AVIONICS FAULT DATA ACQUISITION / A CONCEPT FOR CIVIL TRANSPORT AIRCRAFT

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ABSTRACT

Airborne centralized maintenance systems improve the efficiency of avionic line/ramp maintenance. Architecture and operation of such a system, developed for AIRBUS A320, is presented. The final chapter highlights what has to be achieved in order to use centralized maintenance systems as the data acquisition part for maintenance expert systems.

1. Maintenance Cost

Airlines prime objective for fleet modernization is to sell seat/cargo - miles with a healthy profit margin. There is no room for self complacency about technological advance if it does not go along with a reduction of operating cost.

Fig. 1a shows the cost elements involved. It shows direct maintenance cost derived by the analytical method of the Association of European Airlines;

Fig 2b shows an estimate of overal maintenance cost plus cost involved in matters directly linked to maintenance efficiency such as a dispatch delays, flight cancellations, AOG, test and repair resources etc.

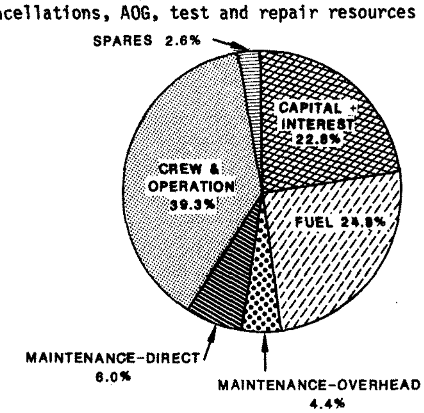


Fig 1a Direct Maintenance Cost

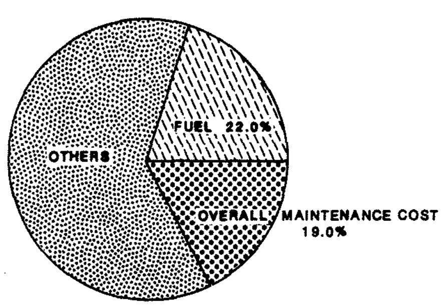


Fig 1b Overall Maintenance Cost

Of course progress must continue on crew/operation cost as well as specific fuel consumption. Nevertheless maintenance cost is not neglectable. In fact it approaches the cost of fuel. This paper concentrates on the approach chosen by AIRBUS Industrie to improve line/ramp maintenance efficiency.

2. Ramp/Line Maintenance

Past experience has been critically reviewed for potential improvement. The following items have been retained :
- No common denominator in BITE (Built In Test Equipment) concepts due to lack of standardization among equipment suppliers concerning :
  . Bite activation procedures
  . Bite display (instrument flags "Christmas trees", alphanumeric codes etc.)
  . Utilization/Necessity of ramp testers ; sometimes linked to LRU front panel test connectors.

- Necessity for mechanics to enter equipment bays to gain access to trouble shooting information on LRU front panels and verify part number/modification status.

- Only partial access to a complex system for trouble shooting (e.g the avionic bay). Therefore need to visit different areas. Mechanics are tempted to swap or replace most accessible units rather than follow a logical fault isolation approach.

The consequences are :
. high frequency of unjustified removals
. high investment in spares pipeline
. high frequency of unnecessary shop visits
. excessive investment in shop testing;
. need to carry bulky maintenance handbooks on board
. need for more training - especially for outside station personnel
. aircraft dispatch delays.

3. Centralized fault dispaly system (CFDS)

As a remedy for the problems outlined in para 2, a CFDS has been developed for AIRBUS A320.

How does CFDS improve the situation :

1. Consistent concept of fault display on 2 redundant Multi purpose Cathode ray tube Display Units (MCDU) on the flight deck
   - by display in plain English and standard abbreviations,
   - by self explanatory menu selection.

2. Monitoring of all systems /units capable of sending BITE info on a digital data bus (ARINC 429 DITS)

3. Reduction of hand written record keeping by use of an optional multi-purpose printer on the flight deck.

4. Easy configuration control by display and print of LRU part numbers. A part numbering system has been developed that reflects requirements dictated by the principle of On Board Replaceable Memory modules (OBRM) on some computer LRUs.

5. Access to equipment bays required only for replacement of defective LRUs identified by CFDS.

6. Reduce quantity of ramp test equipment.

7. Reduce ramp level trouble shooting documentation to a pocket size book.

8. Automatic logbook-like printout of failure events after flight.

9. Compatiblity of CFDS with :
   . AIDS (Aiborne Integrated Data System)
   . ACARS (ARINC Communications Addressing & Reporting System) or equivalent data link

4. CFDS Architecture

4.1 CFDS includes basically (Fig 2) :

- A central computer the CFDIU (Centralized fault Display Interface Unit) installed in the main electronic rack, which dialogues with the electronic systems of the A/C.
- Two ARINC 739 MCDU's (Multipuprose Control Display Unit) used also for FMS, AIDS and DATA LINK, which dialogue with the CFDIU for display of maintenance information or initiation of tests.
- Note : CFDIU is only a message switching device connecting the MCDU'S with each system. The intelligence required for detecting the failures , processing the corresponding maintenance data and formatting messages to be displayed on the MCDU is included in each avionic system.

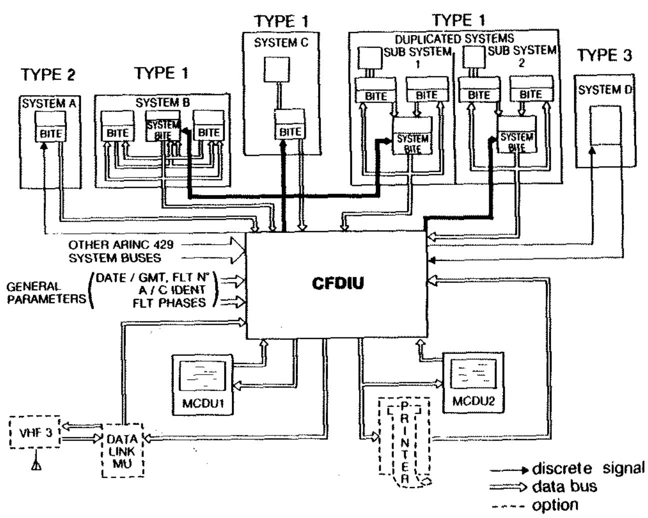


Fig 2 CFDS Architecture

CFDS may also be connected to optional equipment :

An ARINC 740 MULTI PURPOSE printer (used also for FMS, AIDS and DATA LINK) to print in the CKPT all CFDS information available on MCDU.
- A DATA LINK management unit to send to ground, in real time, the failure messages.

4.2 Type of systems connected to the CFDS :

- All avionic systems, except GPWS, are connected to the CFDIU (see list in appendix).
But in a complex system (duplicated system E) advantage is taken of crosstalk between units to minimise the number of buses required for the interface with the CFDS by providing a single "SYSTEM BITE" interface.
- Maintenance information is sent on general system output bus (no need for specific maintenance bus);
- 3 types of system are connected to the CFDIU (see fig. 1 and appendix)
  . Type 1 - Systems with and ARINC 429 digital data bus input dedicated to maintenance and an ARINC 429 output.
  . Type 2 - Systems with an ARINC 429 output but no specific ARINC input. For these systems, discrete input signal(s) are generally provided, which can for example :
    - initiate a test
    - initiate transmission of data additional to the line maintenance information.
  . Type 3 - Systems with neither an input bus nor an output bus, and for which a limited number of discrete links are provided.

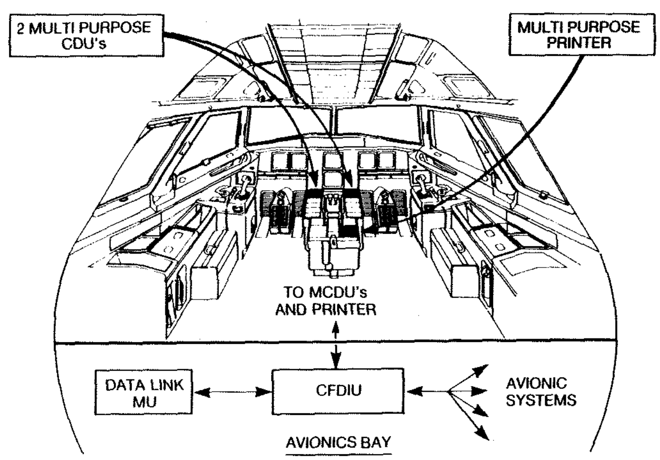
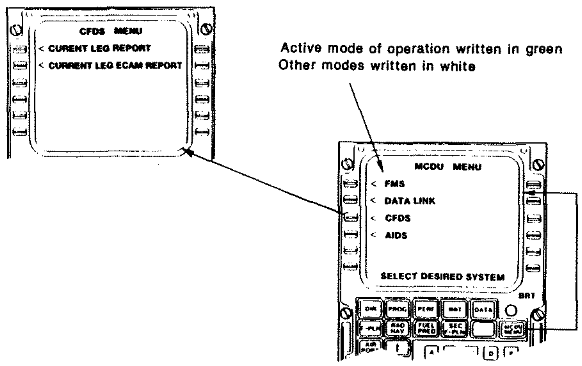


Fig. 3 Component Location

4.3 CFDS MENU

Fig 4 CFDS menu IN FLIGHT (limited number of functions)



As CFDS is primarily a maintenance aid, the menu for in flight use is reduced.

Fig 5 "POST FLIGHT" report
- Concerns all systems connected to CFDS
- Is the sum of the "LAST LEG" and "LAST LEG ECAM" reports

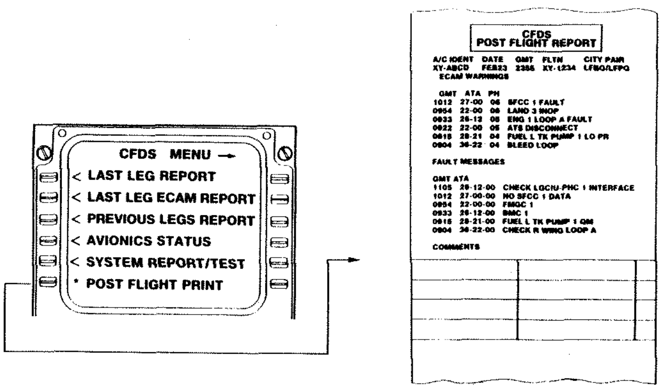
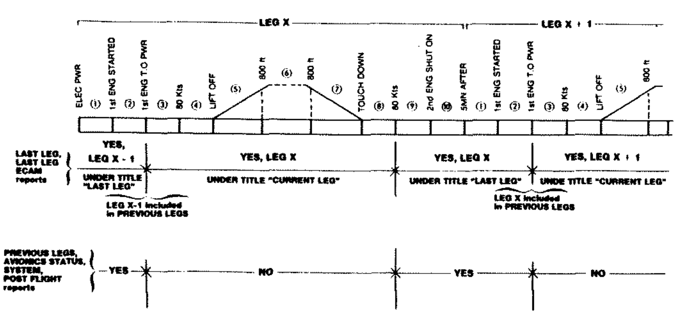


Fig 6 Availability of the reports listed in CFDS menu
- LAST (or CURRENT) LEG report, LAST (or CURRENT) LEG ECAM report
- OTHER reports and, in case of failure, BACK UP MODE available on ground after landing (When speed inf or = 80 KTS) and until 1st ENG T/O POWER application



In the following reference is made to "CLASS 3" failures.
These equipment failures
- are not indicated to pilots
- can be left uncorrected until a scheduled maintenance check per maintenance planning document.
- a list of these failures is accessible on :
  . MCDU with the AVIONICS STATUS and SYSTEM REPORT pages
  . Printer (hard copy of MCDU pages)

Fig 7 "AVIONICS STATUS"

- Concerns all systems connected to CFDS
- Displays real time the list of systems affected by an internal or external failure.

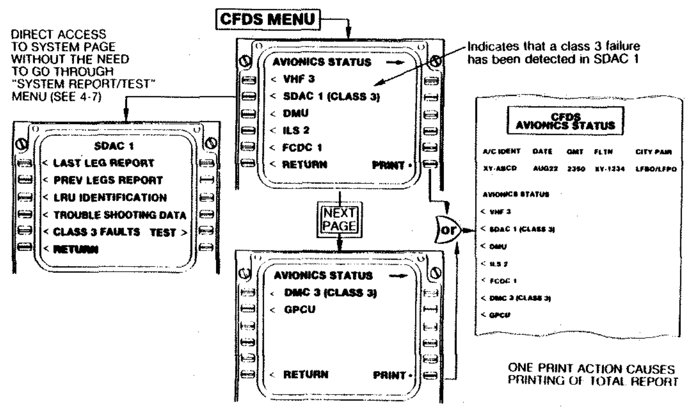
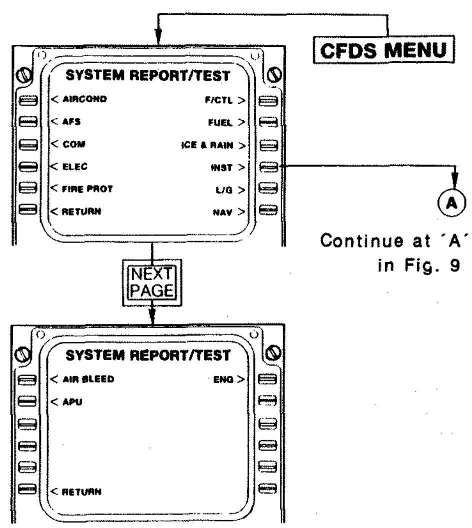


Fig 8 "SYSTEM REPORT/TEST

Main system menu :
- allows access to all computers linked to CFDS
- "SYSTEM REPORT" varies depending on system type ("TYPE 1, TYPE 2, or TYPE 3" see def in para. 4.2)



Continue at 'A' in Fig. 9

Fig 9 "TYPE 1" SYSTEM REPORT (example SDAC 1)

- "TYPE 1" system menu is generated by the system itself and includes :
  . LAST LEG REPORT
  . PREVIOUS LEGS REPORT
  . LRU IDENTIFICATION

- Other menu items are displayed only if required by system architecture (List given for SDAC 1 does not cover all possible menu items)

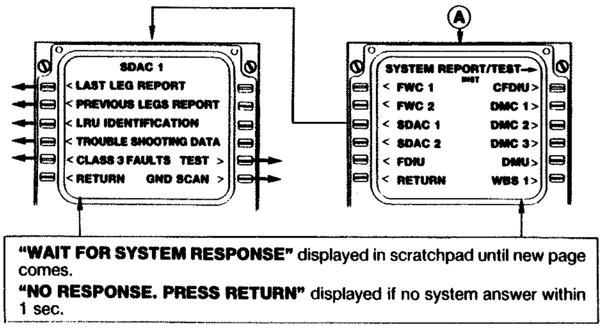


Fig 10 "TYPE 1" SYSTEM REPORT - Cont'd

- The system "LAST LEG REPORT" and "PREVIOUS LEGS REPORT" concern a dedicated system only (here SDAC 1) and have to be diffentiated from the general "LAST LEG REPORT" and "PREVIOUS LEGS REPORT" shown in Fig 5

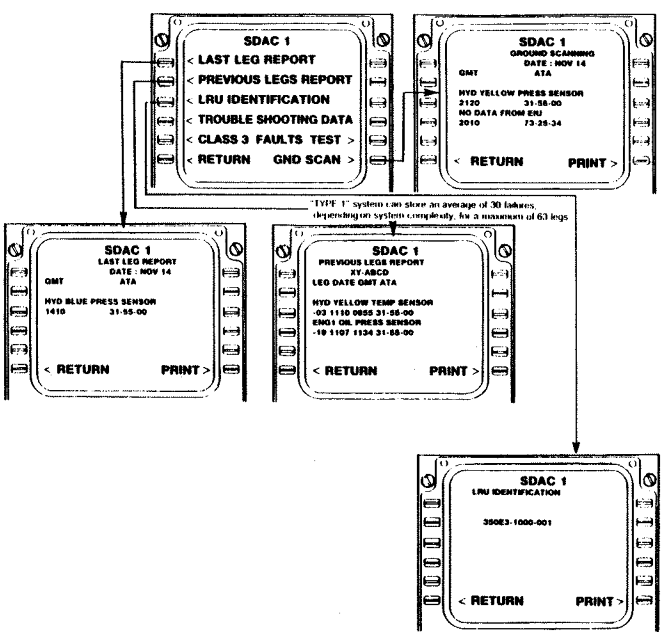
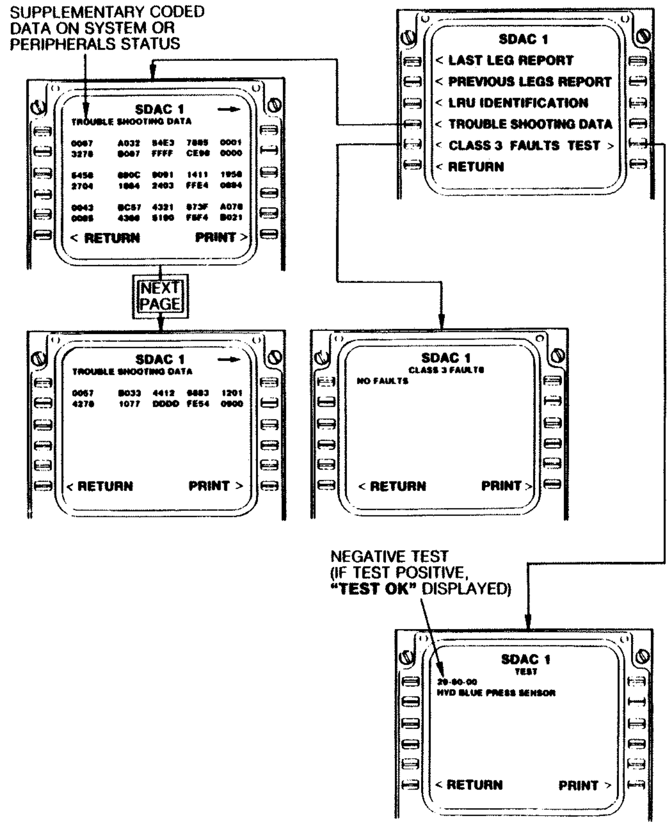


Fig 11 "TYPE 1" SYSTEM REPORT (Cont'd)



5. Outlook to the future

Progress in artificial intelligence research brings "expert systems" within reach for maintenance diagnostics. Expert systems consist of two main elements :

- A data base of human knowledge
- An inference system which is capable to explain it's own reasoning.

Some precautions have to be taken before applying inference systems.
Otherwise they can act as "nonsense amplifiers". The following introduces the theorem of paranoid system behavior as an example

$$I_{out} = f(I_{in} \times D) - f(C)$$

with I : Irrevelance of Data
D : Depth/soundness of reasoning of a system using irrevelant input data (D inf. 1)
C : Capability of a system to assess the relevance of input Data

The deeper the reasoning of the system, the more convincingly the system will justify it's non sensical outputs (decisions, conclusions) caused by nonsensical/irrelevant input data (paranoid behavior).
Ressemblance to human behavior :

The mania of being persecuted is a typical example of paranoia.
People suffering from this mania are extremely logic in explaining why and how they "are" persecuted. The problem is adequate perception of the outside world (wrong input data).
An inherent capability of an inference system to detect/reject irrevelant input data is conceivable. However such a capability can reduce input data below the minimum required. The result will be a degraded mode of operation or system halt.

5.2 Protection against paranoid behavior

5.2.1 The input data to a maintenance expert system will consist essential of BITE messages.

5.2.2 For satisfactory expert system operation the relevance of BITE data must come very close to 100 %

5.2.3 Experience with the a310/767 aircraft generation shows that the whole industry is still far from achieving a quality level of BITE data meeting the requirement of items 5.2.2

5.3 Today's BITE - What has to be improved :

5.3.1 BITE generally worked well on small subsystems and selfcontained systems. For such systems BITE relevance usually exceeds 50 %.

5.3.2 However there is room for improvement of BITE for interactive complex systems on the higher system level. Such systems are characterized by :
- Multiple nested control loops
- systems composed of equipment developed by different suppliers.

For such system the relevance of BITE can drop to 50 %.
Fig 12 shows the causes thereof. AIRBUS Industrie's objective is to eliminate these causes in order to achieve the quality of BITE data required for use by expert systems.

Fig 12 Callay's Column

20 % inadequate interpretation of BITE messages by aircraft operator e.g defect or abnormal events;

25 % conceptual short falls of BITE e.g lack of software instrumentation, probabilistic conclusions rather than causalistic ones, design to testability etc.

35 % insufficient specification of monitored system (including systems periphery) available to designer of BITE

20 % BITE development running behind modifications of the monitored system and it's periphery

CONCLUSION

1. Support of BITE development and modification follow up have gotten higher rank on design offices priority lists;

2. BITE must be able to distinguish between hardware defect and abnormal event not linked to hardware efficiency. The causes of abnormal events must be identifiable by BITE and software instrumentation.

FINAL CONCLUSION

- On the airborne maintenance data acquisition side a system will enter service in early 1988.

- An analytical effort will be made in order to assess the relevance of BITE data available via CFDS. It should be understood that based on the first months of service experience some fine - tuning of BITE - software may become necessary.

- Once service operation has proven a satisfactory quality of BITE data, a decision can be made of how to support the development of a maintenance expert system.

- The ATA 100 system breakdown has become meaningless for modern highly interactive control systems. A completely different concept has to be developed sooner or later, for use with expert systems. The author is working on a proposal.