phase of the mission and the intention is to provide him with just that information which is relevant to his immediate task. Hence the mission has been broken down into phases such as take-off, climb, cruise, penetrate etc. and the displays organised to provide the appropriate information. In addition a mission system keyboard has been included, which is split into three areas: a mission phase keyboard, a system keyboard and a numeric keyboard. The phase of flight is selectable from the mission phase keyboard. The possibility of accessing details of any sub-system is made possible by depressing the appropriate key on the system keyboard. This is possible at any stage of the flight and allows the pilot to access, for example, fuel contents or communication frequencies when they would not be presented to him as a natural selection of the phase of flight. The numeric keyboard provides the ultimate, if laborious method of entering data to the system.

Once a particular sub-system has been selected its operation, mode selection etc. is caused by use of dedicated sub-system panels on the port side of the cockpit. Hence each sub-system, e.g. navigation, communication etc, has its own dedicated panel. The starboard side of the cockpit is used for "once-a-flight" switches such as engine start-up etc. The pilot is then able to operate mostly without the need to take his hand from the flight control stick.

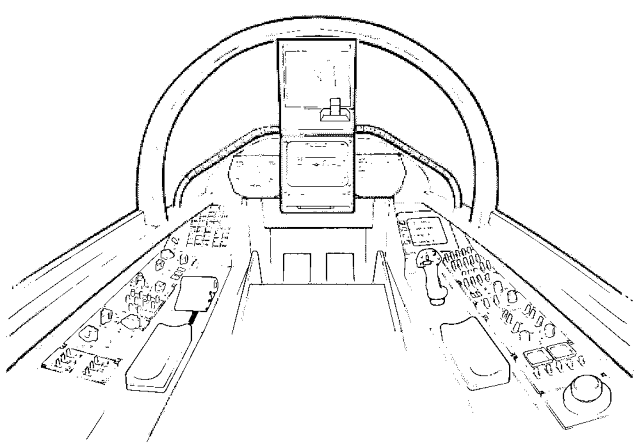

Fig.4 ADVANCED COCKPIT

It should be noted that the Pilot Alerting and Warning System - the traditional central warning panel - is positioned round the coaming on either side of the head-up display. It operates by providing the pilot with emergency and cautionary warnings. Further information on the problem is available following cancellation of the warning light. The displays are again caused to reconfigure to provide pilot action check lists and further data related to the cause of the problem.

The display system architecture is very dependent on the design assumptions incorporated. For example, the failure philosophy adopted significantly impacts on the way in which the waveform generation is organised, particularly the level of redundancy which is included. The system adopted allows the first failure to be absorbed with no apparent effect and the second failure allows all information to be accessed but not necessarily on the chosen display surface. Other arrangements are possible depending on the cost/failure absorption trade-off decision taken.

3.2. System Control

It has been stated that one of the prime objectives has been the demonstration of system acceptability to the pilot. Hence in addition to a major emphasis in the cockpit design on the ergonomics of the pilot task it is important to consider the pilot workload and to achieve the correct balance between direct pilot interaction and automatic system actions. A major aspect of the total system design therefore is the organisation of the automatic control of the system.

3.2.1. Executive Control. This function has been termed Executive Control and is defined as that control of the total system which manages the combined operation of the various sub-systems to achieve the required overall system state. Executive control uses pilot selections and sub-system status data feedback in the form of status words and state response words, to generate the control commands to the sub-systems. These commands are transmitted over the data bus in the form of state control words and are used to provoke changes in the overall system state. These required changes, as indicated above, can be as a result of pilot interaction or as a consequence of for example sub-system failure. Clearly there is a need to re-configure in the event of a sub-system failure and this is the responsibility of the executive.

The executive function can be arranged in different ways depending on the degree to which the control is centralised or distributed throughout several sub-systems. Ideally, for this programme it would have been desirable to produce a system architecture that would have enabled a comparison of techniques to be made. However, such a system would have been expensive to implement. Following detailed study it was decided to adopt a relatively centralised control concept, but allowing autonomous sub-system control of their own internal functions which do not directly affect other sub-systems.

The executive function must be capable of coping with any operating conditions that can occur and must include sufficient redundancy to meet the system integrity and availability requirements.

3.2.2. Bus Control. The executive function interacts very closely with the bus controller (Fig.5) and in fact in many implementations is likely to be resident in the same unit. The bus controller is responsible for initiating the various information transfers, as required by the data transmission standard MIL-STD-1553B, and the timing of message transfers.

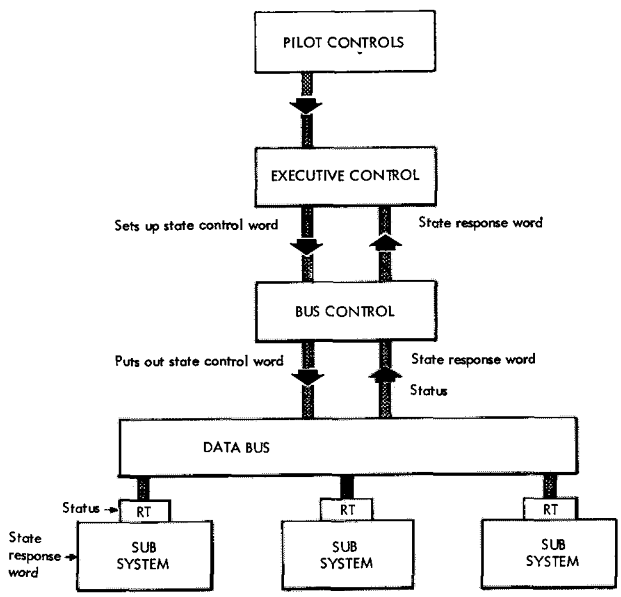

Fig.5 SYSTEM CONTROL

The information transfers can be commands, status or data words. As stated, the commands arise as a consequence of executive control initiative. Much of the rest of the bus communication consists of data transfers between the sub-system as a consequence of the normal system operation. The bus controller directs this bus traffic by causing the system to cycle through a set of data sequence tables which are stored in the bus controller. Once more the system designer has several options that he can consider. In simple terms fixed or dynamic sequence tables are possible. With the former all data is transmitted all the time and the executive must transmit information to the sub-systems to indicate how to use the available data. With the latter, only the data that is required for the current mode of system operation is transmitted. The data is organised so that packages can be exchanged to effect the changes in the data transfer required by the executive. With both of these methods state response words and status words from each sub-system keep the executive informed of the operation of the functions within each sub-system. These are processed by the executive and where necessary state control orders are issued by the executive to achieve total system control.

It is also possible with both techniques to have a series of sequence tables which cover the different phases of the aircraft mission, such as start-up, take-off, cruise etc. In that way it is possible to achieve significant reduction in bus traffic. Fixed sequence tables for each phase of the mission are held in the bus controller and the appropriate one chosen upon command from the executive. With dynamic sequence tables the situation is more complex since it becomes necessary to patch all the tables to maintain coherance when changing from one flight phase to another.

The implementation used is based on fixed sequence tables but with flight phase separation as described above and the possibility of patching the sequence tables when sub-systems are duplicated. Then both of the sub-systems would receive all the relevant data but only the operative one would output data for use by the rest of the system. The operative sub-system is again selected by the executive.

Each sequence table is a complex combination of the above concepts and the requirement to arrange the transfer of different data packages at different iteration rates between 64Hz and 1Hz. Hence each sequence table is arranged on a cyclic basis with the major cycle iterating at the slowest data rate. Within that cycle, minor cycles corresponding to the highest data iteration rate are arranged, and the intermediate data rates packed into these minor cycles. It must be noted however that it is necessary to allow a considerable amount of time at the end of each minor cycle to allow message re-tries if the first attempt is unsuccessful and to allow acyclic transactions to take place.

Finally, while the data transmission technique used depends on a command-response concept, it has been found in practice to be highly desirable to use a broadcast type of data transfer in certain circumstances to reduce bus loading. This is particularly important for some of the higher frequency transactions.

3.3. The Mission System

Clearly the Mission Group of any system is that which allows the total system to perform its function and hence is fundamental to the fulfilment of the aircraft role. It is not the purpose of this paper to discuss the nature of the role of the Tactical Combat Aircraft, nor to debate those features that should be incorporated in a given system design. The system description given is to indicate the nature of the facility being developed within the U.K.

The Mission Group of systems involves the basic sensors for target detection, recognition and tracking such as the radar and electro-optical sensors. Clearly these sensors interact in a fundamental way with the weapon aiming function. In addition this group of systems includes the means of providing safe and effective weapon release and the essential electronic defensive aids.

A number of weapons simulations will be required to produce a realistic response to signals from the weapon aiming system and the weapon release system. Each weapon type will be capable of being "released" and typical failure cases will be introduced via the outside world system under the control of the command and monitor system.

The weapon release system provides safety critical outputs to the aircraft/weapon station interfaces. It will use initially loaded briefing data and in-flight inputs from the pilot to prepare attached packages. After receiving committal demand signals from the pilot, the necessary release outputs will be generated.

The defensive aids system will sense the presence of a threat and assess its priority on the basis of the current threat environment. It will also select appropriate counter measures for deployment either manually or automatically.

The weapon aiming system processing is being carried out in the navigation system for air-to-ground and in the radar system for air-to-air weapons. In this way it is believed that data transmission is reduced to a minimum.

The radar emulation will perform air-to-air and air-to-ground target acquisition and will calculate air-to-air missile launch success zones.

3.4. The Navaids Systems

The Navaids Systems provide the basic necessity of all aircraft to be able to navigate and communicate effectively. The group consists of inertial sensors processing, radio navaids, communications and briefing aids.

The inertial sensor function will provide aircraft attitude, body angular rates and flight vector data, from data supplied via the outside world. The navigation functions will provide aircraft heading, velocity and position in an earth reference frame. In addition the system will provide the required heading, track, ground speed and time to go, to make good a desired destination or route. In the case of ILS the steering function will provide a descent slope. The fixing capability of the system will allow planned and unplanned, on-top and off-track fixing. The navigation management function will carry out fault detection and system reconfiguration based on simulated fault demands received via the outside world bus.

The communication system will allow the emulation of communications with forward air control, air traffic control and ground control.

The briefing aids allow the insertion of preflight briefing information into the system and are concerned mainly with navigation and weapons data.

3.5. The Aircraft Group

The Aircraft Group consists of those avionics sub-systems which are concerned with keeping the aircraft flying safely. Hence the Aircraft Group is considered to be mainly safety critical and can be divided into flight control, general services and maintenance data recording.

The flight control facility will consist of a full authority ACT flight control system and an engine controller. Engine demands from the cockpit pass via the FCS to the engine controller. The flight control facility will have supplied via the outside world bus, all necessary sensor data to enable it to perform basic inner loop mode of operation. The design is such that it is intended that the flight control facility will be capable of operating in isolation from the rest of the avionic system. Demand signals from the cockpit flight critical controls will be routed to the FCS via direct multiplexed fibre optic links.

The general services sub-systems will include fuel management, hydraulic management, environmental control and the associated sensors and actuators. They will be arranged so that the management functions are distributed and associated with at least two processing units and communication between them is exercised over the general services bus. Hence the general services system is distributed throughout several processors. These processors are distributed geographically throughout an aircraft to allow data from the sensors to be collected and co-ordinated. Each processor would be expected to carry out one of the main management functions, secondary data control and local data collection. It is intended that each sub-system should be capable of independent but reduced operation in the event of a bus failure.

The maintenance data recording system will record both trend and fault diagnostic data from the various sub-systems. The data will be stored for subsequent retrieval and will provide rapid and direct interpretation of a failure by ground personnel. More detailed maintenance data is available for off line analysis.

4. AVIONIC SYSTEMS DEMONSTRATOR RIG DEVELOPMENT

The development process for the Rig is based on an evolutionary approach and progresses via a series of identifiable intermediate stages.

4.1. The Simplex Bus

The initial requirement was the development of a functioning simplex data bus system (Fig.6). The intention was to use a commercially available microcomputer, Plessey Miproc 16-AS, to host the hardware interface and the software to cause the microcomputer to function as a Remote Terminal data bus interface. The basic requirement from the machine was processing speed to allow the necessary MIL-STD-1553B response times to be met.

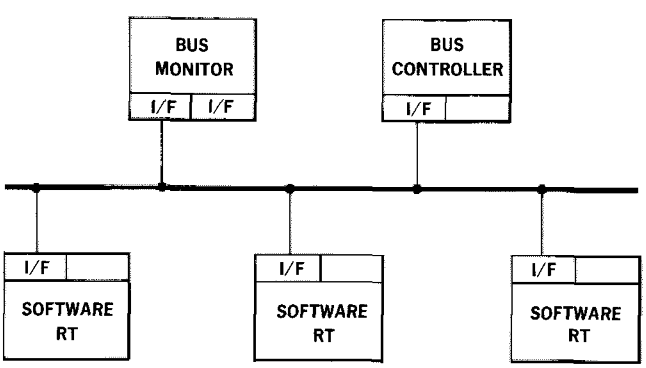

Fig.6 SIMPLEX BUS

In addition it was possible to use the same set of cards to provide the hardware interface and we developed the software to provide the bus controller function. The Fairchild data bus monitor completed the initial system. It simply had the capability of transferring artificial data from one location to another over the data bus under the control of the bus controller and governed by the requirements of MIL-STD-1553B.

That configuration had the basic intention of allowing us to derive an intimate knowledge of MIL-STD-1553B and provided a simple but flexible and effective tool upon which to develop. It also served as a vehicle on which to use the software management process.

The next step was to develop the capability to communicate over a dual redundant databus.

4.2. Stage 1

The configuration which is designated Stage 1 is shown in schematic form in Figure 7. The system was developed to this level to satisfy several purposes. It provides a "mini" system, connected via a data bus to a pilots displays and controls. The sub-systems, navigation and fuel, allow a simple navigation mission to be flown and provide a mix of high and low repetition rate data on the bus.

The major achievement of this stage has been the development of an embryo executive function which is capable of being developed for later stages of the rig. It is resident in the same microcomputer as the bus controller. The executive has been developed to allow data scheduling according to the flight phase, to accept acyclic data transactions input via the cockpit controls, to select between duplicate data sources and to reconfigure following failures.

The general purpose computer provides the "outside world" stimulation to the system in the form of aerodynamic and engine models, outside world display data and the rig command and monitor function. Figure 8 shows the Stage 1 rig demonstration layout.

4.3. Stage 2

The Stage 2 rig is shown in Figure 9. A second data bus has been introduced to provide the means of controlling the general services functions. The so-called general services bus has its own bus controller and executive. That bus controller also has an RT interface onto the avionics bus.

Another important feature of the Stage 2 rig is the clear distinction between the system and the outside world stimulation. The outside world as been provided with its own bus and bus controller to allow communication between the general purpose computer and those functions requiring stimulation. In general, it has been considered difficult and expensive to provide on the rig the aircraft sensors such as radar, IN platform etc and then to attempt to stimulate them. Instead emulations of the sensing functions have been provided such that the interface with the rest of the system appears to be realistic, but with the sensor data being supplied over the outside world bus.

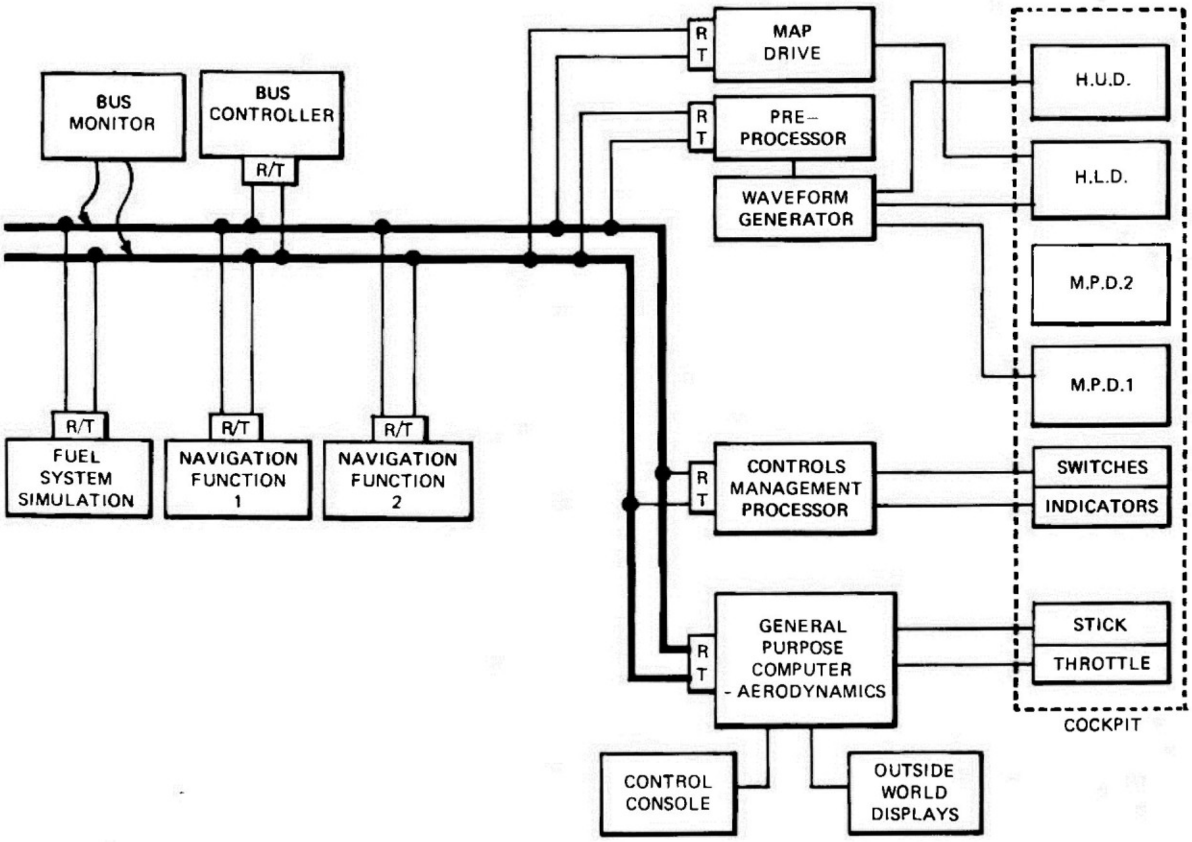

Fig.7 THE STAGE 1 RIG

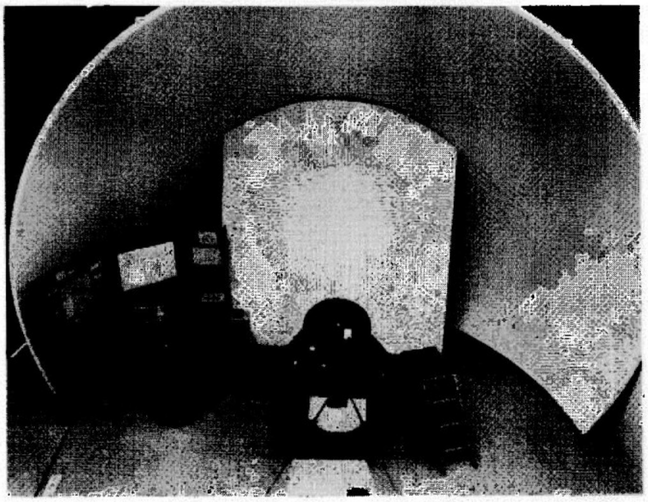

Fig.8 DEMONSTRATION LAYOUT

Redundancy of the executive and bus control on the avionics bus and of the waveform generation for the pilot displays has been added at this stage of the rig development. In addition the ability to monitor, record and analyse off-line the data bus traffic has been provided by developing an interface to the Fairchild DBM to download the data into a mini computer and then onto hard disc storage.

Hence the issues which are being investigated and resolved at Stage 2 include:-

a) Data transfer between asynchronous data buses

b) The devolution of limited executive control to the general services executive from the avionics executive

c) The design and operation of a bus controller which has an interface to a second bus

d) The design and operation of dual bus controllers with the need to resolve the possibility of disagreement between them during operation and the organisation of handover of control. It is intended that only one of the bus controllers will be in control at any instant.

e) The ability of the display system to survive failures

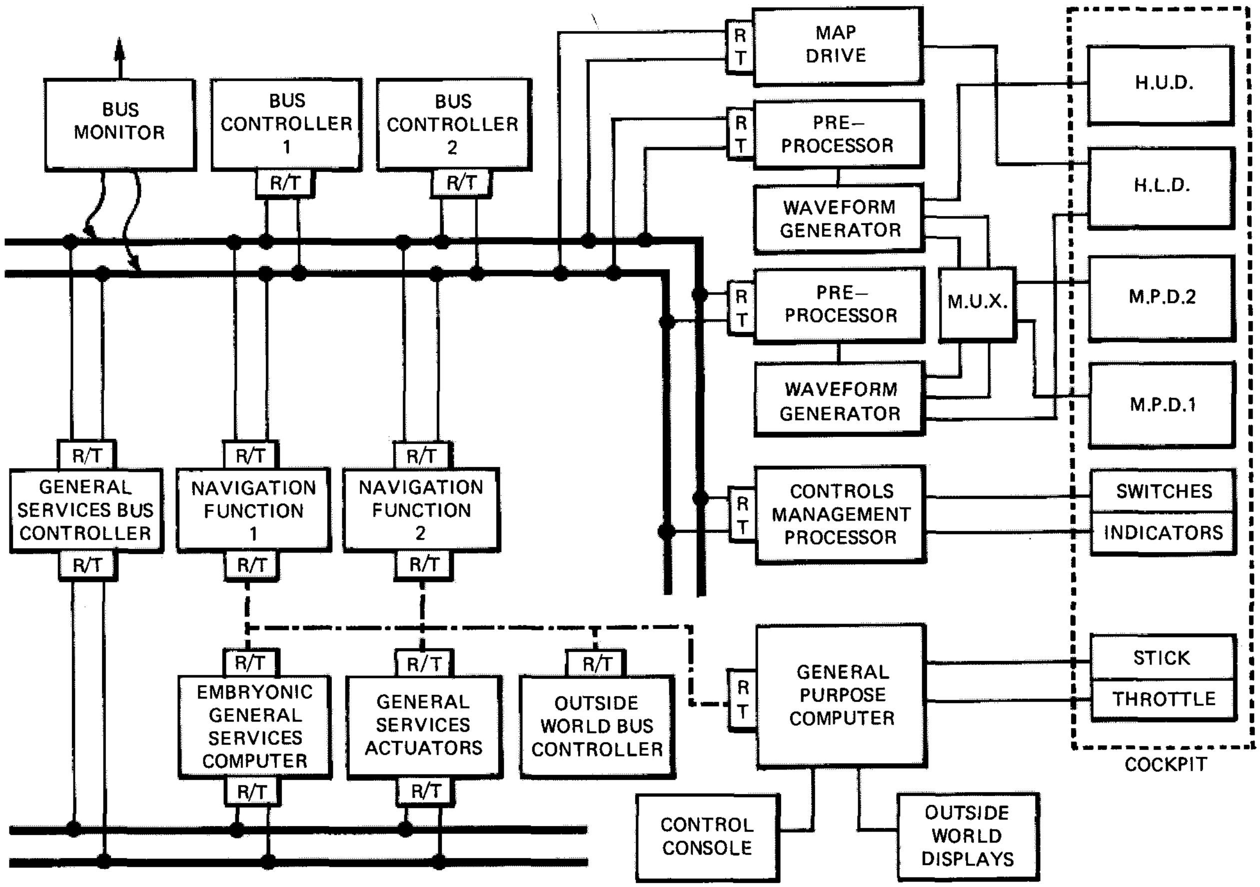

Fig.9 THE STAGE 2 RIG

f) Monitoring and analysis of bus traffic

g) Procurement of equipment from external suppliers. While Stage 1 was developed within B.Ae using commercially available equipment, several items for Stage 2 such as the avionic and general services bus controllers are being procured from the U.K. avionics industry. Hence there has been a need to provide comprehensive specifications in a timely manner. Because of the integrated nature of a data bus based system it is necessary to have completed the bus related design early.

In addition the use of LSI remote terminal interfaces is becoming possible and they are replacing the internally developed RT's described previously as they become available.

4.4. Stage 3 (Fig.10)

The essential elements of Stage 3 have been described in Section 3. It is important to realise that the system provided is in many respects more comprehensive than would be included in a single aircraft system, but provides the facilities for further development work.

4.5. Timescales

The initial contract was placed in mid 1980 and is in tended to continue until early 1984 when Stage 3 will be complete. Stage 1 was completed in Autumn 1981 and Stage 2 is scheduled for completion in late Summer 1982. The definition, specification and procurement for Stage 3 is well advanced.

4.6. The Design Process

The design of the system for the rig was bounded by adopting the following guidelines:

a) The system should be representative of that required for a Tactical Combat Aircraft.

b) The system is intended for a rig and therefore requires a degree of flexibility wherever possible.

c) The system requires to be separate, both philosophically and practically from the 'outside world' stimulation.

It was necessary in the first instance to make assumptions about the nature of the operational requirements for the aircraft as a whole. The need was to establish the operational performance levels which affect the avionic requirements. In particular the aircraft missions have been defined and hence the approximate aircraft size and capability. In addition it has been necessary to define the weapon loads required to fulfil those missions.

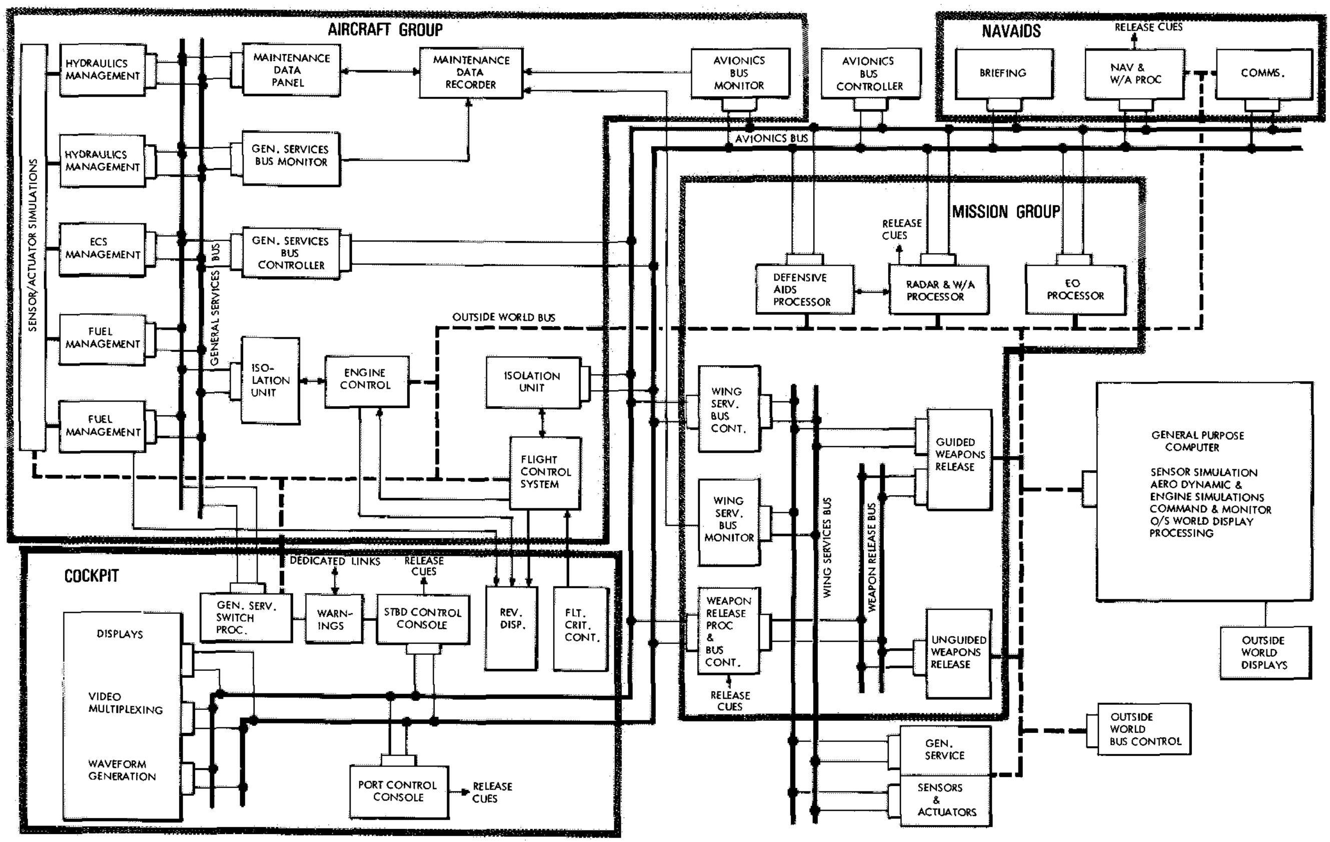

Fig.10 THE STAGE 3 RIG

It then becomes possible to establish in detail the overall Avionic requirements, with assistance from MoD to provide clarification where necessary. In addition to the normal design constraints such as timescales, equipment performance, failure absorption capability etc., it has been necessary to include specific constraints imposed by a ground Rig, such as the desire wherever possible for flexibility. Partitioning of the system into functional groups and with due regard to integrity requirements is then possible. Fig.3 shows the way in which the present system has been arranged.

Then, for each of the identified functions a Functional Requirement Specification has been generated. These specifications have served two purposes: to provide the raw material from which the total system architecture has been derived and to provide the basis from which the system procurement has been achieved.

Further detailed definition is necessary in several areas as the design progresses. In the first instance it is necessary to consider in more detail the philosophy behind the operational use of each sub-system. Only then can the detailed design of the display and control functions be achieved. Ultimately the production of the Pilot's Notes has to be carried out.

Definition of the mission management logic is necessary at an early stage to allow the executive logic to be determined. Other items that require early definition include:-

- bus controller handover philosophy
- interbus communication philosophy
- bus traffic definition
- bus protocols and software interfaces
- start-up philosophy

These are required early in the procurement process to allow production of equipment specifications.

5. THE CONTROL PROCESS

In addition to the technical development achieved as part of the rig programme, another important aspect has been the development, the use and refinement of the necessary control processes which provide the mechanism for achieving the rig.

In essence the intention has been to treat the rig programme as an aircraft development programme but on a much reduced scale. Clearly, much of the cost benefit could be squandered by an excessive indulgence in paperwork. The art is in achieving the compromise which allows sufficient control without absorbing vast resources.

5.1. The Procurement Process

The procurement process begins after the preparation of a Functional Requirement Specification for each of the sub systems. This forms the basis from which the Equipment Procurement Specification is produced. This latter specification consists of two parts. Part 1 will be common to all specifications and will detail general conditions which are applicable to all equipments. Part 2 should be written sufficiently broadly to allow each vendor sufficient flexibility to offer proposals that they consider to be advantageous to the project. At the same time it should be sufficiently precise to guarantee that the equipment provided will fully meet the defined requirements.

The formal request to tender will be sent together with all relevant documentation and references, with a covering letter detailing the classification of the project and the date by which formal quotations are required to be received.

On receipt of this request for proposals each vendor would assess the requirement and seek clarification of any ambiguities.

In parallel with this activity, contact would be made between commerical representatives of each vendor and the design authority to discuss and agree the commercial and contractual conditions.

The completion of both these activities would allow the formal tender response to be prepared for dispatch to the design authority.

It is the design authorities responsibility to provide themselves with a gauge of the ability of each company involved to carry out the work satisfactorily. This 'confidence level' information will be essential background against which each proposal will be evaluated.

On receipt of each tender the engineers involved with the project will undertake a first assessment of the proposal and compile a list of questions to be sent to the company concerned by telex.

This process will be repeated for each tender received to enable the completion of a response comparison chart.

The following criteria form the basis upon which to make the choice of vendor.

a) Can each proposal satisfy fully the requirements detailed in the Equipment Procurement Specification.

b) How do each of the cost estimates compare.

c) How do each of the delivery dates compare.

d) What are the relevant design advantages and disadvantages of each submission.

5.2. Software Control

From the outset it was clear that a major element in a successful rig programme would be the accurate definition and specification of software and the control of its development. Hence for software developed internally a set of guidelines, procedures have been set out.

The design process starts with the preparation of a software requirement document and a brief study of the feasibility of satisfying the requirement. The design authority will define the overall project timescale and in conjunction with the quality assurance representative will appoint a moderator who becomes responsible for both the technical and QA aspects of the design process.

A team of engineers is selected by the moderator to carry out the feasibility study which will produce the software specification.

The program designer will then prepare a structure design chart of the program he envisages will meet the specification. This will be subject to inspection before approval by the moderator.

As a parallel but independant task the programmer will prepare a unit test specification which describes the overall testing strategy, and is based entirely on the software specification.

Following the above design process, the coding of a program becomes straight forward.

During program coding and debugging the program designer will produce a number of internal test specifications to demonstrate that the code produced works correctly. The coding and internal test specifications are subject to inspection and the internal test specifications must be approved before testing can begin.

A program which interfaces with another item of software will require a test harness in order to run independently of the external software.

The testing phase has two stages: internal and "black box". Internal testing is intended to demonstrate that the code produced operates correctly. Boundaries are explored and un-representative data input to determine under what conditions the program will fail. "Black box" testing is intended to demonstrate that the program meets its specification.

A final report and user notes must be prepared before the software can be accepted and released for general use. Final acceptance requires the approval of the originator, the moderator and the design authority.

The documentation required is a reference file that contains:

1. The software requirement
2. The software specification
3. The event diary
4. Program structure design chart
5. Source code listing
6. Test specifications and calibration data
7. Test results
8. Minutes of all meetings
9. User guide

10. Release approval form

11. Post design amendment record

In addition, the following documents may be included as appropriate:-

12. Interface agreement form

13. Test harness structure design charts

14. Final report

For software which is supplied from external sources it has been considered to be prohibitively expensive in terms of cost and timescale to insist that all suppliers conform to the detail of our internal code of practice. Nevertheless it is essential that the product that we receive is to an acceptable standard, and conforms to the specification. Hence prior to the placing of contracts we require to be convinced that acceptable procedures will be followed. In addition the contract specifies that a documentation folder will be supplied by the sub-contractor which will contain:

Program specification

Program description

Construction diagram (structure design chart/ flow chart/ACP diagram)

Source listing

User guide

Test specifications

Test results

6. CONCLUSIONS

It is believed that the Avionic System Demonstrator Rig will be the only facility of its kind which will produce as its outcome conclusions about the implementation of a full avionic system based on MIL-STD-1553B. Such fundamental questions as availability and levels of redundancy are being considered.

In addition the U.K. is provided with a development facility which is available for use in a number of avionic programs.

However, technology moves ahead rapidly and it is important that an investment of this nature should be capable of responding accordingly. Questions which must be considered include:-

1. What degree of standardisation is desirable?
2. What are the potential benefits to be derived from MIL-STD-1750A?
3. What is the requirement for high speed data buses and what are the problems?
4. What is the role of fibre optics in aircraft internal data communications?
5. What are the implications of the VHSIC programme?
6. What video standards are desirable?

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ACKNOWLEDGEMENTS

The authors wish to acknowledge the help provided by colleagues at British Aerospace during the preparation of this paper. Permission to publish the paper is by courtesy of British Aerospace. The opinions expressed, however, are entirely those of the authors.