The Design and Development of the **BITE** Facility for the **CONCORDE AFCS**

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THE DESIGN AND DEVELOPMENT OF THE BITE FACILITY FOR THE CONCORDE AFCS

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The information given in this paper is based on the current design state of the Automatic Flight Control System for the Production Concorde Aircraft and may be subject to revision by the Aircraft Constructor or Equipment Suppliers before the aircraft is certified.

The Dual Channel ITEM system, which provides the Central Organization of the AFCS BITE, is not included in the basic equipment fit of a "Standard Aircraft" but has been ordered by Air France and British Airways.

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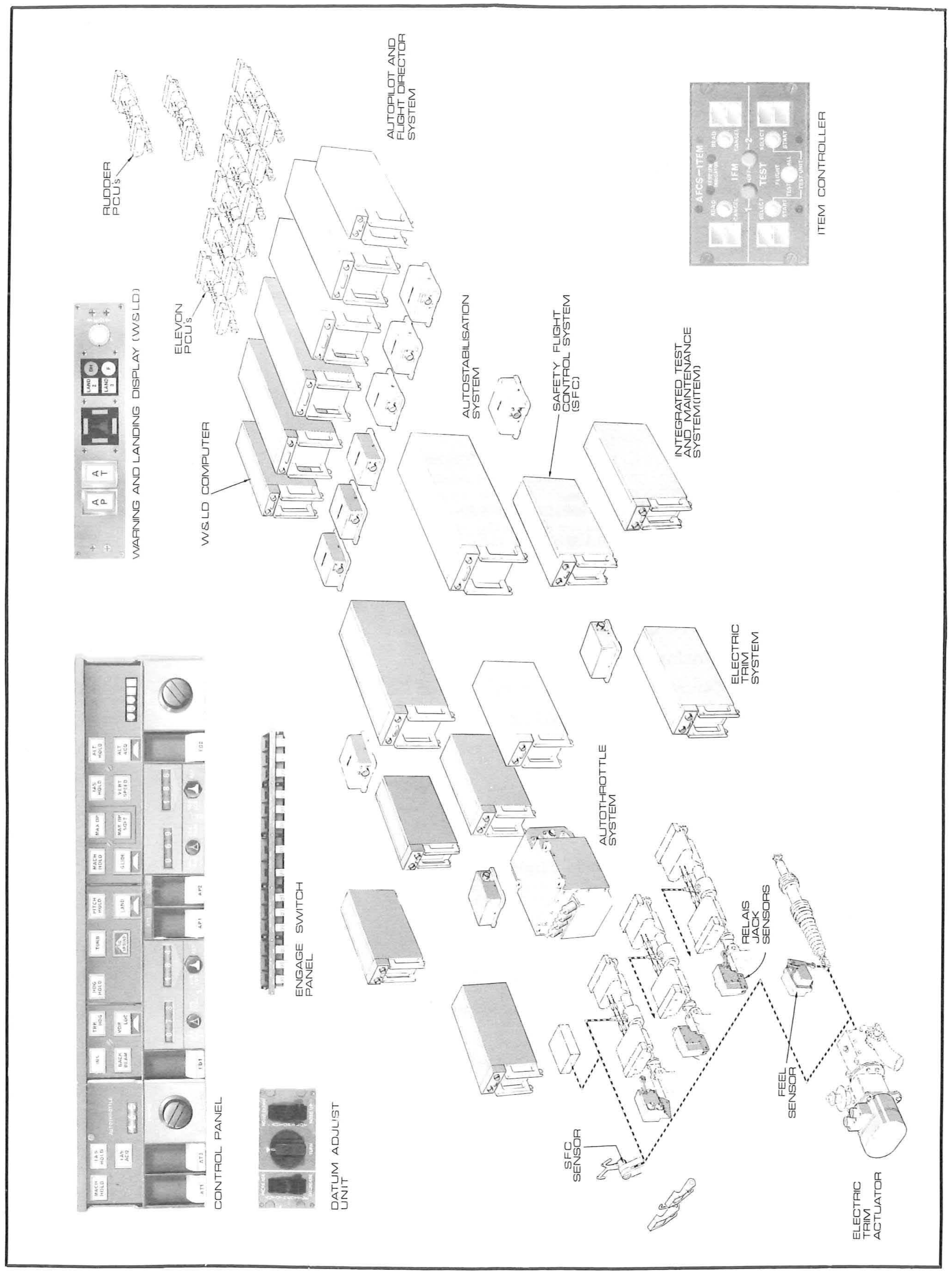

Figure 1 Concorde Automatic Flight Control System

THE DESIGN AND DEVELOPMENT OF THE BITE FACILITY FOR THE CONCORDE AFCS

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SUMMARY

The system design philosophy and implementation details arising from the design and development of the "CENTRALLY ORGANIZED and DISTRIBUTED BITE" adopted for the Concorde AFCS are described. Particular reference is made to the trade-off decisions considered when the system was evolved as an overall aid to minimize the cost of ownership of the AFCS, the final philosophy involving a combination of improved in flight fault indication, built in test facilities and simple ground checks. The predicted success rate and the effect on economics of the philosophy are discussed.

The work described is being carried out by a team comprising Marconi-Elliott Avionic Systems Limited (England) and SFENA (France) on behalf of the Aircraft Constructors, Aérospatiale and the British Aircraft Corporation.

INTRODUCTION

With the advent of increased complexity in avionic systems great importance has been given to the minimizing of unscheduled maintenance delays associated with the Concorde aircraft and its AFCS. To this end an effective fault diagnosis system has been provided to reduce the cost of ownership and thus maximize the potential source of revenue it provides from premium fare paying passengers.

This fault diagnosis system for the AFCS is termed ITEM (Intégré Test Et Maintenance) with two prime functions:

- Distributed and Centrally Organized BITE
- In Flight Monitoring

The concept of Distributed and Centrally Organized BITE was facilitated by the inherent design of the AFCS computing, each system of which is dual channel, self monitored. Although the complexity of the AFCS has been increased by only 17%, the cost of ownership has been kept virtually the same as a result of reduction in the spares holdings arising from the reduced replacement of LRU brought about by minimizing unscheduled removals. A further inherent advantage of course will be reduction of despatch delays, unnecessary LRU handling and a reduction of ATE time.

The essential features of the Concorde AFCS are shown in figure 1 the complete system comprising 38 units, 16 of which are electronic computers associated with the following systems:

Integrated APFD - including automatic landing	4 Computers
3-axis AUTOSTABILIZER	2 Computers
AUTOTHROTTLE	2 Computers
ELECTRIC PITCH TRIM	2 Computers
WARNING AND LANDING	2 Computers
SAFETY FLIGHT CONTROL	2 Computers
TEST AND MAINTENANCE	2 Computers

It is the association of this last mentioned system with the others that is the main topic of this paper.

In order to appreciate some of the problems arising and their solution as a result of incorporating a comprehensive test and maintenance facility a brief understanding of the AFCS computing philosophy is necessary.

With the exception of the Test and Maintenance system, all control law computation utilizes analogue signal chains using dc operational amplifier techniques with integrated circuit and discrete electronic components. Engagement and mode organization is largely comprised of solid state logic with a small number of MSI devices. The total Dual Channel System contains approximately 40, 000 electronic components of which 4, 000 are Linear or Logic integrated circuits.

The basic principle of each computation system is DUAL CHANNEL each channel being independent and associated with its own set of sensors and services on each side of the aircraft any commonality being limited to priority logic and essential warning features cross fed between the channels. This basic principle is shown in figure 2. Each channel is SELF MONITORED and where failure survival is necessary then both channels are engaged with Channel 1 in control and Channel 2 in a synchronizing standby condition.

Self monitoring is ensured by having MONITOR and COMMAND lanes identical to each other mounted in the same computer and any discrepancy between the lanes is signalled by a comparator and the channel disconnected. The concept is shown in figure 3. Consolidation Techniques reduce the effects of tolerances on the monitoring thresholds and duplex comparators are utilized to retain the integrity requirements with acceptable periods between checking of the monitoring devices.

The provision of this monitoring lane is the key to BITE as it provides an already built-in model against which the performance of the control lane may be measured. Thus the additional hardware is limited to that necessary for organization and interpretation of the test results.

The BITE facilities in each computer are centrally organized by the ITEM test facility and comprises

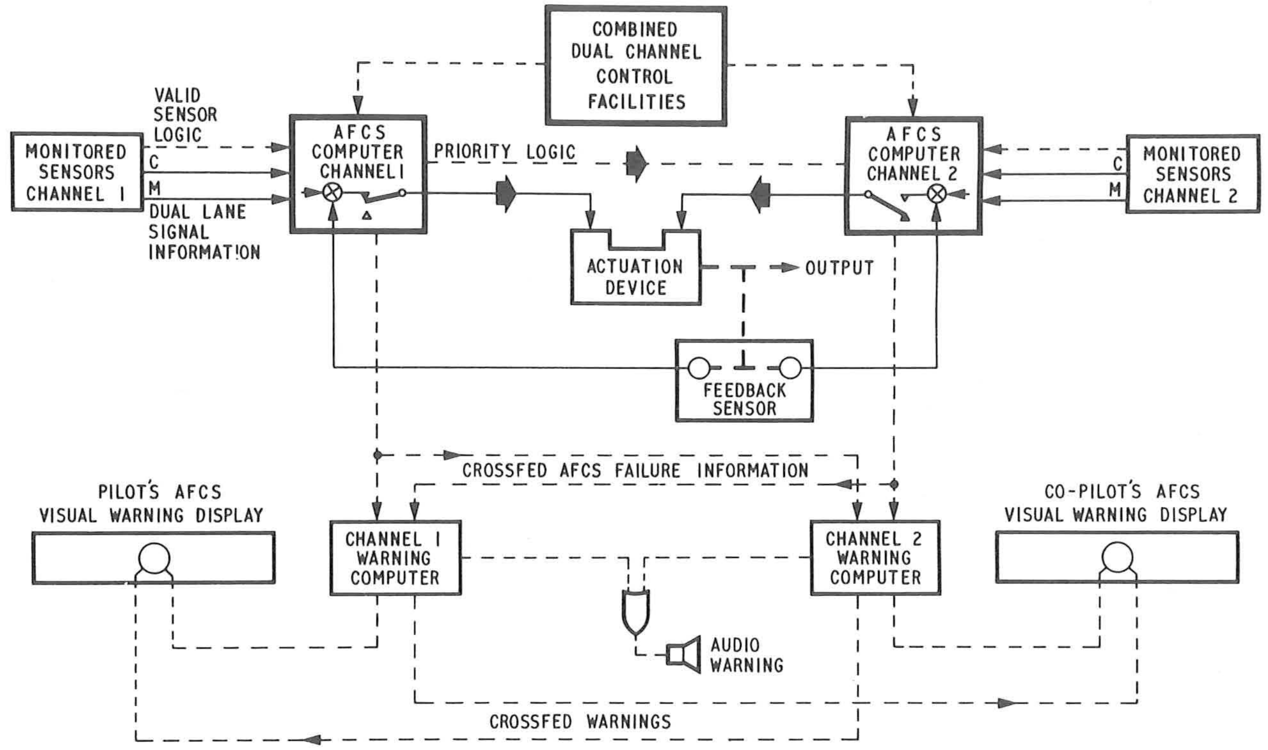

Figure 2 Dual Channel Configuration - Concorde AFCS

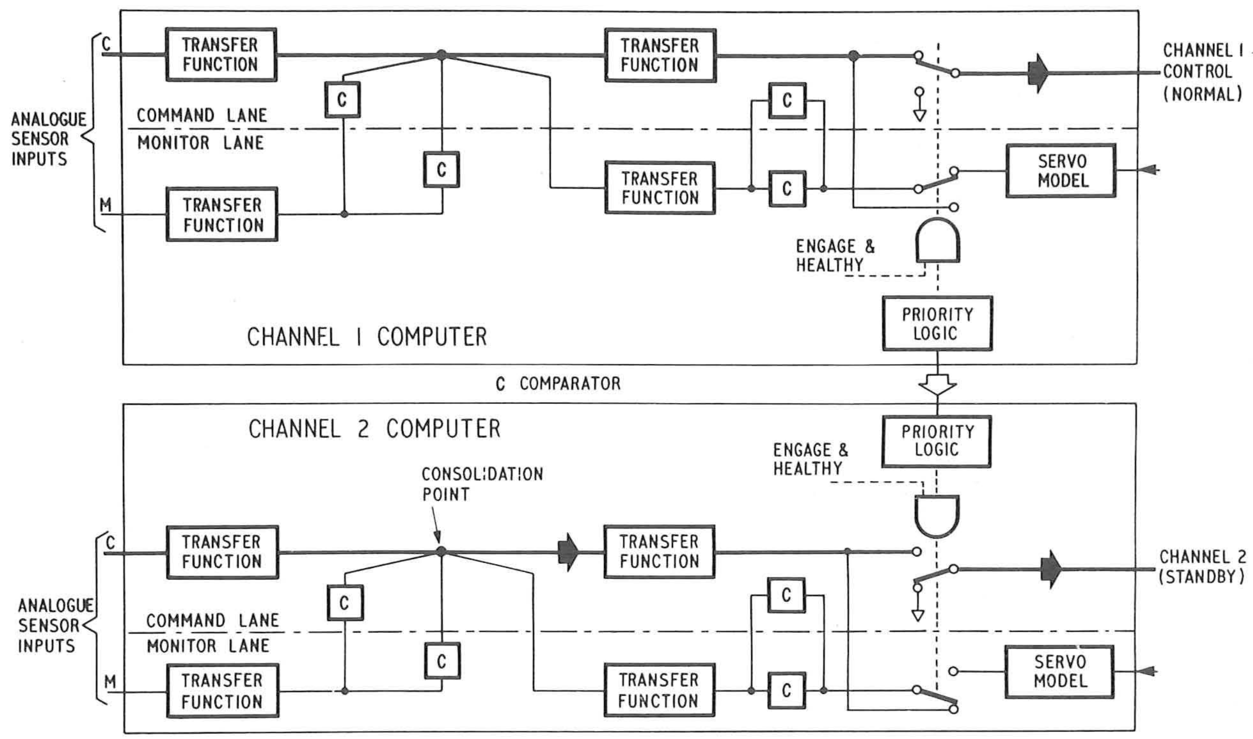

Figure 3 Self Monitored Concept

a small dedicated digital processor controlled from the flight deck. With this provision, the maintenance philosophy was further advanced to improve the IN FLIGHT fault diagnosis of the AFCS. The IN FLIGHT MONITOR (IFM) facility monitors continuously the status of the critical interlocks and system engagement states on a mode dependent basis thus enabling the crew to improve their fault reporting:

Thus the maintenance philosophy of the Concorde AFCS may be summarized as:

- IMPROVED IN FLIGHT FAULT DIAGNOSIS giving
- BETTER FLIGHT LOG FAULT REPORTING resulting in
- QUICKER ATTENTION TO SUSPECT UNIT with
- COMPUTER BITE TO CHECK LRU OPERATION supported by
- SIMPLE MANUAL CHECKS so giving
- REDUCED INCORRECT LRU REMOVALS

The development, implementation operation and predicted success rate of such a system incorporated with the Concorde AFCS are discussed in more detail in the following sections of this paper.

PHILOSOPHY OF SYSTEM CONCEPT AND TRADE-OFF DECISIONS

With the large degree of system integration and the multiplicity of systems associated with the Concorde AFCS, minimization of the overall cost of system ownership has been approached in two ways:

- IMPROVED IN FLIGHT FAILURE DIAGNOSIS
- BITE for electronic LRUs, particularly for those areas difficult to test on the ground

In considering the first of these requirements, analysis of present day avionics suggested that not less than 25% of faults appearing on the flight log which required a maintenance action were either incorrect or invalid.

It must be conceded that contemporary systems have little or nothing to indicate the likely problem area to the flight crew. It is also particularly difficult to effectively diagnose and record transient failure conditions for a subsequent maintenance action when the immediate problem on the flight deck is to cancel the resulting warnings and return the aircraft to a normal operating configuration. Experience suggests that a significant number of defects under the classification "system could not be engaged" are due to external interlock conditions rather than genuine faults within the reported system, this problem becoming more severe as system integration and operational dependency between systems increases.

Thus the requirement for an IN FLIGHT MONITOR was developed. The principle of this facility is shown in figure 4. For each channel a total of 88 engagement/interlock and mode status discretes are processed to give 21 possible indications of system/unit failure conditions. In considering the amount of information that should be processed and displayed, the following criteria were applied:

- The minimum of additional hardware and aircraft wiring should be added. The concept should only utilize information that was already available in the harness (the majority of signals being already available in the AFCS shelf).
- The indications should be aligned to LRU identification since essentially the Flight Line problem is one of LRU identification and not functions within a particular LRU.
- The system should be simple to interpret in flight.
- It should be possible to recall the in flight indications on the ground.

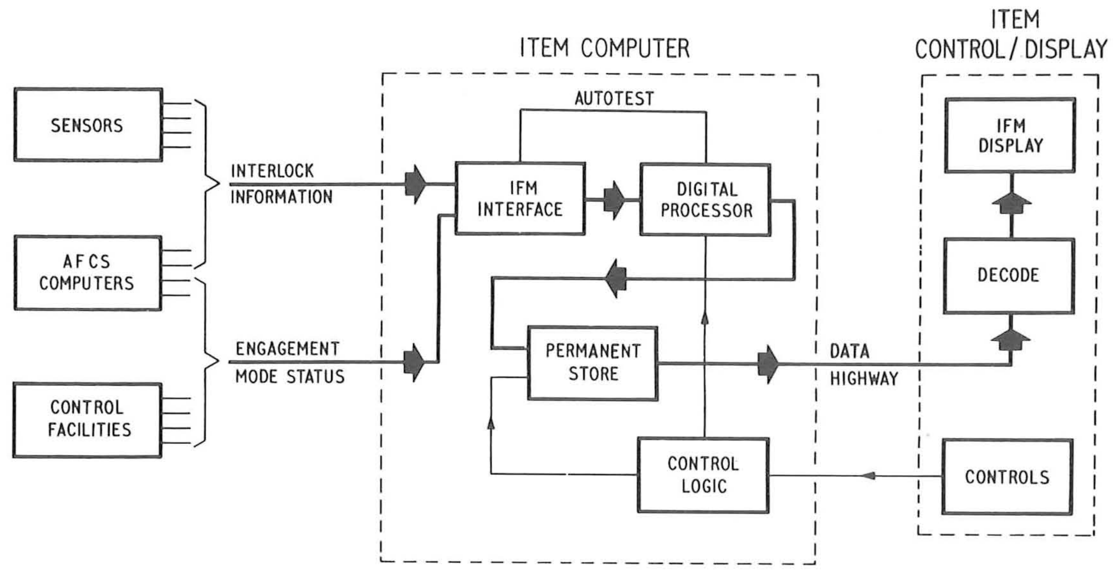

Figure 4 Principle of In Flight Monitor - IFM

It clearly would have been an ideal situation if an optimum solution could have been satisfied, ie correct identification of all faults to the correct LRU, with a 100% confidence level and with no input from the line maintenance engineer! However, attainment of this ideal, in multi-unit analogue systems with a significant amount of operational dependence and interface between units and other aircraft systems is improbable in the light of the increased capital investment resulting from over complexity purely for BITE. Any compromize solution should not add to the complexity of flight line maintenance and utilize the available airline skills that are necessary for other reasons.

Whilst it may look good in a sales promotion to show that a particular equipment will automatically identify all possible faults, it is clearly not cost effective to penalize the airline with 1% of additional hardware if the fault can be readily identified by the ordinary flight line mechanic at a cost of say 4$.

Thus the choice is not only one of HOW MUCH TO TEST by BITE but WHAT TO TEST? These two criteria will vary between aircraft system configurations and it is important to acknowledge when making any decision which involves a compromise, that these criteria are interrelated. It is believed that the decisions made in respect of the Concorde AFCS form a good, sound economic balance within the constraints that exist.

Before examining the economic penalties for incorporation of BITE, it is well to recall the other two requirements which demand the provision of BITE to satisfy the regulatory requirements:

- confirmation that various safety and monitoring features are working to correct limits and have not suffered a dormant failure.

- correct operation of redundant or non-operational control lanes/functions.

These two features tend to be somewhat mandatory but if they form part of an overall BITE philosophy they make the overall concept more cost effective.

At first sight if one ignores any penalties in terms of cost, weight, volume, etc., it appears possible to test an electronic LRU to a very high confidence level. However, if one considers the number of interfaces between an analogue unit and the outside world (say up to 400 in a more complex unit), it is impossible to economically confirm if a failure exists in the last wire from the output device within the computer, the computer plug pin itself or the socket in the aircraft rack. It has been found in Concorde AFCS units that approximately 4 to 8% of the total unit predicted failure rate lies in this area and this sets the 'theoretical maximum' limit for any test technique within a particular unit.

In considering HOW MUCH TO TEST the first problem is one of increasing complexity and Figure 5 illustrates the simple economic advantages/penalties of incorporating BITE into AFCS analogue computers. The confidence level of a test rises quickly as additional complexity for BITE is added until the 'theoretical maximum' is reached but as the BITE complexity increases, it soon becomes a law of diminishing returns. The shape of curve varies slightly between units but the principle remains the same.

Ignoring any other constraints (such as difficulty of diagnosis of a particular fault due to system configuration) it would not be cost effective to increase the BITE complexity beyond point 'A' when the slope of improving the confidence level is less than the effective usefulness.

Figure 5 suggests that for a typical unit the ideal BITE complexity would be approximately 50%, but this was not acceptable within the weight and volume constraints of Concorde and it is doubtful if such an increase could be justified on purely economic grounds either. Accordingly, a design aim for all AFCS computer LRU was set at 10%, this amount of additional complexity also to include the mandatory test requirements referred to earlier. If such a limit imposed constraints in the confidence level two points were of paramount importance when considering WHAT TO TEST.

- After satisfying the regulatory requirements, the areas tested should be those which are most difficult (therefore most costly) for an airline to test at the flight line.
- Central organization of the test facilities from a central source could effectively increase the usefulness of the nominal 10% by incorporating such common facilities as timing circuits, readout devices, etc. within the central source.

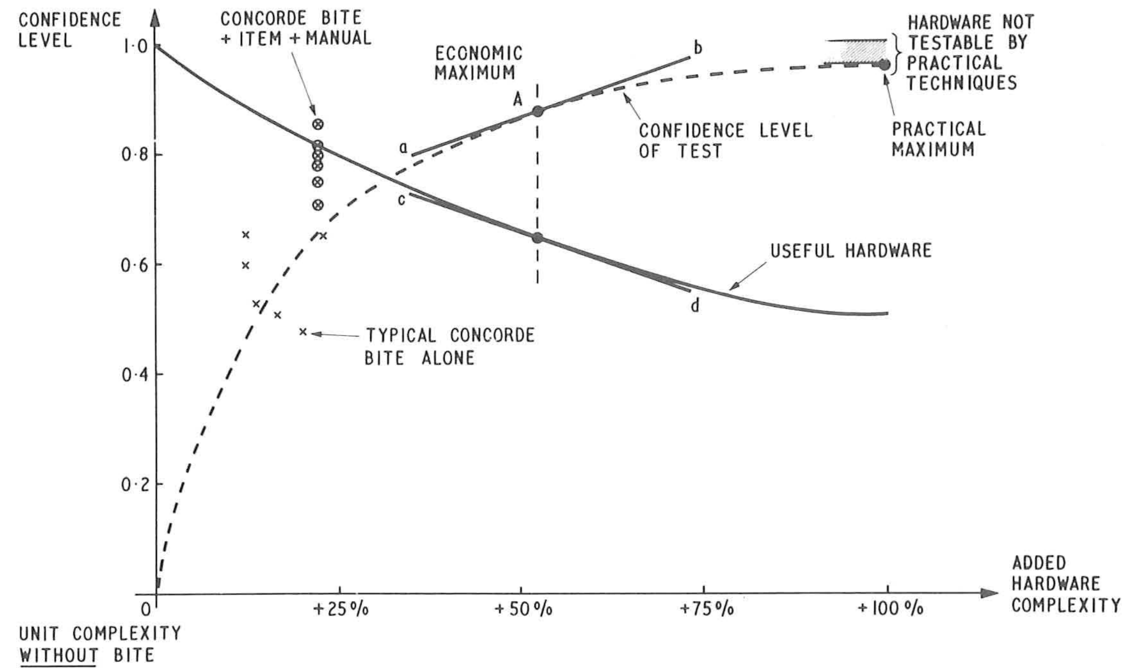

Figure 5 Economics of BITE in Terms of LRU Complexity

In examining the case for the most cost effective area to be tested, it was found that flight line problems associated with AFCS could be categorized into two main types:

- Problems associated with analogue signal chains.
  Normally such signal chains are interfaced with analogue sensors and require additional 'carry on' test equipment to exercise and measure the results. Not only is this time consuming but it requires experienced and skilled flight line personnel.
- Problems associated with engagement and mode selection logic where the problems are quite different to above. Normal cockpit engagement and mode status information provides a good indication of logic functioning without any additional supporting test equipment. Also such checks are rapid and can be carried out by less skilled personnel using check list procedures.

Clearly problems arising in the first category are a more severe maintenance burden and to this end, the additional complexity provided for BITE was utilized to check the analogue signal chains, it is perhaps fortuitous that in many cases this coincided with the mandatory test requirements. The simple manual testing associated with engagement and mode status logic indications is not difficult and when combined with the BITE result give a high confidence level, 75 - 85% being typical. A more detailed discussion on the predicted success for the Concorde AFCS is presented later in this paper but the principles of testing the analogue signal chain are shown in figure 6.

It is important to note that only digital test instructions are transmitted outside a unit and when a suspect LRU is returned to the repair shop, it will be complete with its decode, test stimuli and encode functions, and thus the probability of repeating the actual test conditions in the shop will be high. Thus one of the main drawbacks of a "completely centralized" BITE facility have been eliminated.

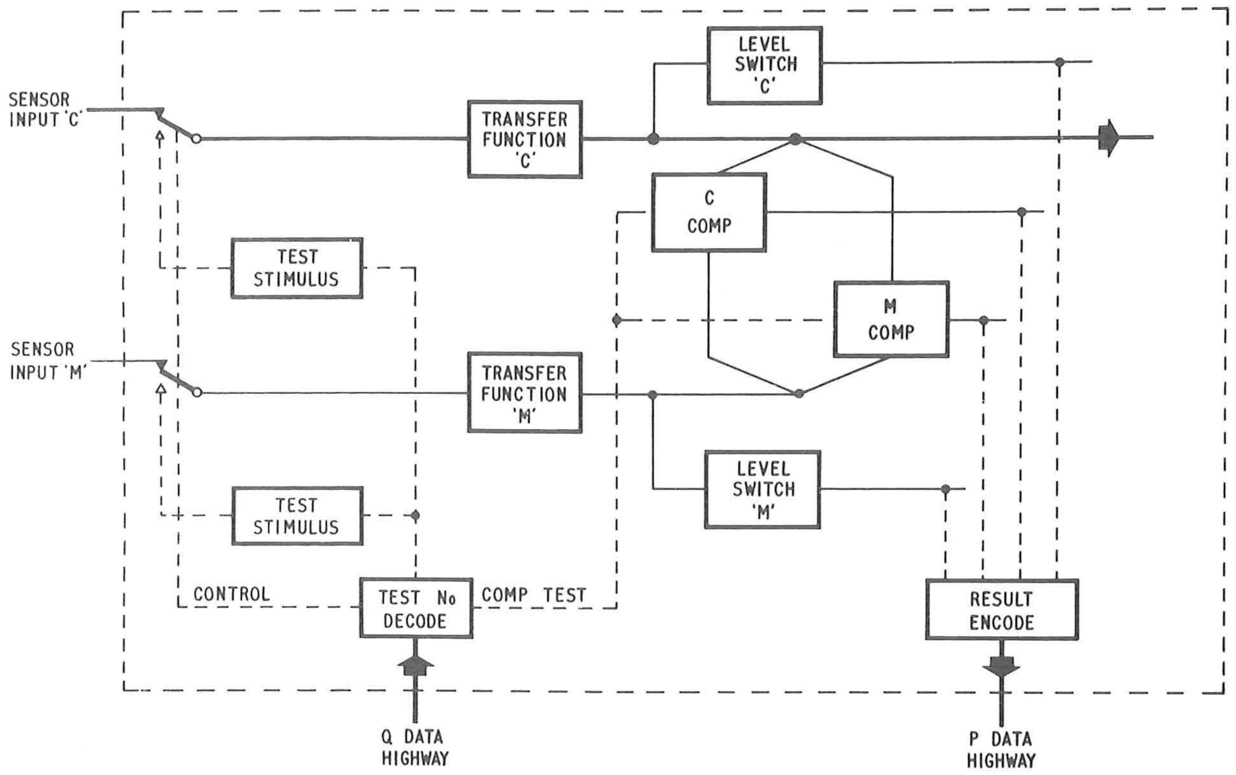

Figure 6 Principles of Analogue Signal Chain Testing

The initial concept of central organization rather than individual controls/indications mounted on the front of each LRU was motivated to avoid the need for access to the computers during the period of fault diagnosis as the AFCS computers are mounted in a busy flight deck area. The central organization was initially proposed as a "Carry On Unit" as used on Prototype and Pre-production Concorde aircraft but for logistic reasons this has been rejected by Air France and British Airways and their aircraft will have fitted an "ON BOARD" ITEM computer for each AFCS channel with a combined Dual Channel Control/Display Unit mounted at the third crew member's position.

In adopting a small dedicated special purpose digital processor for the ITEM function, it has been possible to time accurately the test sequence which increases the versatility of the testing that may be

attempted. Consider the alternative of incorporating individual timing circuits within each LRU to be tested. Not only would there be more hardware but it is likely that the accuracy of such test timing circuits would have been similar to the functions under test and so give rise to erroneous test results. Incorporation of an autostart facility for the ITEM TEST function with a high confidence level is more easily achieved with a digital solution.

In addition to minimizing the electronic complexity within the AFCS computers, it was necessary that the overall aircraft penalty in terms of the total installed weight and harness complexity of a centrally organized system was at a minimum. This was achieved by configuring a data highway concept such that test instructions are transmitted along a parallel binary data highway common to all units with a separate discrete address wire to each unit. In a similar way the test results are passed into a common highway for interrogation by the ITEM Computer. Thus for a total of 31 wires (16 address, 12 result and 3 unique power supply wires) it is possible to address 7 computers with a total of 224 tests. (It has not been found necessary to use all possible 32 test configurations in each computer and by selective control of test pattern using a time sequence, it is possible to extend the use of a single test pattern for more than one test within an LRU. The only penalty for this common data highway is that it is only possible to address one LRU at a time but since when all units are being tested, the progression between units is automatic, this is not considered an undue burden when offset against the saving in weight of the aircraft harness.

All data transmission is at "hard" logic levels with a high degree of noise immunity.

Similarly, to minimize the wiring interface to the Control Display Unit, 8 wires in a parallel binary configuration shared between IFM and TEST function carry a total of 70 indications (21 IFM and 49 TEST). The principles of the BITE signal routing for the ITEM TEST function are illustrated in figure 7.

Therefore the essential features of the BITE philosophy developed for the Concorde AFCS may be considered as:

- BITE with a nominal increase in computer complexity of 10%
- BITE organized to check integrity features, redundant facilities for mandatory requirements and analogue signal chains to aid flight line diagnosis
- Central organization by digital processor having good autotest facility
- When supported by simple manual checks correct fault diagnosis is expected to be 75 to 85%
- LRU contains own decode, test stimuli and encode functions
- Impact on aircraft wiring at a minimum
- Data transmission has a high noise immunity

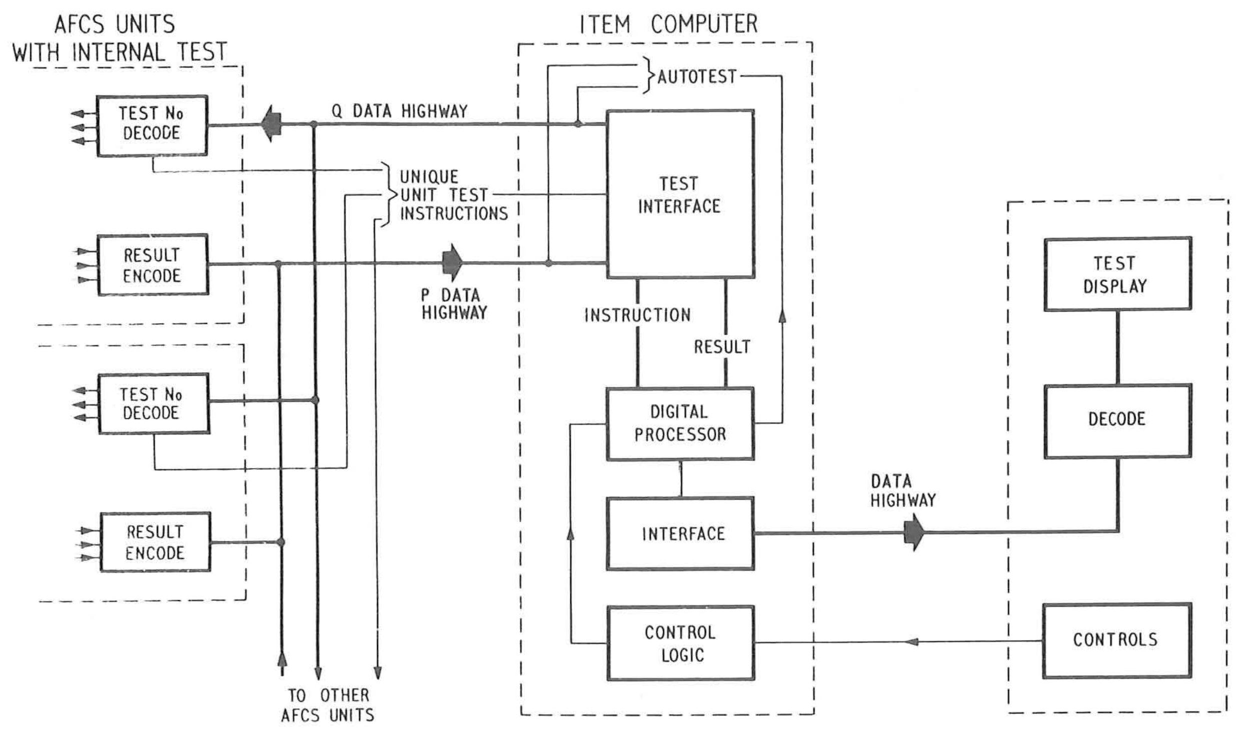

Figure 7 Principle of Central Organization of Distributed LRU BITE

DESIGN OF HARDWARE - IMPLEMENTATION

The concept of BITE and IFM developed for the Concorde AFCS requires that the implementation is considered under three distinct headings:

- BITE within individual electronic LRU
- Design of the central organization, ie ITEM computer
- Presentation and operation of Display/Control facility

The previous section stated that economic and physical considerations suggested that the limit on the amount of additional electronics for BITE in individual electronic LRU should be of the order of 10%. Figure 8 illustrates a typical example of how the additional electronics have been implemented. To ensure a successful test can be carried out, independent of sensor input conditions, transistors Q_1 and Q_2 isolate the sensor input by stimulus ST1 (which is common to all sensor inputs). Test stimuli can then be applied to the signal chain via R_1 to check the succeeding signal path. By the choice of suitable scaling, the stimuli may be used to check the threshold of the comparators/level switches and the outputs of these devices being encoded to give a test result on the P data highway. The test sequence is initially configured to validate comparator operation to a 20% accuracy either by direct injection of stimuli into the comparator input or via the preceding signal chain. Although figure 8 illustrates a single test level, more complex stimuli are used where necessary, eg a ramp voltage to stimuli

decreasing radio altimeter signal. Where the signal chain is a complex transfer function, then it is necessary to examine the state of the various level detectors and comparators using a "window" technique but since the central ITEM computer has a clock with an accuracy of 1 part in 10^4 this does not present a problem. The test duration varies between 0.2s and 240s with a programming resolution of 10 μs. To conserve the integrity between command and monitor lanes separate stimuli and decode interfaces are used. The amount of additional hardware added to analogue computing cards is usually less than 5% and the total complexity added to an LRU for BITE is between 11 and 26% with an overall average for electronic LRU of 15%. By applying the test stimuli at the point shown, only resistors Ra and Rb and the associated connections from the input pins of the unit remain untested.

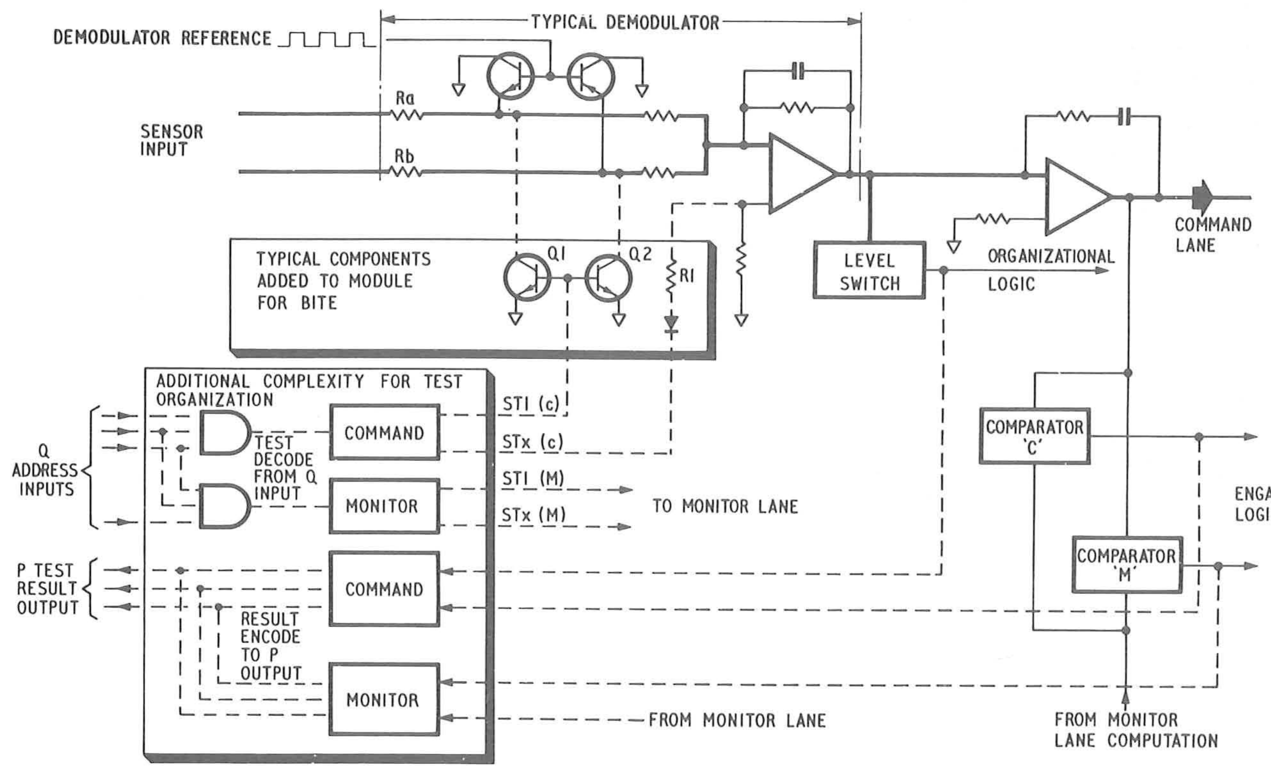

Figure 8 Typical Example of Detailed BITE Implementation

In addition to their use at the flight line, the test stimuli, encoded results together with level switch and comparator outputs (which are usually available on the computer front panel connector) provide a useful aid to fault diagnosis in the repair shop with a view to locating the suspect module.

When considering the choice of technology to be used for the central organization of the Concorde BITE, two basic options were available:

- A hard wired device using conventional combinational logic
- A small digital processor

Although the latter solution introduced a new technology into the AFCS, it was adopted because it was possible to utilize two features that were considered essential to the success of the concept of both IFM and TEST functions.

- The capability for an effective autotest routine to ensure a high confidence level in the indicated result
- A reasonable degree of flexibility in the reorganization of test programmes following development modifications to the AFCS.

Because of the simple nature of the problem (essentially COMPARE, WAIT, JUMP and DISPLAY are the major processes involved), it was possible to configure the machine with only 8 basic instructions using a single 16 bit word containing both INSTRUCTION and DATA. The block diagram of the processor is illustrated in figure 9. The programme store is implemented in EPROM (Electrically Programmable Read Only Memory) and has a total of 2048 words each of 16 bit utilizing parallel working. In addition 1024 words are provided as a store modifier to permit incorporation of minor programme modifications, this facility being utilized by reprogramming the EPROMS that are fitted or to exchange the Memory Modifier module.

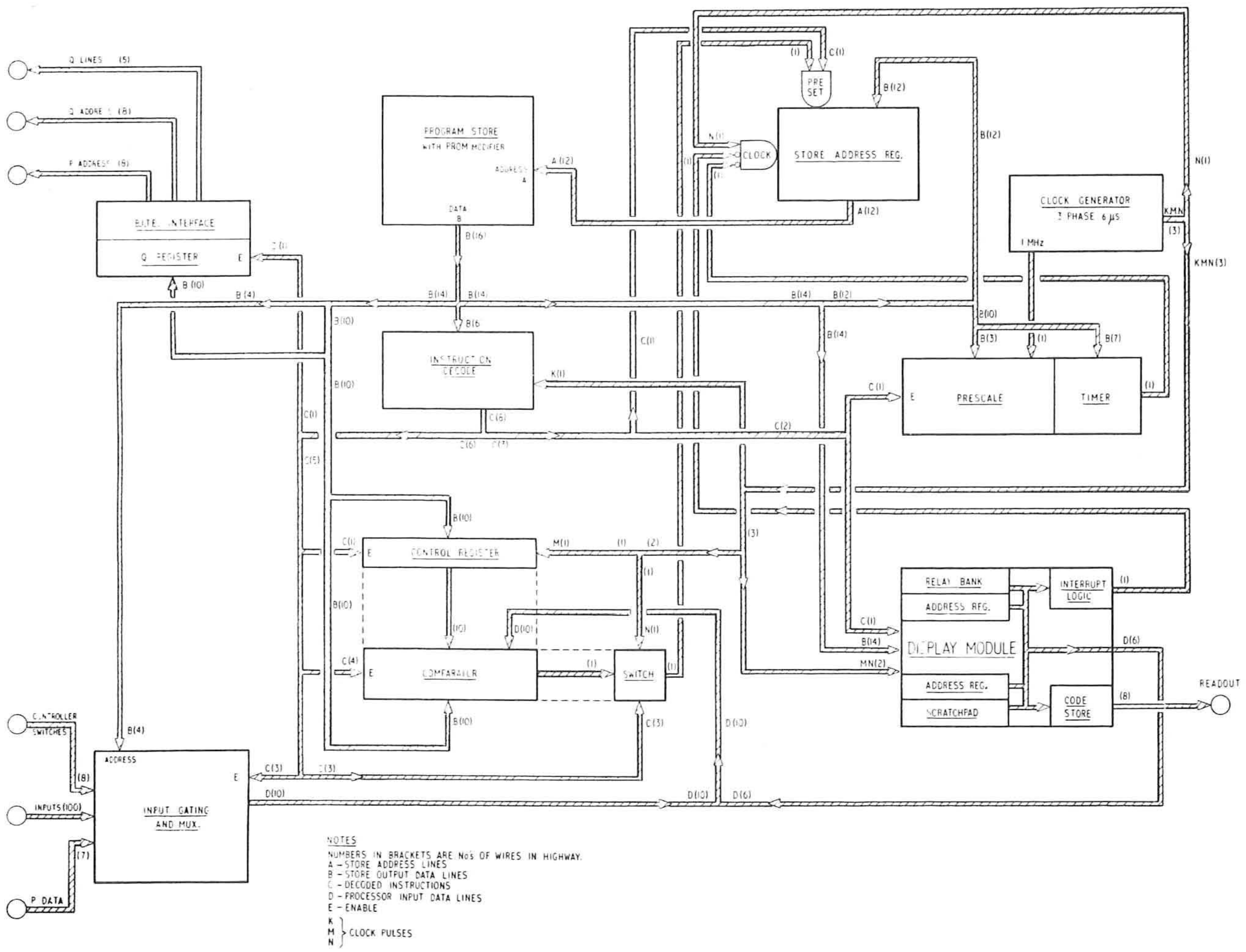

Figure 9 Functional Block Diagram of ITEM Computer

A large amount of the ITEM computer is concerned with input and display interface and particular attention has been paid to ensure that the TEST function cannot be activated in flight. The built-in autotest facilities of ITEM utilize 1% of hardware and 20% of software and achieve a confidence level of 99% and 91% in the TEST and IFM functions respectively. To improve the fault location of ITEM at the shop level, a number of the modules are fitted with Light Emitting Diodes as fault annunciators and a special buffer module has been fitted to permit the internal data highways to be brought out on the unit front test connector so enabling an AUTO DIAGNOSIS to be achieved without special automatic test equipment.

The IFM function is continuously cycling in flight with a 200 µs period examining the interlock state until a system disconnect occurs when simple decision taking logic takes place. A simple example is shown in figure 10 the time between scan diagnosis being typically 5 ms with the WAIT period being 50ms to confirm the diagnosis. The IFM result is passed to a non-volatile store so that the in-flight result can be recalled on the ground.

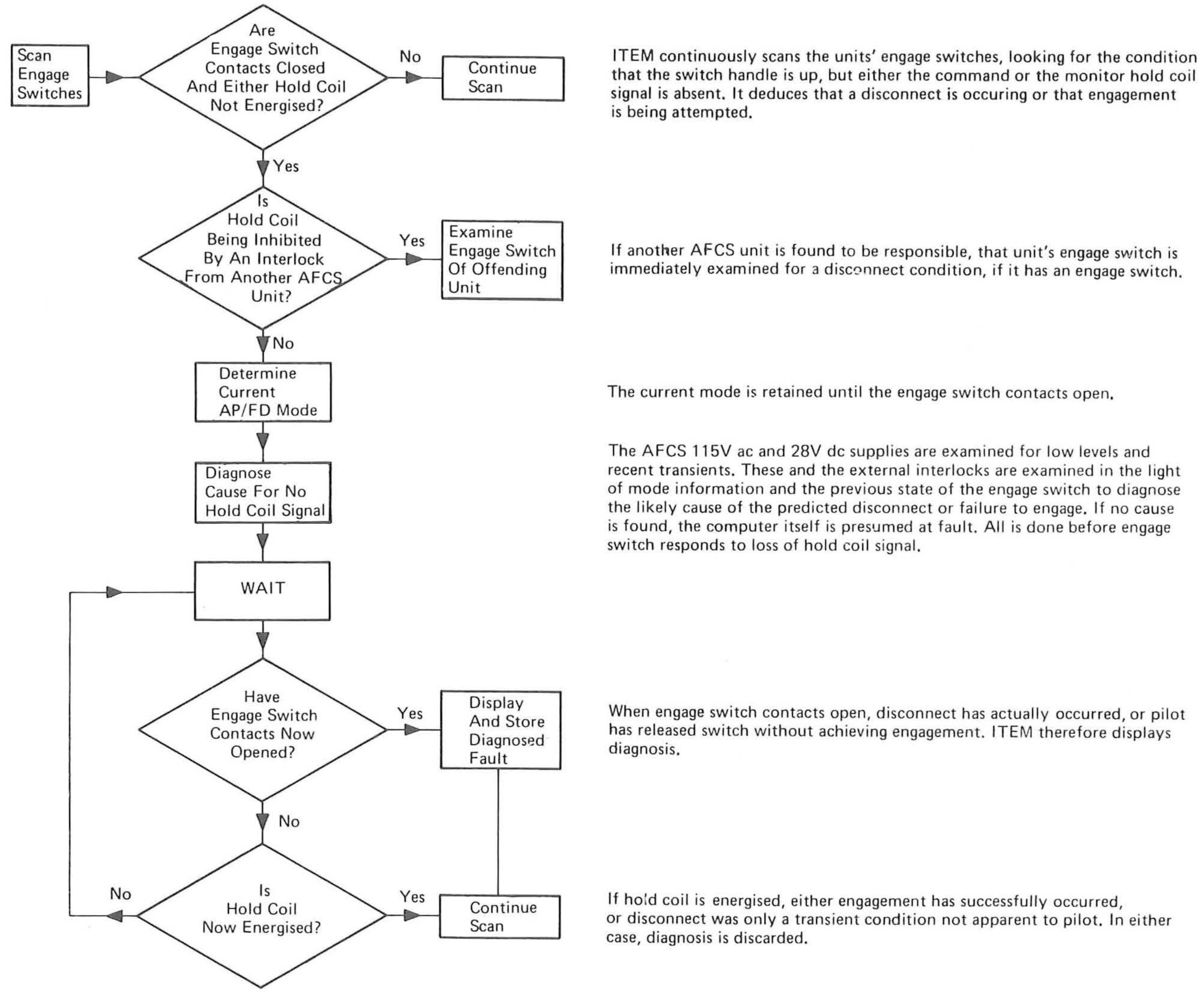

Figure 10 Simplified IFM Flow Chart

Since a traditional reason for loss of AFCS is transient conditions of the aircraft supply it was decided to indicate power supply failures. This necessitated the design of a power supply for ITEM which remained operational at a voltage level lower than that at which the AFCS would disconnect.

Figure 11 shows the ITEM computer, it contains 15 modules and has a weight of 5.4 Kg.

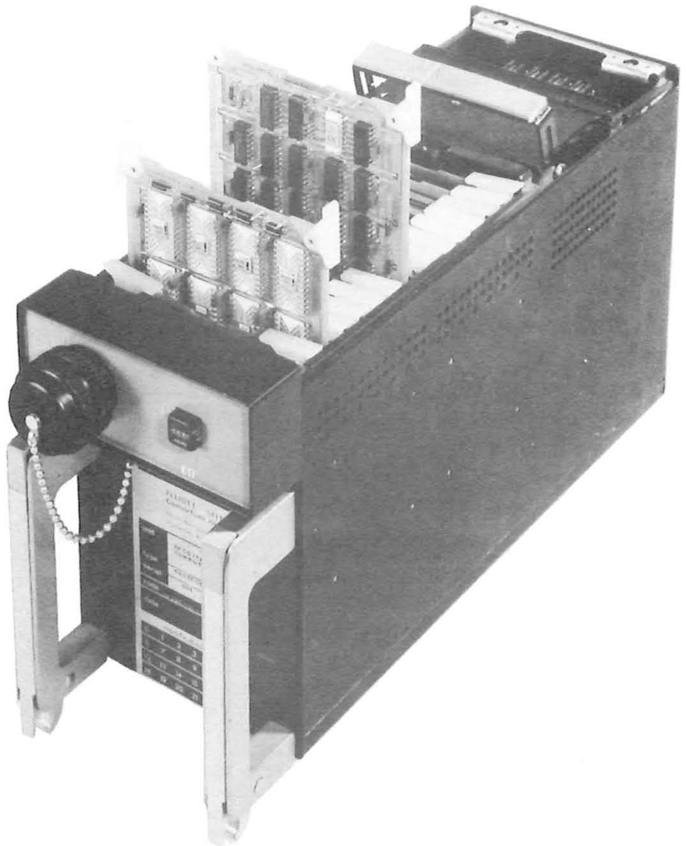

Figure 11 Concorde ITEM Computer

The Dual Channel Control/Display Unit associated with ITEM is illustrated in figure 12 and the upper half is concerned with the In-Flight IFM function whilst the lower is used to organize the AFCS LRU BITE when the aircraft is on the ground. It is symmetrical between left and right for Channel 1 and Channel 2 respectively. Each channel has four 11 way indicators, two for IFM function (21 possible indications) and two for TEST (49 possible indications).

When selected to the in-flight configuration the IFM autotest is automatically initiated (approximately 40s when the word ITEM will be displayed). Should a system disconnect (or engagement not be possible upon initial selection), then the suspect system will be displayed, eg ADC, IN, A-STAB-P etc. and this indication at the same time will be passed to the permanent store. Should this indication be the result of an incorrect crew operation (eg Autopilot disconnect due to pilot disconnect of an associated Auto-

stabilizer axis), then it is possible for the third crew member to remove the indication and erase the store by operation of the switch to CANCEL. In the event of a second IFM indication appearing then the first indication will be removed and the new indication presented. At any time it is possible to read all stored IFM indications by moving the switch to the READ position. At any time in flight the auto-test function may be initiated by momentarily selecting the IFM switch to the OFF position. The data highway and all IFM indications may be tested at any time by the TEST IFM INDIC function which causes all IFM indications to cycle in turn.

Figure 12 Control/Display Unit

The TEST function is only operable on the ground and upon selection initiates a 2 minute delay for the autotest of the ITEM TEST function and the analogue circuits within the individual LRU to stabilize to a quiescent state. Following this, the test procedure will automatically sequence through each unit in turn if selected to TEST ALL and the end result 19 minutes later will be "ALL PASS" or in the event of failure then the title of the failed unit is presented. (Should more than one unit fail, then the units will be sequentially presented).

Should it be required to initiate the test on a single LRU then the function switch is set to TEST UNIT and the SELECT switch operated when units will be sequentially displayed. When the desired unit is indicated the test is then initiated by selecting START.

ACHIEVEMENT OF OBJECTIVES

As the system concept described in this paper will not be exposed to airline experience until Production Aircraft No. 3, achievement of the objectives must at this point in time have an element of conjecture. Already, it is apparent that ITEM will make a significant contribution to minimizing the cost of owner-ship at the flight line without an undue penalty of either complexity or capital investment.

The predicted improvement in overall flight line maintenance in comparison with contemporary systems for a typical AFCS is illustrated in figure 13. The overall improvement results from:

- Improved in-flight information IFM.
- More direct and accurate information on which to initiate corrective flight line maintenance
- Better facilities for on board testing of major LRU by BITE to reduce the unconfirmed defect rate at the shop level

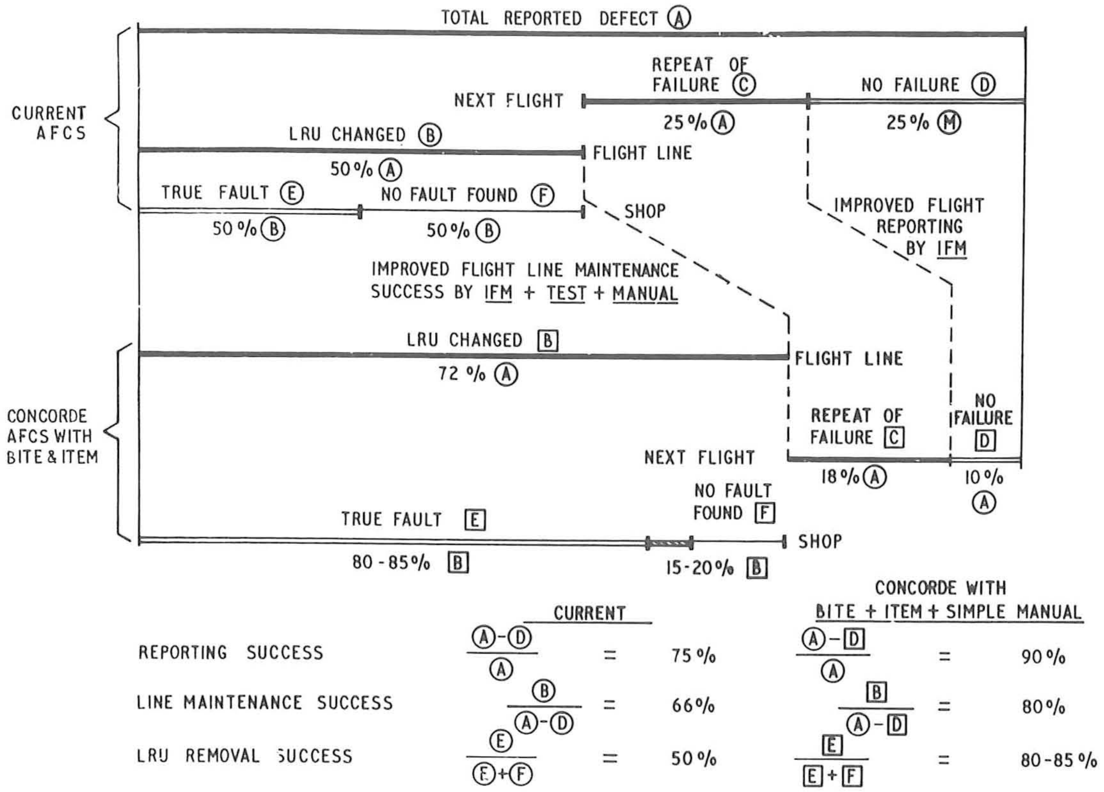

Figure 13 Predicted Success of Concorde Flight Line Philosophy

Achievement of the suggested results will depend on the necessary disciplines being adopted by both flight and line maintenance personnel and on the success of the simple manual testing necessary to support the automatic facilities but the proposed tests are simple to initiate and the results obvious, eg Light 'x' should illuminate or Throttle levers should move forward etc.

It is acknowledged that many of the faults not located with this philosophy will be those areas which are traditionally more difficult to locate but it is confidently expected that the philosophy will locate 75 - 85% of the faults arising. Figure 14 illustrates the decision taking process associated with this philosophy.

A detailed examination of the Autopilot/Flight Director Pitch Computer, which is one of the more complex electronic LRU, shows in detail the impact of the Concorde BITE philosophy and is presented in figure 15, Table 1 summarizes the expected results for all AFCS units tested by ITEM using BITE. The confidence level of the TEST function within ITEM is 99% and since the majority of faults in the data highway are either detected or would give simultaneous erroneous results for all the units the

overall confidence level of the Central Organization will be high. A failure in the LRU BITE hardware will normally indicate a failed LRU. The configuration of DECODE, STIMULI and ENCODE being such that an incorrect indication of a healthy LRU when there is a true fault is remote.

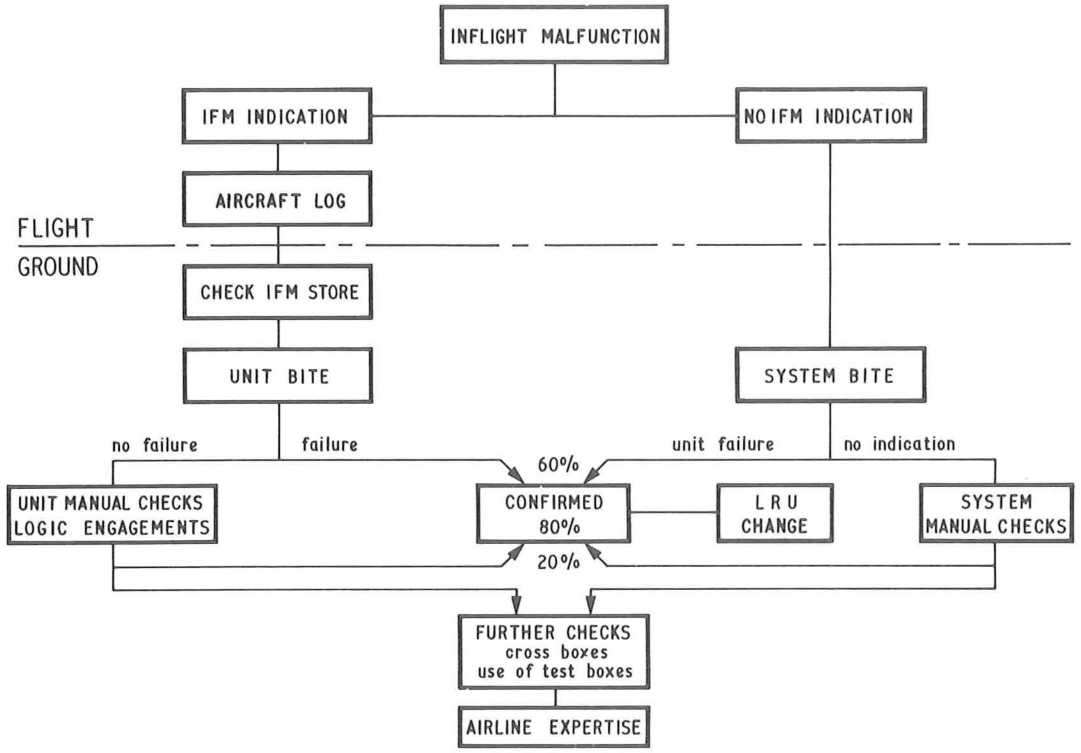

Figure 14 Fault Location Technique

The effectiveness of the IFM function relies on three main features:

- The total amount of possible channel failure rate indicated by the data taken into the ITEM IFM function, eg in automatic landing this is approximately 89 % of the total possible failure rate which would cause the channel to disconnect.
- The accuracy of individual failure flags of sensors. It is clearly not possible to ensure that all failures which would cause a downstream unit to disconnect are monitored by the sensor internal flag logic but a typical confidence level of the warning flag logic of the essential sensors is 95%.
- The accuracy of the IFM function within ITEM itself. Due to the detailed interface check and the autotest routine, it has been possible to obtain a confidence level up to 99 %

Thus the probability of a correct IFM indication is the product of these three features and will be in the region of 83 %.

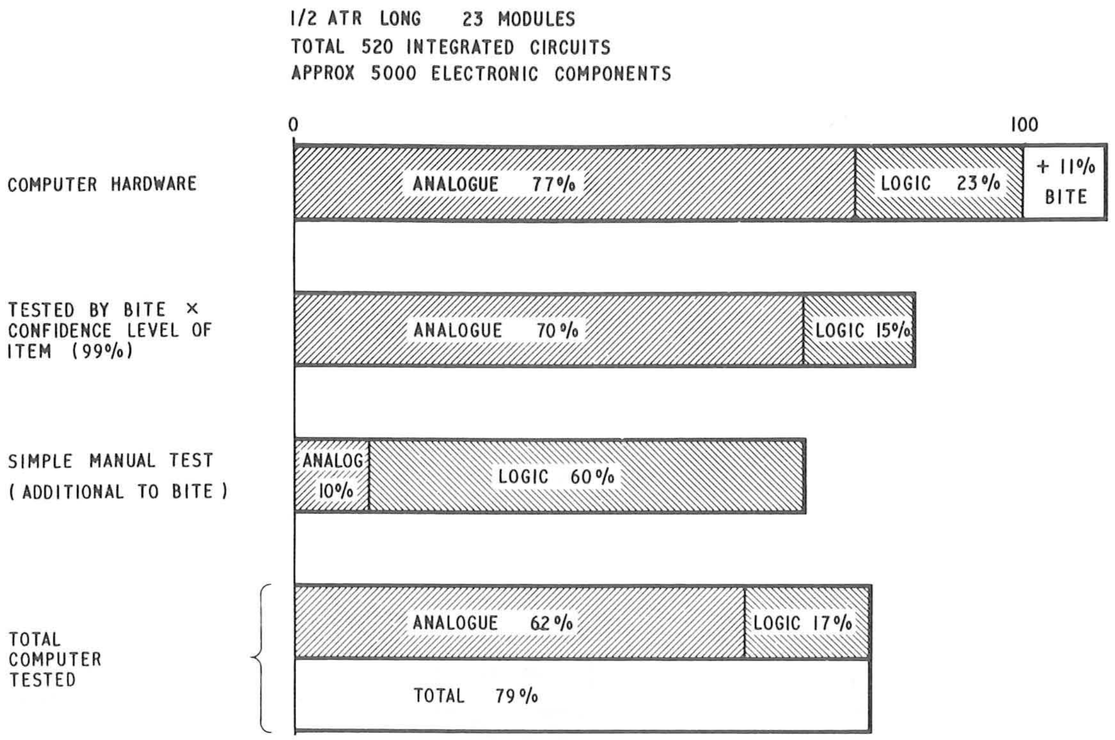

Figure 15 Test Confidence Level of Pitch Computer

Thus it is confidently believed that the combination of IFM + BITE + SIMPLE MANUAL testing will significantly improve present day flight line fault location techniques and the achievement suggested in figure 13 is realistically achievable if the correct disciplines are applied.

Consideration of the achievement of the design objectives would not be complete without considering the commercial impact of the additional complexity. Analysis shows that for the 7 Electronic computers, 3 Rate gyros and 2 Accelerometers associated with each AFCS channel, the overall impact of including BITE has been:

- 14% increase in overall complexity of units tested (10% for overall AFCS)
- 5.6% increase in unit weight
- 7% increase in the prime cost of the tested LRU (5.5% for overall AFCS)

These figures are pessimistic as a penalty for BITE hardware, since it is believed that a significant amount of this increase would have been necessary to ensure satisfaction of the system integrity requirements. If one adds the penalty of installing a Dual Channel ITEM system, then the overall impact of the Distributed BITE with Central Organization is:-

- 17% increase of total complexity of the AFCS
- 10.3% increase of total system weight (including additional 1.8kg of aircraft wiring associated with the ITEM system)
- 12% increase in total cost of AFCS

Clearly the impact of an additional 12% of system investment is of importance. If one considers a fleet of 5 aircraft (ie 10 installed computers of each type) with 4 spare units and the philosophy permits a reduction in the spares holding from 4 to 3 units for the same fleet size, examination shows that the total capital investment for prime fit and spares in each case is the same to within less than 1%. This reduction in the level of spares provisioning is not considered over optimistic for the expected reduced unscheduled removal rate of LRU.

Any other financial savings accruing from this philosophy can only be to the benefit of the operator and whilst the financial savings of quicker flight line fault diagnosis and reduced despatch delays will be obvious, there will be other secondary savings such as unnecessary LRU handling, reduced investment in flight line test equipment, less ATE time required for the AFCS and it is confidently believed that the maintenance philosophy developed for the AFCS will be cost effective to the Concorde operator.

Unit (Electronic Computer)	Hardware Configuration			Tested by BITE		Manual Test		Total Tested (1)	Remarks
	Analogue	Logic	Addition BITE	Analogue	Logic	Analogue	Logic		
Autopilot/Flight Director Pitch	77%	23%	+11%	70%	15%	10%	60%	79%	BITE also used for test of automatic landing (3)
Autopilot/Flight Director Azimuth	76	24	+15	64	16	14	55	76	(3)
Autostabiliser	86	14	+26	63 / (2) 81	69	5	5	69 / (2) 81	Separate BITE for each axis. BITE also tests gyros and accelerometer
Autothrottle	74	26	+11	84	8	5	64	84	BITE tests accelerometer
Electric Trim	78	22	+20	55	11	25	75	82	
Safety Flight Control	70	30	+12	69	13	10	40	71	
Warning and Landing Display	-	100	+17	-	55	-	26	81	BITE also used for pilot test function

(1) Hardware tested excludes BITE hardware

(2) Amount tested including rate gyros and accelerometer

(3) Separate test indications for Autopilot and Flight Director also Cruise and Automatic Landing

Table 1 Expected Success Rate for Concorde Electronic LRU

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