REAL TIME PRESENTATION
FOR RAFALE
IN-FLIGHT TESTS

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ABSTRACT

The current control rooms at Dassault Aviation, Istres were built in 1978 for the flight tests of the MIRAGE 2000 GENERATION. After 13 years of gradual improvements, the time has come to renew our instrumentation. New concepts and future technologies have been taken into consideration and the new equipment that is implemented must allow flight tests to be performed throughout the current decade.

These changes have occurred to enable testing of a new breed of combat aircraft, i.e. the RAFALE, for the coming years.

However, this improvement is in keeping with what has already been achieved over the last 22 years at DASSAULT AVIATION.

A brief background reminder will allow assessment of the company’s real time philosophy.

A ground control room provides two types of displays, namely:

- a decommutator controlled display for minimum refresh rates. It is concerned with flight monitoring and hence safety.
- a second display is connected to the host computer dedicated to data handling during flight time.

A more accurate description will show how a locally available item of equipment was customized to match specific requirements and to enhance its basic functionalities so as to make up the display chain needed for flight safety.

INTRODUCTION

The real time processing and display technique is one of our preferred test methodology tools. With more than twenty years of experience in this field, we have proved that it provides:

- increased safety during flight,
- a reduced number of flights,
- shorter development times,
- a reduced number of aircraft being tested.

1. A TOOL AT THE SERVICE OF A TEAM

Methods implemented during test flights are designed to satisfy needs expressed by test teams. In order to complete these tests in complete safety, the DASSAULT AVIATION Company has always taken care to respect the following basic principles:

- Composition of homogeneous teams under the control of a test engineer. This engineer must be thoroughly familiar with the aircraft in order to assist the pilot in carrying out the tests.
- The best possible knowledge about allowable limits and the risks involved.
- Thorough and strict preparation of test flights between the pilot and the test engineer. After being informed, the pilot takes responsibility for the flight. The test engineer on the ground provides him with assistance by monitoring safety parameters.

At the present time, a typical test team for carrying RAFALE D C01 in flight tests comprises:

- the pilot
- the test engineer, assisted by:
  - a flight monitoring assistant engineer,
  - an engine specialist engineer,
  - one or two avionics systems engineers,
  - an electrical flight control system engineer,
  - an operations engineer,
  - a forces engineer,
  - a flutter engineer.

For technical support, there is also the aircraft preparation technician, flight line team leaders and representatives of cooperating companies. The latter attend the flight in the control room but do not have any display equipment. They attend simply as advisers to the test team.

2. CURRENT DISPLAY PRINCIPLES

Real time display facilities must be a tool capable of:

- Flight monitoring:
    - by making it possible to check that the flight is taking place as planned and that the aircraft remains within the planned exploration range.
    - by providing intermediate results for deciding whether or not to pursue the test sequence.
- To inform when a failure occurs- generated by the aircraft system.
- To inform about an anomaly- not detected by the aircraft system. The airborne measuring system transmits information for its detection.
- To provide decision elements- complementary to the above two cases.

3. CONFERENCE PLAN

After this introduction, we will present a brief history describing the development of our real time display resources since their origin. The second part will then describe the principles on which these resources are selected and designed.

We will finish with an outline of improvements to appear in the near future, and a conclusion.

PART 1 - HISTORY

Since its appearance in 1968, the real time technique has continuously and regularly evolved. Always driven by the arrival of new prototypes, improvements are made in master plans marked by three major landmark dates:

1968: Display by FM channel and decommutator. Some real time monitoring by computer.

At this time, preferred methods were galvanometers and indicators, strip chart recorders and megascopes. Galvanometers were driven by:

- continuous FM channels for basic aircraft parameters (altitude, incidence, speed, etc).
- PAM and PCM decommutators for engine information.
- the computer for calculated parameters (for example Mach).

Information transmitted by the five PAM messages were displayed on the megascope. Strip chart recorders logged parameters obtained from FM channels and decommutated outputs.

The PAM decommutator processed sixteen parameters and the PCM decommutator processed twenty two.

Programming was elementary, based on a matrix of diodes and a patch panel. The computer monitored a small number of parameters and controlled indicators and a TEKTRONIX 611 storage CRT on which twelve alphanumeric parameters were displayed. This computer was an IBM 1800.

There was an interaction by means of a function key.

Flutter phenomena was monitored by a TIME DATA 100 two-channel analyzer, from which the copied spectra went to the control room.

The MIRAGE G8 variable geometry aircraft, the MERCURE short haul aircraft, the ALPHA-JET tactical support-training aircraft, FALCON 100, FALCON 50 aircraft were developed with this equipment.

1978: Arrival of a single PCM message for surveillance.

For the MIRAGE 2000 tests, and after ten years of experience between 1968 and 1978, we made a significant development in our processing methods. The appearance of electrical flight controls systems, new on board systems and new structures based on composite materials all contributed to a new telemetry:

- a PCM DANIEL message, already described in previous ITCs and ETTCs,

- a 15-channel FM multiplex for flutter analysis,
- a video message associated with transmission of the pilot's voice.

Ground processing resources are also far more powerful:

An INTERTECHNIQUE 78-420 decommutator based on a minicomputer capable of processing about fifty parameters (16 analogue outputs, 32 alphanumerics on screen, 4 digital output ports). Sixteen galvanometers were still used for the basic safety related display resources, together with a screen displaying 32 parameters converted into engineering units by means of simple AX+ B and A/X algorithms. The disappearance of PAM cycles and corresponding advantages is compensated for by an innovative function of the unit: four screens are capable of displaying 32 consecutive parameters in the minor frame in the form of bar graphs.

A new generation computer was used. The SEL 32/55 outputs displays on a 1024 x 1024 graphic screen, an alphanumeric console and indicators.

Interaction is provided by a function key and an alphanumeric keyboard associated with the console.

This provides a larger scale surveillance and the result is displayed on the graphic screen and is synthesized on alarm indicators.

The flutter analysis is carried out by a two-channel analyzer, but the operations work is carried out by a second SEL 32/55 computer equipped with an AP 120 B Array processor. The result is sent to a specialist engineer on a graphic screen. These facilities were used for the development of the MIRAGE 2000, the FALCON 900 and 200, the ATL 2 maritime patrol aircraft.

SEL 32 computers evolved in a 32/77 80 configuration. They were replaced by a GOULD 32/97 for the RAFALE experimental aircraft.

1991: For the coming decade, and in particular for carrying out test flights on the RAFALE D family, we will be using a new generation of displays.

Control rooms are now equipped with:

- 3 workstations for analogue and synoptic type displays.
- 4 high resolution color graphic terminals for real time plotting and modal analysis.

- 5 alphanumeric consoles, video monitors, indicators and screens showing strip chart recorders.

We will review the requirements which resulted in this organization.

PART 2 - CURRENT METHODS

1 – PRINCIPLES

1.1 Flight monitoring

The test engineer, responsible for the flight procedure together with the pilot, must be able to:

- be aware of flight conditions and the aircraft condition within a fraction of a second.
- carry out a detailed analysis of the operation of a specific system.

1.1.1 Fast awareness

Clear symbology must provide results defining the aircraft condition at a glance. The following are the vital surveillance parameters:

- basic parameters: altitude, speed, attitude, etc.
- parameters quantifying the operation of the engine(s).
- alarm and blip display defining the aircraft configuration (air brakes out, engines in PC, etc.). Fast (at least 10 views per second) and simple displays are required.

1.1.2 Detailed analysis

These are obtained by alphanumeric display (time plots and cross plots) and synoptics. This concerns:

- vibrational phenomena,
- structural forces,
- electrical flight controls,
- avionics systems.

Parameter analysis and interpretation is carried out by specialist engineers assisting the test engineer.

1.2 Alarm on appearance of a fault

When failure bits transmitted by the measurement system are received, it must be possible to:

Generate synthetic information, the results of logical boolean operations on tens of possible failure bits, by lighting up color blocks on the screen.

Display a plain text message describing the nature and severity of the failure.

1.3 Alert on anomaly

This is surveillance of parameter limits.

1.4 Decision elements

This involves operations work during the flight. Access to these elements requires reference to failure files and the display of information recorded a few instants earlier.

2 – ORGANIZATION OF CURRENT DISPLAYS

We developed the following restitution chain architecture in order to satisfy these requirements:

2.1 Restitution chain architecture

Information is processed as follows (figure 1).

After demodulation and demultiplexing, the following information is useful to flight monitoring in the control room:

- Distributed unprocessed, as for the video signal, voice and vibrations.
- Decommutated by the PCM decommutator for fast and safe display.
- Processed by the computer for real time operation and related tape storage for archiving and disk storage for replay.

2.2 Displays using raw data

2.2.1 Video signal

We receive a PAL color 625 line CCIR analogue video signal which is transmitted through a wide band telemetry link from several sources on board the aircraft: camera in the sights, symbol generation box, etc.

Restitution takes place on color monitors. This is a simple flight monitoring method.

2.2.2 Pilot (or crew) voice

An IRIG 19 C or J subcarrier transmits the audio signal either in analogue or digital in the case of encryption. This is one of the flight monitoring components.

2.2.3 Vibration signals

Analogue information is still the fastest, safest and most economic display method. It provides the experienced engineer with a reliable surveillance tool. The 15 vibration signals transmitted by telemetry are displayed for this purpose.

2.3 Displays from a decommutator

Historically, due to its simplicity, this instrument was known to be the safest part of the display. This was unlike the computer, more complex but less reliable at the time and used with software which was not always completely debugged.

Although this caricature is now anachronic, the commutator is still a computer standby, and still produces the fast displays required for flight monitoring.

2.3.1 For flight and alarm monitoring

2.3.1.1 Outputs under the supervisor animation software

IMAGIN (registered trademark of the SFERCA company) is a graphic display program which is used with a high performance animation system to create analogue shapes - bar graphs or dials are associated with alarm windows (figures 2 and 3).

On a DEC VS 3100 workstation, the refreshment speed is of the order of 14 pictures/sec for the fastest displays. Two screens are thus animated. One screen is assigned to basic aircraft parameters, its configuration and its alarms. The second screen is provided for engine parameters and engine alarms.

Using a switching keyboard, a large number of different views can be called on each screen. The keyboard has proved to be a faster access tool for the test engineer than the mouse or the track ball.

2.3.1.2 Link between the decommutator and IMAGIN stations

Parameters necessary for flight monitoring used to be produced by the decommutator analogue outputs. The animation software now reads a standard file. This file is prepared by the INGRID interface (Fig 4).

Designed by Dassault, this interface is driven by a TAG/DATA module in the Loral Instrumentation System 500 decommutator. This produces data-label pairs.

The interface, programmed to receive selected data, listens to the TAG/DATA module which outputs information as soon as it is available. On recognition of the label, the interface stores the data in the file. This file is transmitted as the contents of a current-value table at the rate set by IMAGIN workstations.

2.3.1.3 Decommutator outputs

2.3.1.3.1 Parallel outputs for the workstation

These outputs are produced by the TAG/DATA module. Parameters selected for flight monitoring and alarm restitution are created on the decommutator with a distribution code for directing them towards this module immediately that they appear or immediately after their processing by the FPP or the compressor.

2.3.1.3.2 Digital outputs

The four 16-bit ADP 170 digital outputs module animates indicators in order to restitute alarms or statuses.

2.3.2 For detection of anomalies and decision elements

This role is carried out by the normal decommutator display. DATA PAGES are used mostly. The “warning” and “critical” functions on the display mode inform engineers about anomalies. DATA PAGES propose listings useful to engineers to analyze the flight in more detail.

2.3.3 Special processing

One new feature compared with previous decommutator generations is the use of a powerful and easy to use processor. This FPP processor, together with a standard compressor, processes input data obtained from the telemetry. We have developed the following algorithms in addition to the basic algorithms provided by the manufacturer:

MACHNORM

Calculation of the MACH number from the ambient pressure and DELTAP. The output is on a 16-bit integer (the output is actually MACH* 103).

MACH LARG

Ditto above, but output in IEEE 32-bit floating format.

RAPP ASURX

Calculation of the ratio of a coefficient A and the source X.

XSY NORM

Division of the source X by the source Y. The output is integer (set to zero if Y = zero).

YSY LARG

Ditto, but with output in IEEE 32-bit floating format.

TEMPS

Calculation of 3 integers (hours, minutes, seconds) from a DANIEL packet time sources.

PUISSANCE A

The source parameter is raised to a power A input as a coefficient. The output is in IEEE floating format. The power A is floating.

SURVEILLE 1

Check that a parameter remains between a high and a low limit. If it is outside the limits, 1 is output on the MUXBUS.

SURVEILLANCE 4

Check that four parameters remain within their respective limits.

If any parameter goes outside the limit, the corresponding bit is set to 1, otherwise the value 0 is output on the MUXBUS.

Examples:

SOURCE 1 outside limit	0001
SOURCE 4 outside limit	1000
SOURCE 2 and 3 outside limits	0110

SURVEILLE 8

Ditto, same as SURVEILLE 4 but for 8 sources.

COMPA S2 S1

Check that a parameter remains between a lower limit value and the value of a second parameter. LOWER < S2 < S1.

COMP S1 S2 A

Ditto but S1 < S2 < UPPER.

COMP SI S2 S3

Ditto, but SI < S2 < S3.

CALCULZP

Calculation of the altitude based on the ambient pressure.

BIBUS

Surveillance of a parameter on the two aircraft buses. These algorithms are not especially optimized and are fairly efficient (the execution time is 20 to 40 fs). They enrich displays on the IMAGIN workstation. The service quality is comparable to that provided by a computer.

Obviously, DATE PAGES also make use of these algorithms.

2.3.4 Synthetic displays, synoptics

A third workstation animated by IMAGIN and driven by INGRID includes circuits complementary to the displays designed for specialists. In this case INGRID can take this information output from the decommutator or the computer.

The decommutator is used when data acquired by telemetry is sufficient to animate synoptics.

When animation is the result of an existing calculation elsewhere in the host computer, the engineer selects the host computer as the source for INGRID (figure 5).

2.4 Computer generated displays

An ENCORE CONCEPT 32/97 80 computer participates in each flight by systematically exhaustively acquiring the PCM surveillance message generated by the telemetry.

The acquisition rate of 10 500 data per second is maintained knowing that the processing procedure consists of:

- acquisition of raw data from a frame synchronizer,
- conversion to engineering units by the application of polynomial and segmented calibrations,
- parameter dating,
- the calculation of derived parameters such as the corrected Mach, the mass, the centre of gravity, the Cz, the real incidence, etc.,
- monitoring limits.

This first class of software is used together with display software and operation software which may run during the flight time

2.4.1 Displays

There are three types of displays in the control room:

- 4 high resolution graphic screens, one of which is intended for flutter specialists and is connected to a second ENCORE CONCEPT 32/97 80 computer equipped with an Array processor. It is used to carry out modal analysis during real time.
- 5 alphanumeric consoles,
- 48 indicators,
- 1 workstation screen shared with the decommutator.

2.4.1.1 Graphic screens

These screens are 1280 x 1024 resolution graphic terminals. They feature time plots with scrolling or non-scrolling curves, X-Y plots, spectra, frequency damping tables and other items.

There is also an alphanumeric parameter display window. Screens are connected to a color hard copy unit.

2.4.1.2 Alphanumeric consoles

These are used with the graphic screens. They are used to access surveillance files, failure listings and out-of-limit display by means of simple commands.

2.4.1.3 Indicators

To provide more clarity, limit overrun information is synthesized and displayed on ergonomically laid out indicators.

2.4.1.4 Synoptics screen

This function, described above, was added to reduce the number of indicators and to enrich synthetic surveillance displays.

2.4.2 Other computer functions

2.4.2.1 Listing printout

2.4.2.2 Interaction

Using alphanumeric keyboards, engineers can control the computer requesting the execution of programs relevant to the current test, change plot scales, and select parameters to be displayed.

2.4.2.3 Magnetic archives

These are provided firstly to create a complete history of the flight, and secondly to allow playback of flight passages after storage on the disk, to provide decision elements during the current test.

2.5 SYSTEM 500 - LORAL INSTRUMENTATION

The SYSTEM 500 currently being used at Dassault Aviation, Istres consists of two major components these being the ACQ 510 chassis and the colour graphics workstation, namely a DECstation model 3100 running under the ULTRIX operating system. The ACQ 510 chassis houses the telemetry decommutation, processing and output modules to provide real time functions in the telemetry front end. In addition the ACQ 510 has a module to control an external Bit Synchroniser. All control, setup and administration is accomplished via the colour graphics workstation over an industry standard TCP/IP Ethernet LAN. The workstation and application software provide a very user friendly interface.

Real-Time flight test data is derived from either a telemetry receiver or pre-recorded flight test. The external bit synchroniser provides data and clock signals to the ACQ 510 chassis. Housed within the ACQ 510 chassis are the following modules to perform the necessary decommutation, processing and output of standard IRIG or Daniel PCM data streams:

- External Bit Sync Controller
- System Controller
- Ethernet Processor
- Single Board Decommutator
- FPP Daniel Decommutator
- FPP
- Data Processor/Compressor
- Analogue Output Ports
- Rear Panel Interface
- Tag/Data Output

Each module has access to the ACQ-510 administration bus and the high speed parallel ‘MUXBUS’. The MUXBUS is a fully arbitrated broadcast bus - data is passed on the MUXBUS as a 32 bit token made up of 16 bits of TAG and 16 bits of data. MUXBUS speed is 4Mega Words/sec.

2.5.1 External Bit Sync Controller

The EBSC controller module allows the remote programming of a Intertechnique 7700 bit sync from a set-up window on the workstation display.

2.5.2 System Controller

The System Controller module is the data acquisition subsystem’s control processor - on power up it initialises itself and performs a memory check. Each module in the ACQ-510 is interrogated and logged in before executing a system generation. The System Controller module is based on an 8086 processor operating at 4 MHZ.

2.5.3 Ethernet Processor

The Ethernet Processor module functions as an I/O device between the ACQ-510 and the workstation. Set-up and control information is passed over the standard TCP/IP Ethernet network. In addition the EP module transmits display information from the ACQ-510 to the graphics workstation over Ethernet.

2.5.4 Single Board Decommutator

The Single Board Decom is a standard IRIG telemetry decommutation module performing frame and sub-frame synchronization up to 2Mb/sec. The serial PCM data is converted to parallel then tagged before outputting to theMUXBUS. This module is also used to synchronise a Daniel data frame and provide parallel words to the MUXBUS. These words are passed to the MUXBUS and include the Program ID word used by the Daniel FPP module.

2.5.5 FPP Daniel Decommutator[1]

The Daniel FPP module is based on a dedicated FPP module to provide a word based decommutator under software control. Decommutation of Daniel zones, MS & LS time plus data is accomplished by creating the necessary Daniel prime parameters within the parameter environment of the SYSTEM 500. These Daniel parameters are then tagged and output to the MUXBUS for further display, processing and output.

2.5.6 FPP (Field Programmable Processor)

A major advantage of the SYSTEM 500 is its ability to provide substantial processing power on a single module, the FPP. A single module can process over 2000 parameters at aggregate rates up to 750K words/sec. As a practical example each FPP performs 220K fifth-order EU conversions per second. The peak processing rate for 64-bit floating point processes is 20 MFLOPS or 10 MIPS.

A standard library of processing algorithms is provided for, but more important is the ability to create custom algorithms which can simply be added to the standard library. A high level language environment allows unique algorithm development using “C”. Utilities such as linkers, loaders, debugging tools and simulators are provided with the algorithm development environment.

2.5.7 Data Processor/Compressor

In addition to the FPP the Data Processor/Compressor module provides further front end processing algorithms such as bit manipulation, logical functions, in and out of limit checks and decommutation of embedded asynchronous data streams within an

IRIG PCM frame. This processing module is based on the AMD29116 bit slice processor which allows preprogrammed algorithms to run at typical throughput rates of 280K parameters/sec.

2.5.8 Analogue Output Ports

This module provides eight analogue output ports for presentation on a oscillograph or similar strip chart recorder. The resolution of each analogue output is 12 bits.

2.5.9 Analogue/Digital Output Ports

This module provides 4xl6 bit output ports for discrete data output. In addition each parameter output also is available in analogue form.

2.5.10 Tag/Data Output

The Tag/Data output module allows selected prime and processed data to be output in parallel for interfacing to external devices and host computers using the DR11W interface standard. In this particular application it passes data to the Dassault INGRID device for providing synthetic displays and synoptics.

2.5.11 Rear Panel Interface

The rear panel interface simply provides connections to all external devices from the modules within the ACQ-510 chassis.

2.6 System 500 Software and Workstation

The SYSTEM 500 a high level user interface taking advantage of high resolution colour graphics displays. Pull-down menus and pop up windows controlled by a mouse or keyboard provide an easy to use operation. The Applications software provides for various security levels to restrict access to unauthorised users. Focusing on industry standards, the X windows system client/server architecture allows the multiple display terminals to access applications on clients physically located on computers or workstations on the Ethernet.

2.6.1 System Administration

A series of windows allow tasks such as system management, front end set-up and algorithm development. In addition alarms and user history review and module configuration and status viewing is featured. A standard, commercial, high performance database management system with integral SQL is used to manipulate alarms, system errors and operator history files.

2.6.2 System 500 Parameter Database

The system server manages the parameter database information that the user stores on hard disk and which is downloaded to the ACQ-510 at system set-up. Files in the parameter database consist of two types of information:

1. ACQ 510 Sub-system setup
2. Workstation display setup information

Once parameter databases are created for each platform to be tested, they are stored and recalled from the workstation hard disc.

2.6.3 Standard Data Displays

Any parameter which has been created and stored in the data base can be displayed on the workstation display in bar chart, strip chart or simple data tables. The size and colour of such displays can of course be changed to suit user preferences. At the very top of the display is a status panel and an annunciator panel for quick look display of flight critical data.

2.6.4 Display Builder Software

For customising the display of data for presentation to engineers attending a flight test, LI’s Display Builder software provides such an environment. The standard catalogue of widgets includes strip charts, meters, bars, scrolling data pages, bit mapped images and process diagrams of on-board systems.

To automate the display changes, macros can be assigned to function keys. Such macros could be triggered by parameter value, time or alarm conditions.

Several tools are provided to enhance the interpretation of analogue data displays. It is also possible to engage rulers and cursors to determine exact values of analogue data anywhere on the tracing.

PLANNED IMPROVEMENTS IN THE SHORT TERM AND CONCLUSION

Telemetry is benefitting from new techniques in order to provide higher and higher performance services. Computer software is being continuously improved to satisfy new demands made by our computer engineers.

When coupled to workstations, the next generation of computers that we will be installing will make the use of powerful calculation and display programs to provide even more complete and synthetic decision elements.

Better use must be made of important results obtained in real time by a significant improvement in the telemetry transmission quality. An effort must be made to reduce the error rate, which means that more frequencies must be allocated.

Relegated to the role of standby to the host computer for many years, the decommutator is coming back into the limelight. With previous generation decommutators, about fifty parameters were processed for a flight.

About 500, or ten times more, are now processed for the RAFALE C D01. Tasks are carried out with a complexity similar to those carried out by a computer.

General surveillance of the airborne measurement installation is provided by the addition of an X terminal equipped with a track ball to access the parameter listpick menu. We are relying on a decisive enrichment of decommutator displays with the arrival of Loral Instrumentation display builder software version 3.0.

The rather simplistic DATA pages will be replaced by custom designed and very clear pictures. Together with the track ball, this will be a flexible and powerful tool available to specialist engineers.

This interesting function should be associated with the imminent programming of the system 500 by the host computer. PCM format description files, calibration characteristics and processing of most parameters will be transmitted through the ETHERNET network to the DS 3100 master station. All parameters will then be input and may be used on the system 500 through parameter selection menus.

Finally, a connection with the host computer is currently being prepared using a TAG/DATA module. This could also replace the currently used frame synchronizer. This would then be the prelude to the system 500 being used as preprocessor. The slow but continuously increasing transmission rates will force us to select information sent to the computer for real time processing.

The SYSTEM 500 is ideally suited to the task. We can see that this decommutator can relieve the host computer from this task and can provide even better performance. This is the purpose of the developments we are making with our supplier Loral Instrumentation.

We hope to make some of our telemetry stations capable of simplified operation by adding a printer to the decommutator, operating with a data spooler being developed by Loral Instrumentation.

Similarly, the evaluation of a disk connected to the MUXBUS bus presages replay possibilities. We anticipate improved performances from this concept. Developments at Loral Instrumentation include the PRO 550 sub-system, offering even greater throughput with the next generation MUXBUS II. This offers a natural upgrade and growth path from the current system.

We have invested in training and the development of algorithms and a methodology for this equipment, which will be the basic principle of the solution to be adapted for DASSAULT Flight Tests over the next ten years (figures 7 and 8).

References

1. Taylor, Larry M., “An Advanced Decommutation System for the Daniel Format,” Proceedings of the European Telemetry Conference, 1987

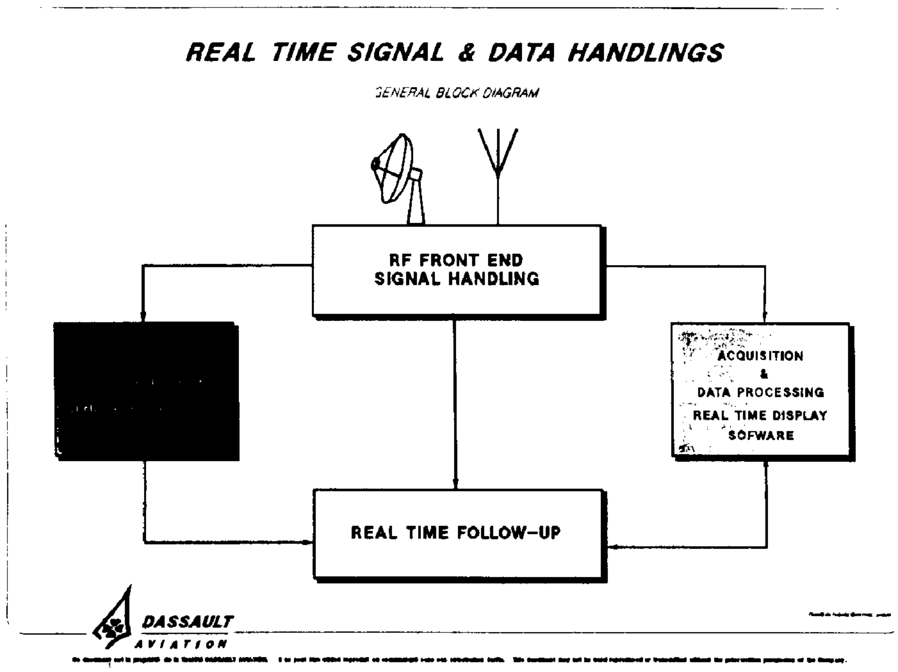


Figure 1.

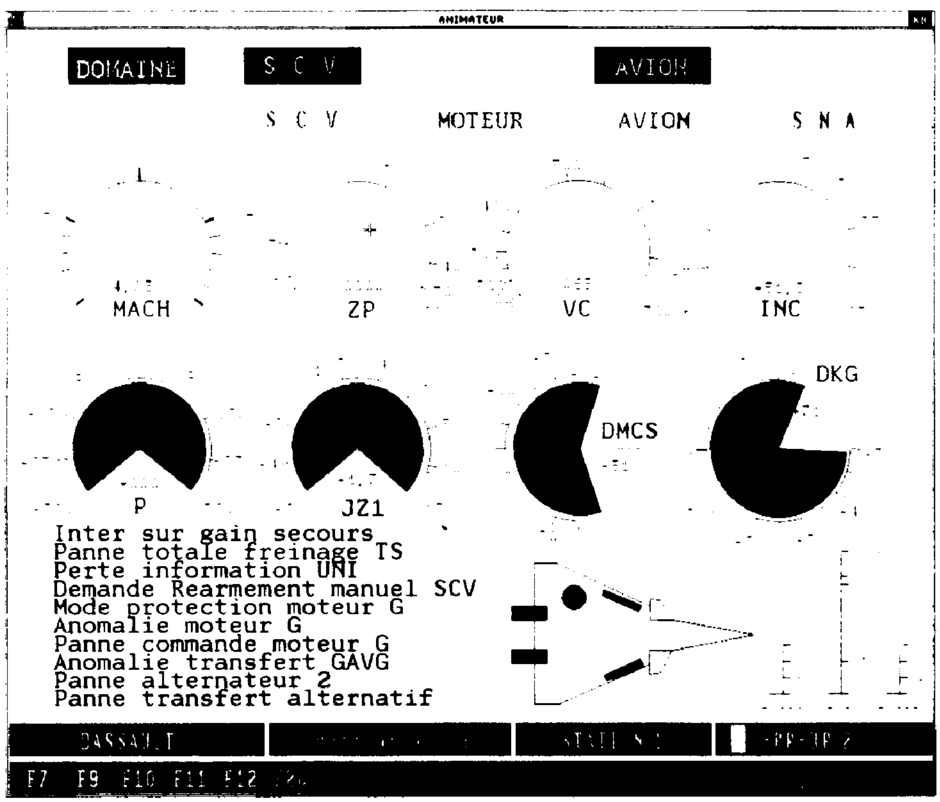
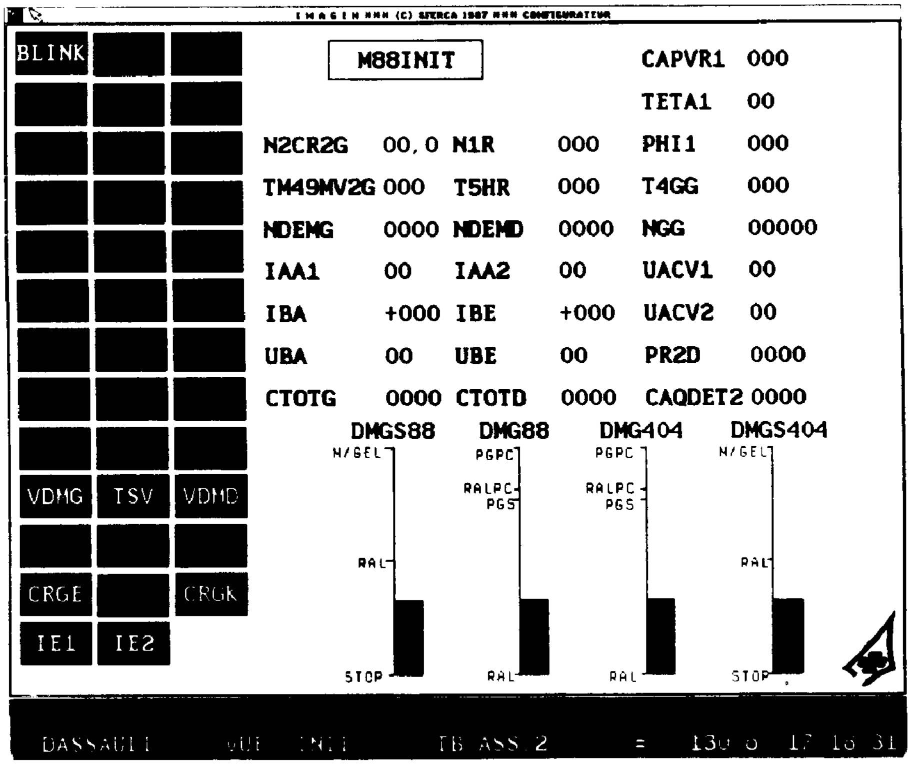


Figure 2.



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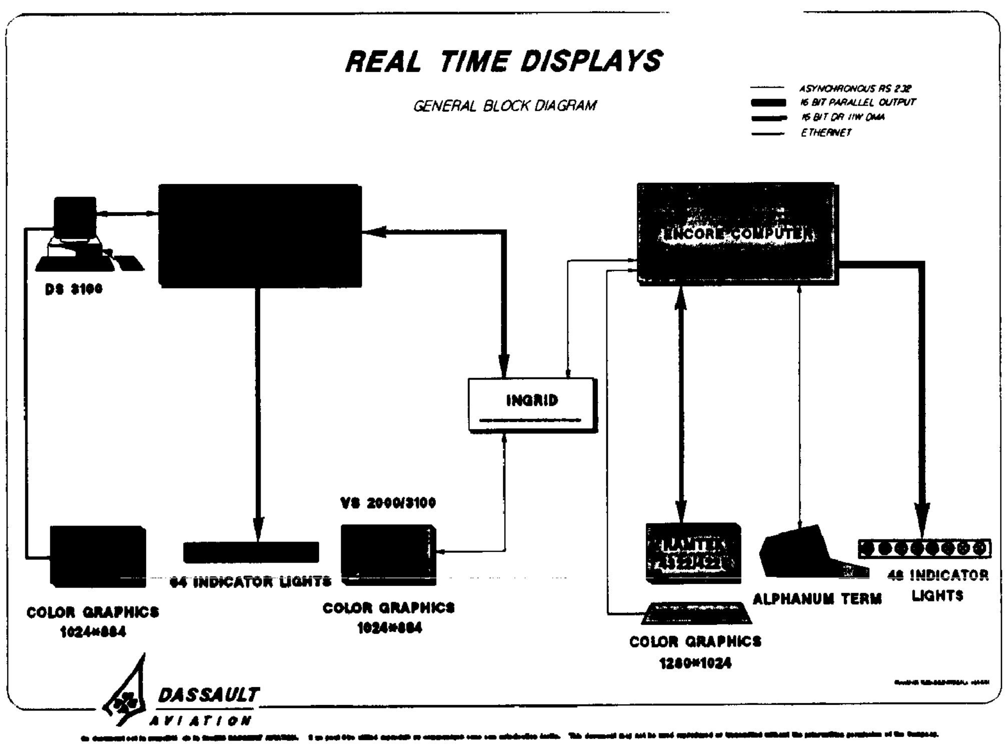

Figure 4.

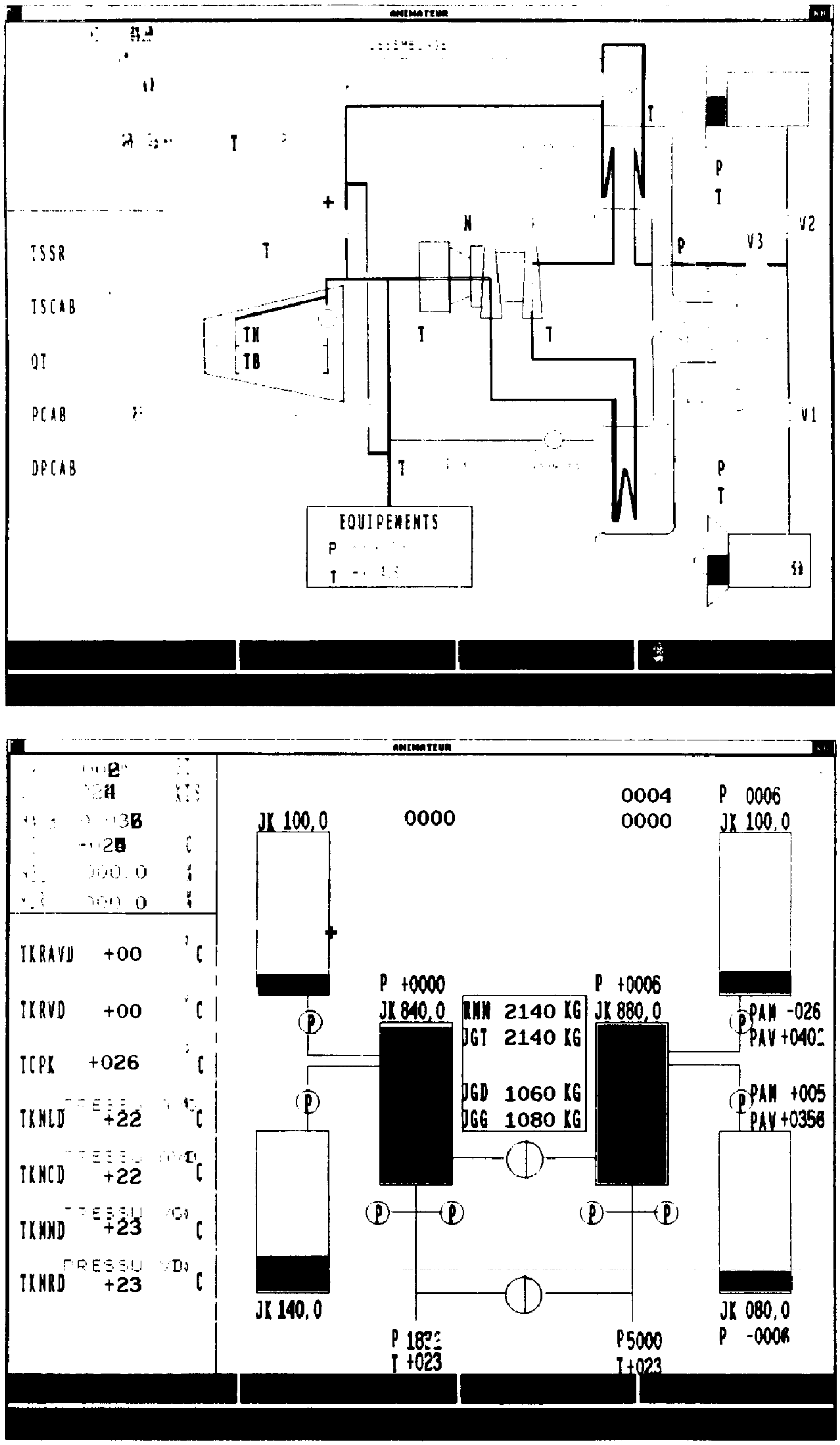
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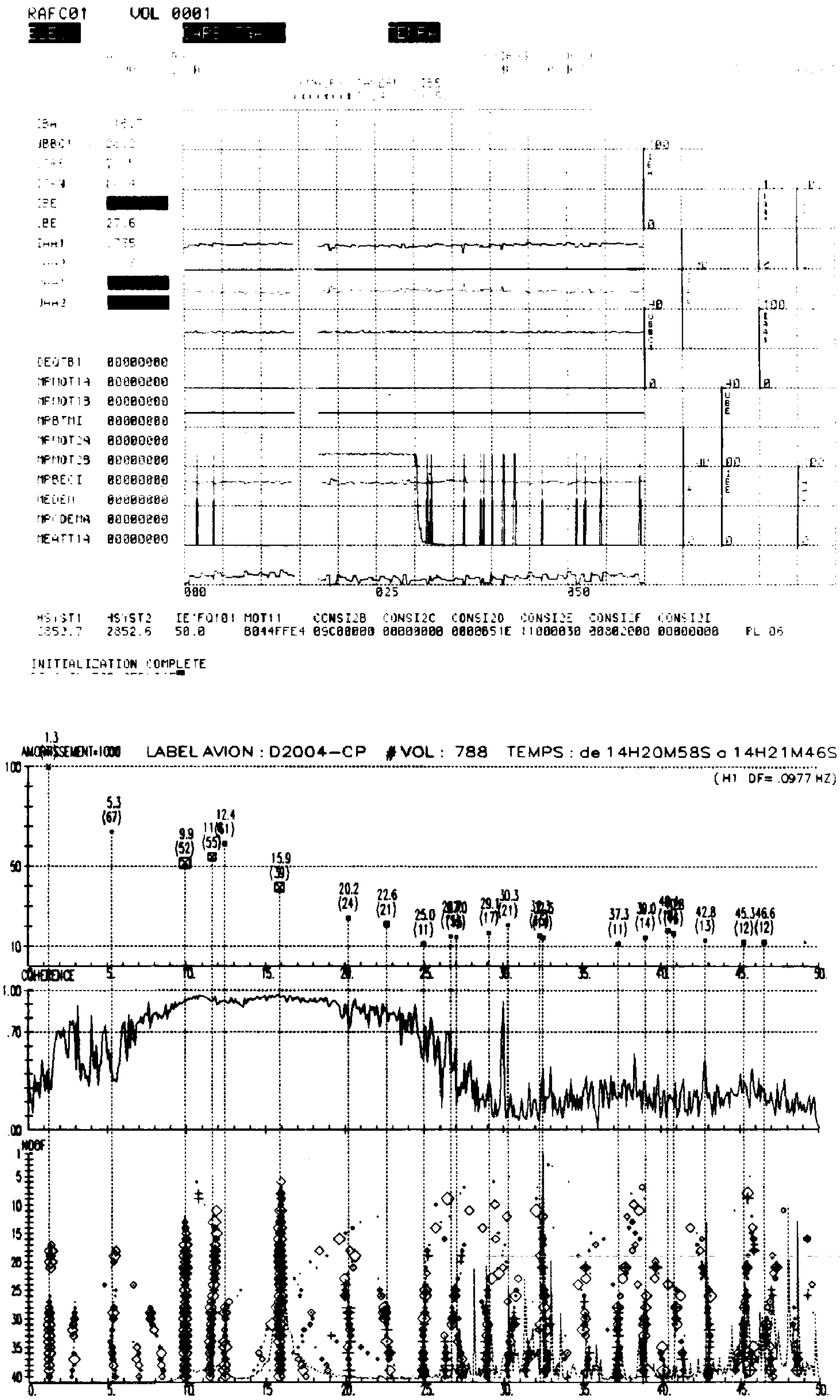
Figure 5.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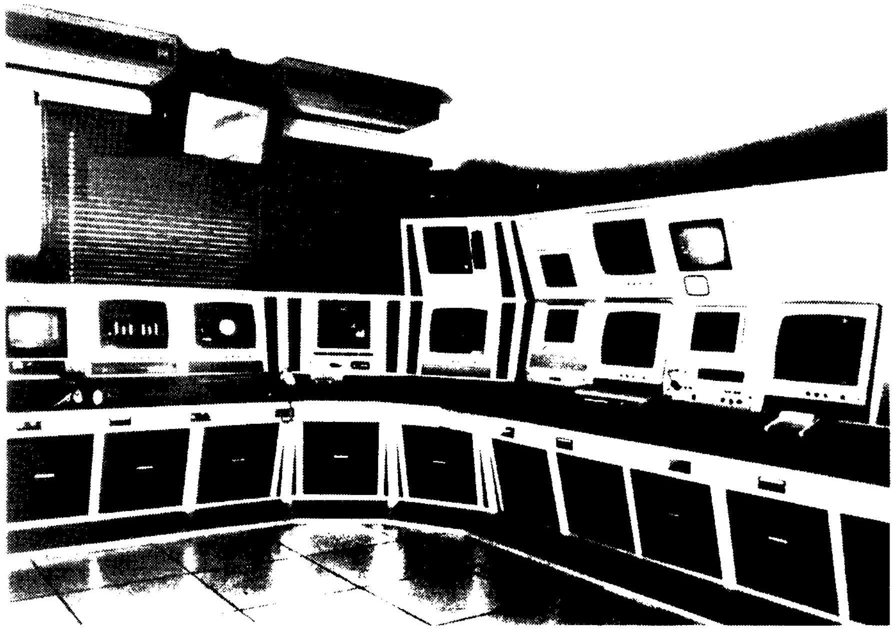

Figure 7.

Figure 8.

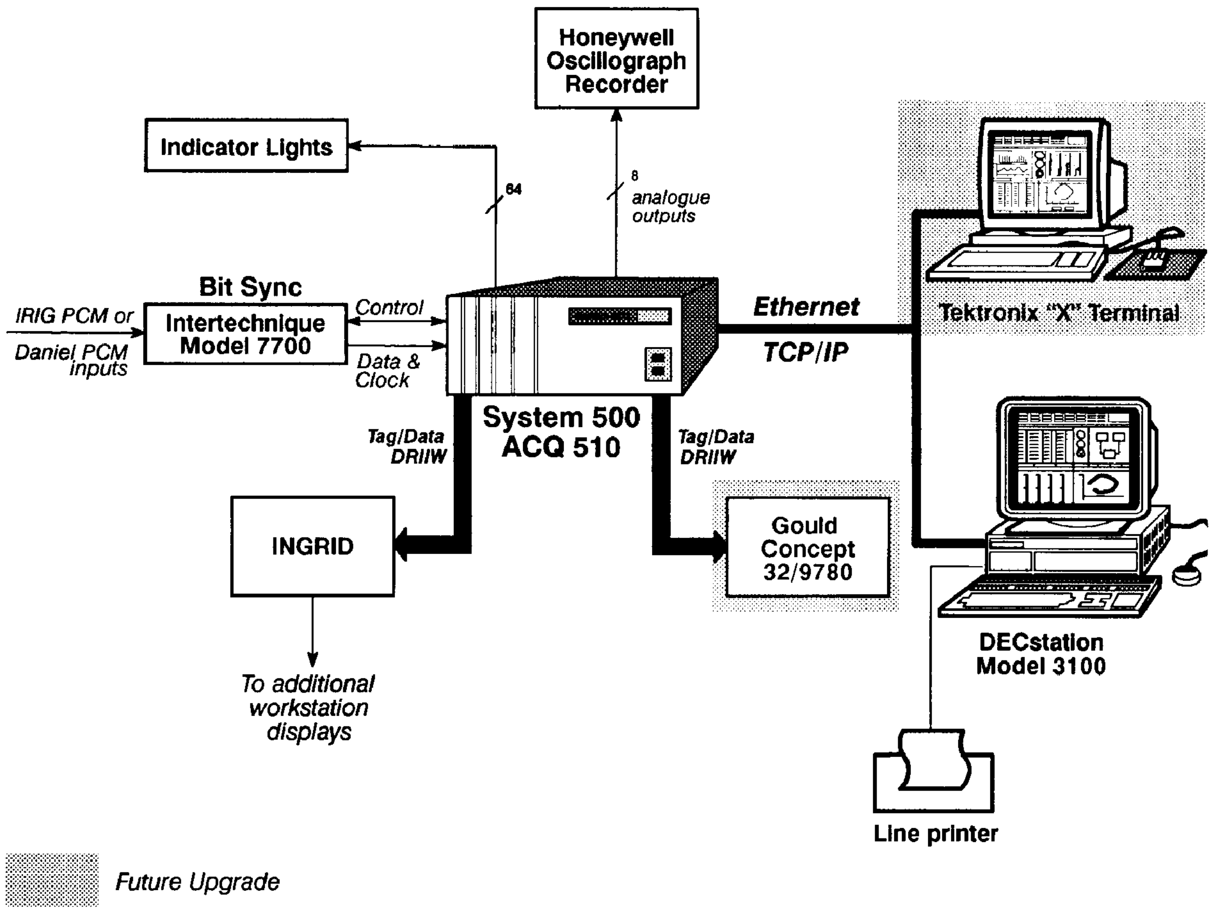

Figure 9. Loral Instrumentation System 500 at Dassault Istres