Conduct of Flight Tests and On-Board Computing for the A380

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SUMMARY

The Airbus way of management of the flight tests activity limits the flight test crew to two pilots, one flight engineer and one (or two) flight test engineer (FTE). The latter is in charge of the flight test program and has to conduct the tests sequences during the flight, in order to validate them, on both qualitative and quantitative aspects. To perform theses tasks, a dedicated station is installed on board the aircraft, first fitted with classical electro-mechanical instruments on Concorde or A300, then becoming entirely computer-oriented on the A380.

As a consequence of the reduced flight test crew, Airbus developed the telemetry techniques, allowing dynamic message adaptation to the test sequence, as well as deferred data transmission when the aircraft is outside the coverage area.

In order to minimize the flight test data reduction time, a dedicated set of computers has also been installed on board to execute automatically a lot of pre-processing tasks.

Since the first A300 up to the A380 and A400M, Airbus acquired a broad knowledge of on-board computing, using now standard computers hardware, software and network techniques to provide tests teams with powerful tools.

1.0 INTRODUCTION

The Airbus Flight Test Centre is located in Toulouse (France) and uses facilities as well as methods and tests activity management principles put in place since decades. To that respect, the flight test crew is limited to few people on board, with only one (or two) Flight Test Engineer (FTE). The FTE is in charge of the flight test program, and has to conduct the tests sequences during the flight. To achieve this mission, he is provided with a FTE Station, which allows him to display and/or monitor the aircraft parameters and FTI status, and to control and command FTI specific peripherals.

Here below are pictures of different FTE Stations generations starting with the Caravelle in the 50's. The first computer-equipped station was used on A310 in 1981: it was a specific real-time computer, hardly ruggedized for military purpose. With the A340 in 1991, VME chassis were designed with various microprocessors boards' types. In 2000 we chose again standard computers with standard Unix Operating System in a totally distributed architecture.
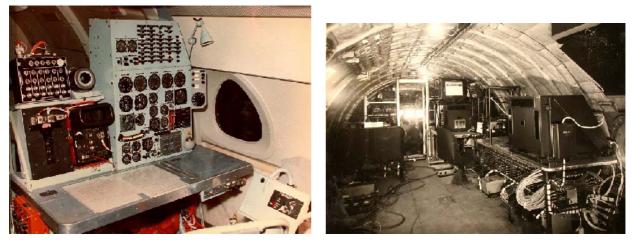
Figure 1: Caravelle (1955)

Figure 2: Concorde (1969)

Figure 3: A320 (1987)

Figure 4: A340 (1990)

Figure 5: A380 (2005)

2.0   A380 FLIGHT TEST INSTALLATION (FTI) ARCHITECTURE

The A380 is the first aircraft implementing a full IENA type FTI. IENA is a concept developed by Airbus of a full-networked FTI. It is based on a four-level architecture:

• L1 (Level 1): Sensor level

There is performed the data conversion from a physical input (pressure, temperature, force…) into a measurable electrical parameter, voltage or current. Some L1 system may integrate a part of L2 functions such as filtering, A/D conversion, etc.

• L2 (Level 2): Acquisition level

L2 systems deal with the analog, numerical and discrete acquisition; they perform the following tasks:

• For analog inputs: sensor driving, analog filtering, data sampling and A/D conversion, limited mathematical functions…

• For numerical inputs: label sorting, filtering

• Time stamping with respect to the global synchronisation (1 micro-second accuracy), data shaping in IENA packets, sorting of packets towards the destinations (groups of L4)

• L3 (Level 3): Concentration & Distribution level

L3 is the IENA-specific level; data flows coming from all the L2 are gathered there and forwarded towards the L4 systems. There is no data modification through L3; the only actions performed are commutation and duplication of the incoming frames. These functions are realised by standard Ethernet switches.

• L4 (Level 4): Recording and Analysis level

L4 systems are on board end-users of aircraft parameters:

- Mass data storage for on-ground post analysis

- On-board analysis computers, performing pre-treatment and display for Flight Test Engineers, as well as control/command for all the FTI peripherals.

- Telemetry functions

The Flight Test Data Base SABRE –in which the configuration of every system is traced– manages all the IENA systems. SABRE describes the long way of every aircraft parameter from the very beginning of its life (physical phenomenon) to its storage in IENA packets. SABRE maintains also the whole history of the parameters along the FTI life (sensors serial numbers, calibration files, drawing numbers, etc.). Thanks to the network architecture, all the components of the FTI can be downloaded from a single point using a laptop computer previously loaded with all the configuration files from the SABRE database.
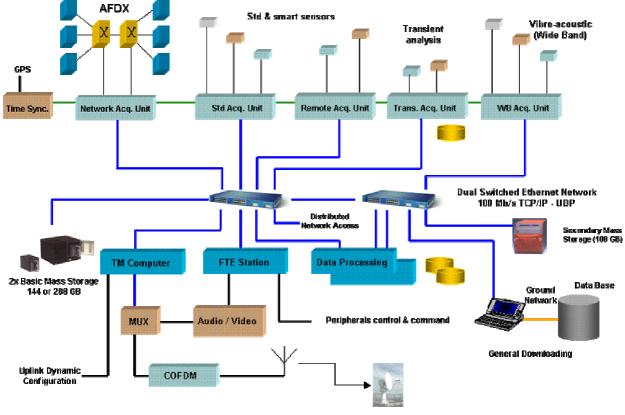

Figure 6 : IENA FTI Architecture

3.0   ON BOARD DATA PROCESSING FUNCTIONS

Thanks to this networked architecture, it becomes very easy to implement various modular functions accessing any of the acquired parameters. Four types of functions have been implemented on the A380:

- Flight Test Engineer (FTE) test sequences monitoring, using synoptic HMI

- FTI peripherals command & monitoring

- On board computing

- Telemetry message management

3.1   Test sequences monitoring

The A380 FTE station can accommodate two engineers and is then made of two identical halves. Each half-station comprises two upper level displays and one low level display. Additionally two Display Units allow each engineer to monitor the aircraft primary flight parameters (figure 7)
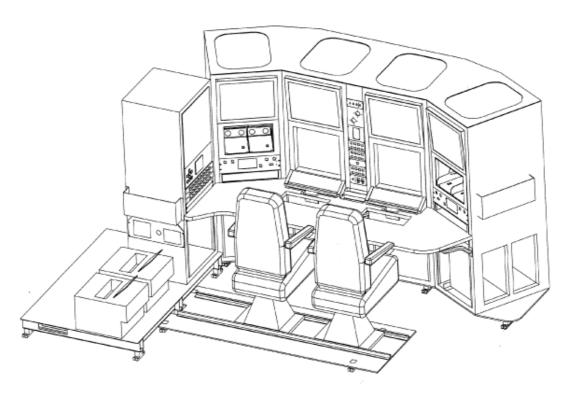

Figure 7 : FTE main station

Upper outside display may be used for video or computer display, inside upper display is used for computer display and lower display may be used for graphic recorder or computer display. Only two computer displays are allowed on the three displays. The configuration can be dynamically established by the FTE thanks to a dedicated computer menu.

A unique HMI has been designed to integrate all test monitoring applications (figure 8). It is made of several zones:

- Fixed zones:
  - Status zone: time and specific parameters table
  - General functions buttons and browsers
- Dynamic zone:
  - Specific visualisation (synoptic, tables, curves, etc.)
  - Interaction zone

In order to avoid too many open windows on the display, the dynamic zone where all test-monitoring applications are inserted uses thumbnails technique. Applications running in a hidden thumbnail are still running in order to allow the engineer to switch from one thumbnail to another in a click. The pointer is either a keyboard integrated trackball or a wireless mouse.
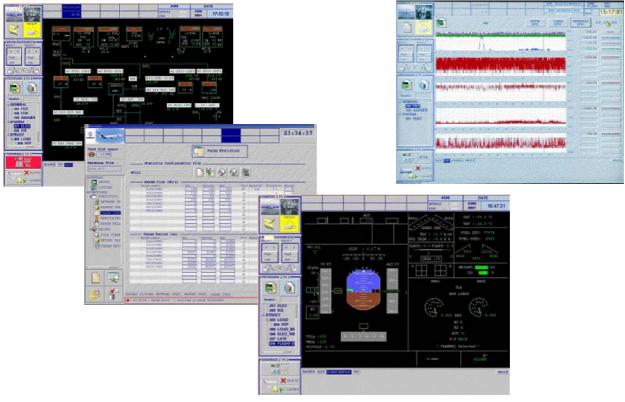

Figure 8: HMI

A dedicated PC computer drives the two computer displays, keyboard and mouse. The pointer can then be managed to move from one display to the other by the left and right-hand sides.

Dedicated applications are used to follow specific tests (flutter, performance, handling qualities, etc.), as well as generic applications, which allow the engineer to monitor anyone of the 200,000 acquired parameters (9,000 measurement chains), or to monitor the aircraft network (AFDX).

Thanks to the Fault Tolerant architecture described in chapter 4.4, these essential functions are always recovered in case of a hardware or software failure, with the same context as before the failure.

3.2 FTI command and monitoring functions

In order to give more flexibility and suppress a lot of dedicated switches on the FTE station panels, it has been decided to command the FTI peripherals from the computer, via graphical buttons using the pointer.

The associated hardware and software have been designed to secure these functions: in case of a computer failure, the external device remains in its present state until recovery.
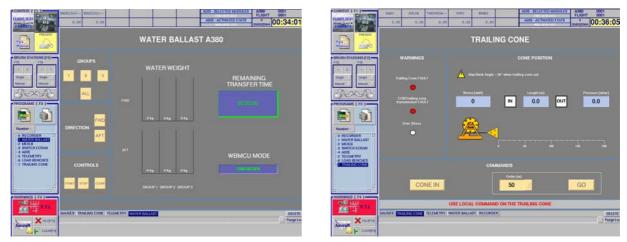

Figure 9: Peripheral command HMI

The controlled devices acknowledge the commands on dedicated serial lines, which are acquired by the FTI. These messages are then looped back to the computer, which can then update the display according to the actual status of the device.

3.3 On Board Computing

A way to avoid overloading the ground data processing centre is to perform as much as possible data processing on board. This has been achieved with a set of dedicated computers with associated removable storage disks. As mentioned earlier, there is a limited test crew on board, so that the data processing system has to be entirely automated.

The general scheme of an on-board application is:

- Condition monitoring (normal event or anomaly)
- On line data capture and storage around the event using circular buffers
- Off-line data processing
- Results storage on removable disks

Real time derived parameters calculation is not considered in this chapter, as it is a nominal function of the system: derived parameters are distributed on the network with primary parameters, allowing applications to use both.

3.4 Telemetry message management

Another way to make real-time data processing is to use telemetry. Due to frequency usage restrictions in Europe and to transmission techniques, it is not possible to transmit the whole set of acquired data thru the

telemetry link (40 Mbits/s sustained rate on board). Although the transmission bit rate has been increased up to 5 Mbits/s, it is not possible as well to use only one configuration of the telemetry message to fulfil all the tests items of a given flight. The idea was then to adapt the telemetry message configuration to the test sequence and to send the switching command from the ground station when necessary. The configuration is established by gathering together a set of generic and specific parameters lists. These lists are stored in the dedicated on board computer and activated thru a radio link by the ground station.

Another new feature of this system is the capability to store several minutes of flight, for example when the aircraft comes out of the range area. When the aircraft enters again the range area, a part of the bandwidth is allocated to non real-time data, which are then sent to the ground together with the real-time data-flow. The bandwidth allocation between real-time and non real-time data, audio and video is remotely controlled from the ground station.

4.0   ON BOARD DATA PROCESSING ARCHITECTURE

4.1   Principles

The design of the on board architecture lies on several main principles:

- Use of standard (ground) equipment

- UNIX and LINUX operating systems, in order to achieve easily near real time performances (1ms accuracy, low latency)

- Fault tolerant distributed architecture

4.2   Standard equipment

The on board environment doesn't require high-level specifications to be covered by the computing devices. It is then easy to find equipments fulfilling the environment constraints (temperature, vibrations, EMC). In order to share development between the ground data processing centre and the on-board installation, it has been decided to choose UNIX workstations. These stations having to interface with FTI peripherals and data flows, it has been decided to use front-end devices in order to keep the workstations as standard as possible. The front-end devices are the only specific systems, based on PCs and running LINUX. It is then much easier to find I/O boards and drivers for a PC target than for a UNIX workstation.

4.3   UNIX and LINUX

The AIRBUS ground data processing centre uses mainly UNIX systems (data servers, data processing servers, analysis tools). Then, in order to minimize redundant developments, it has been chosen to use also UNIX on board, and to implement LINUX on the I/O modules.

A dedicated LINUX distribution, based on a standard one, has been established and distributed on all the PCs. This distribution includes standard extensions to insure near real time performance.

4.4   Fault tolerant

The overall architecture is strongly distributed, making it easy to implement fault-tolerant software solutions. All the on-board functions are categorized and prioritised in configuration files; then, a general monitoring function, running on each machine, can reallocate resources dynamically in case of hardware or software failure, in order to keep the mandatory functions available for the test crew. The user recovers a few seconds later even its present context before the failure.
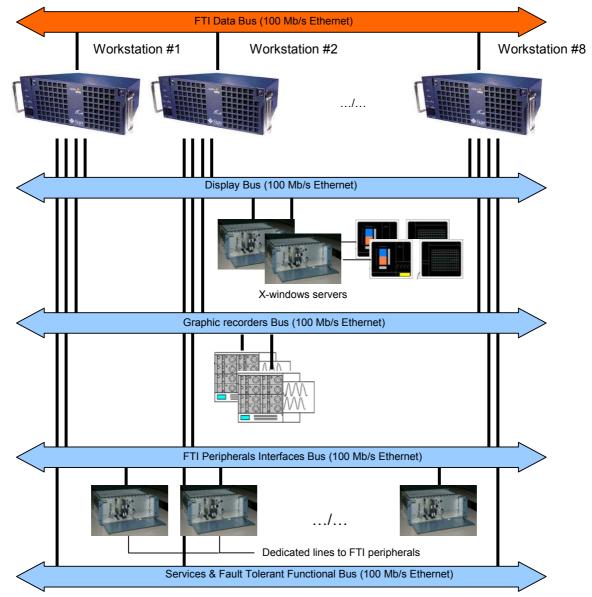
4.5   Overall architecture

Figure 10: Overall Data Processing Architecture

Workstations are fitted with removable disks to store on board applications results or selected data time slices history in order to speed-up ground data reduction.

4.6   Miscellaneous

In addition of this main architecture, some additional functions have been implemented for specific purposes, using the same hardware and software solutions:

*   Aircraft AFDX network monitoring function thru a dedicated gateway, using a modified version of a commercial software;

*   Accident recorder parameters acquisition unit.

5.0   CONCLUSION

The A380 on-board flight test data processing architecture is the result of years of experience of the Airbus flight test teams. It allows answering the various following needs:

- Provide the FTE with reliable validation tools necessary to speed-up the test cycle, avoiding additional flights in case of undetected problem in a test sequence due to FTI, aircraft or method problem.

- Provide the ground engineers with fully validated on-board results to speed-up the data reduction process: all the results produced on board have not to be processed again on ground, as the same software is used in both cases.

- Use of standard off-the-shelf solutions allows easily upgrade of the FTI. Furthermore, this architecture can be scaled down for lightly instrumented or serial aircraft.

- The switched network architecture allows complex interconnection between systems, as sub-networks to provide equipment suppliers with real-time data (e.g. engines), or to isolate specific data on a dedicated recorder. This can be achieved with a minimum of cabling and a simple configuration file.

Major FTI suppliers propose now their equipment with Ethernet outputs and data packets format. This is becoming a new standard for on-board flight test installations, the only way of building distributed modular and versatile architectures.