THE FUTURE COCKPIT OF THE NEXT GENERATION OF CIVIL AIRCRAFT

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ABSTRACT

The next generation of civil aircraft will be equipped with completely new digital systems. The cockpit itself will be fitted with new equipment which improves the man/machine interface. The information will be displayed to the crew on Cathode Ray Tubes which have a full color capacity. The design of the complete cockpit is also new and is conceived in a totally integrated concept. This paper describes the cockpit of a future aircraft : the AIRBUS A.310.

INTRODUCTION

In the history of Aviation, major milestones have marked the introduction of new technologies ; such as the jet engine. To day we are faced with a new milestone which is related to electronic systems and their interface in the cockpit.

The introduction of the Cathode Ray Tube is essentially due to the introduction of new computers such as the Flight Management Computer (FMC) and the Flight Warning Computer (FWC) which perform the classical functions of navigation and warning in a new way. At the same time the technology of Cathode Ray tubes has been improved from the technical and economical points of view. With the new digital world the informations to be displayed to the crew is more and more elaborate and a conventional method of display was obsolete. Such is the case for navigation data for which a map representation is the best method of display.

The Airlines have been convinced of all the potential growth capabilities of such systems for the future and even if in some cases the approach is prudent evolutions are still possible.

GENERAL LAY OUT OF THE COCKPIT

In the case of the AIRBUS, it is not only in connection, with CRT's that the cockpit is novel but also in its overall concept in particular in the FFCC (Forward Facing Crew Cockpit) version. The FFCC is a cockpit in which the flight crew faces forward either with 3 or 2 members. This arrangement best integrates the third crew member in all the flight phases. The controls for the systems are on the overhead panel. The cockpit uses push-buttons which allow the "lights out" philosophy to be used, which means that, when all lights are out "all is well". This feature is a real improvement in cockpit preparation or in the recognition of a typical situation. This philosophy is combined with an consistent use of colour coding :

- red for warning
- amber for caution
- white for systems selected OFF (and normally ON)
- green and blue to indicate systems selected ON (and generally not used for all flight phases).

Those push buttons are well integrated in the synoptics, where they sometimes indicate a continuity, or not, of a flow path.

The size of the lateral panel has been reduced so that the lateral visibility on the right side is improved and the space to store flight documentation is enlarged. This lateral panel is now reserved for maintenance purposes. All the necessaries information to ease maintenance is grouped together on this panel.

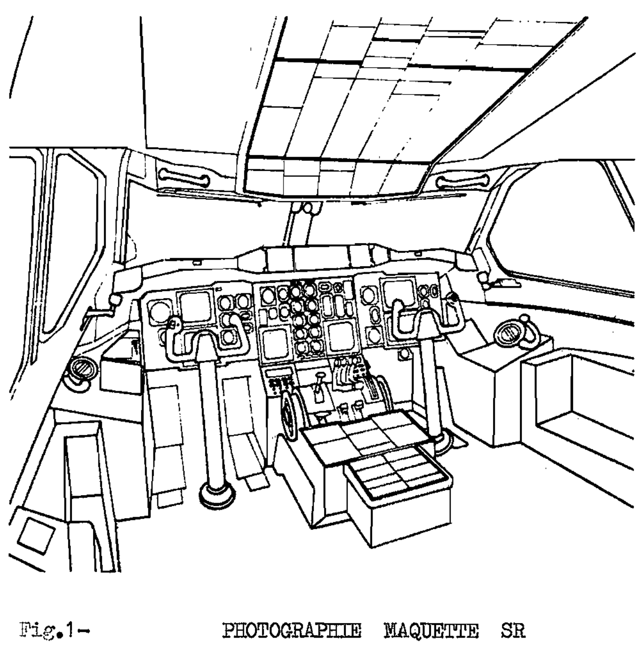

Fig.1- PHOTOGRAPHIE MAQUETTE SR

The flight deck includes six completely interchangeable CRT's :

- four for the Electronic Flight Instrument System (EFIS) which provide flight and navigation information (two at the pilot's station, and two at the copilot's station).
- two for the Electronic Centralized Aircraft Monitoring (ECAM) which provide a complete monitoring of the aircraft systemseither in a normal or abnormal situation.

Conventional instruments are still provided on the flight deck : this is the natural compromise of an industrial product. They serve as a back upor complementary information for the data which has not be integrated on the CRT.

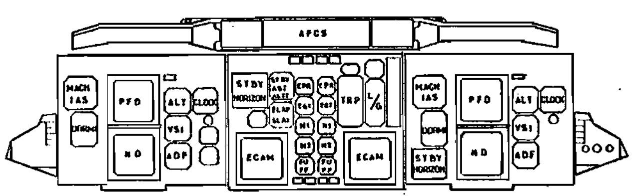

Fig.2- PLANCHE A310

CRT TECHNOLOGY

The CRT installed on the AIRBUS will be of the shadow mask type. At the very beginning two technologies were opposed : the penetron and the shadow mask. The advantages and draw backs were compared : a very good definition and resolution for the penetron but only limited colours ; a full colour capacity for the shadow mask. Finally the colour has been judged to be a definitely major feature.

Many problems must be solved to allow the use of a CRT shadow mask on board an aircraft :

. **Firstly** the resolution : as the screen is seen at a short distance by the pilot a high resolution for the phosphors dots is required, 0.3mm between dots trio.

. secondly the environment : the mask must be fixed rigidely enough to ensure that there is no movement between the mask and the tube ; the heat dissipated must be as little as possible.

The brightness of the tube must be enough to sustain a direct sun Lighting (70.000 Lux at 45°).

The size which has been chosen is 6.25 inches square for the envelope and 5 inches square for the usable area of the screen.

Two arrangements of the guns can be found : in delta or in line. In the case of the AIRBUS the in line arrangement has been chosen, it provides all the well known advantages of precision and eases the various adjustments.

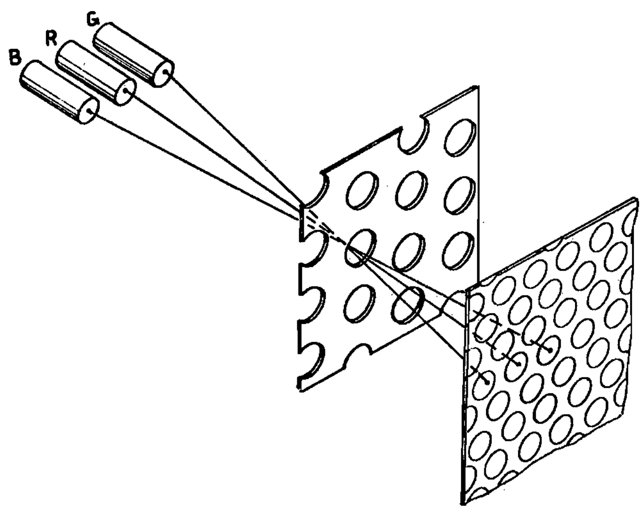

Fig.3- SHADOW MASK TECHNOLOGY

The various colours are made by combination of 3 basic coulours which are blue green and red. Seven combined colours have been selected :

. the 3 basic colours bleu, green, red
. 4 combined colours cyan, magenta, yellow, white.

The symbols are written in strokes which gives a better definition than raster. The width of a line is typically 0.5mm, slightly more than the dots trio resolution.

Stroke symbols can be superimposed on a raster back-ground, which give the sky/ground for the flight instrument or the weather radar information for the navigation instrument.

This superposition must be carefully examined specifically to keep the colour of a stroke symbol when superimposed or not.

E F I S

The Electronic Flight Instrument System (EFIS) is composed as said previously of four CRT's, (two on pilot panel, two on copilot panel). The two CRT's are mounted one above the other, they are surrounded by traditional electromechanical instruments used essentially as a backup : airspeed indicator, altimeter, variometer, radio navigation indicator. The upper screen is called the PFD (Primary Flight Display), it provides for the control (short term) and guidance (medium term) of the aircraft. The lower screen ; the Navigation Display (ND), enables the horizontal situation of the aircraft (long term) to be displayed.

System Architecture

To operate this whole arrangement, there is a system for data acquisition, processing, and display. The equipment that performs this function is the symbol generator . They receive the data from the various sensors in digital form. An integrated processor operates on raw data such as attitude or heading to make it suitable for the display processor, which controls the X and Y deflection.

The system includes three symbol generator units (SGU), one for each group of CRT's and one spare ; each CRT group also has a control panel to control its own mode of operation.

In the event of failure of one CRT it is possible to exchange PFD and ND displayed information. In the event of one SGU failure it is possible to use SGU number 3 in lieu of the one that has failed.

The SGU uses the most advanced digital technology in the field of processing, memory and integration (customs LSI are developed for display processing).

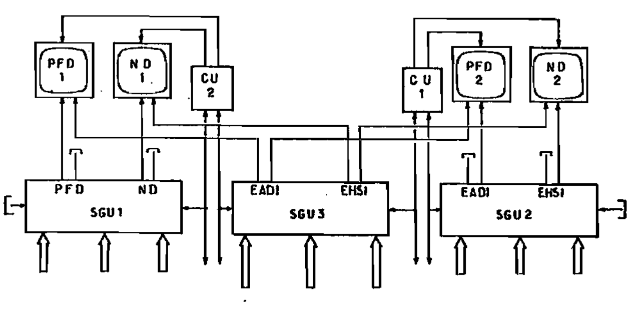

Fig.4- EFI ARCHITECTURE

Basic Rules

A joint human engineering study grouping pilots from airlines and Aircrafts Manufacturers has developed basic rules that apply to the EFIS :

- No additional crew work load

This is achieved by avoiding too numerous selections and by using simple rules for data comprehension.

. No extensive training to use the CRT.

All basic information must be understood without a major change in mental processes, as acquired during previous experience and training.

. Flexibility.

For each flight phase the optimum data will be displayed, but parameters will generally keep their location.

Primary Flight Display

The main objective is to have all the information for the short and medium term to fly the aircraft. The PFD displays the following data :

- Attidude with a full range, either in pitch or roll, with a special display for excessive attitude. The information is superposed onto a sphere with a blue painted sky and a brown earth.
  The aircraft symbol, pitch marking and horizon line appears in white on the back ground.

- Heading displayed on the horizon line

- Slip-skid (replaces the "ball" indicator)

- Flight director or Flight Path vector

When using the Flight Path vector a Flight Path Target is presented to facilitate following a selected track and a Flight Path angle.

- Radio height with digital display and analog display when near the ground.
  Special emphasis is given to attract attention near and at the decision height.

- Airspeed data
  The actual speed and it's trend is presented with various limits :
  maximum speed VMO and VFE of the actual configuration in red
  minimum speed 1.2 VS at Take off, 1.3 VS for landing in amber.
  The stick shaker speed is also presented on this scal in red.

Various "bugs" also improve the use of this scale :

- .V1 set by the Flight Management Computer (FMC)
- . V3 flap retraction speed automatically set (taking into account the weight of the aircraft) by the Flight Augmentation Computer (FAC)
- . V4 for slat retraction
- . Manoeuvring speed of the actual configuration
- . The selected speed (V2 for take off).

This speed scale is really complete and very useful, it shows the actual speed of the aircraft with all the limits. The CRT allows clear comprehension because all the symbols are not in the useful area of the speed scale at the same time, this is a major advantage of the CRT. Ths screen is not cluttered with unused information, it is displayed automatically when needed.

Mach is also displayed in digital format :

- Barometric altitude information in digital format
- Trajectory deviation in vertical and horizontal planes.

  In the vertical plane the display gives the deviation relative to a selected altitude or flight level or a glide slope.

  In the horizontal plane it gives deviation relative a selected VOR course or a Localizer.
- Autopilot/Flight director mode annunciation with a better flexibility than conventional means.

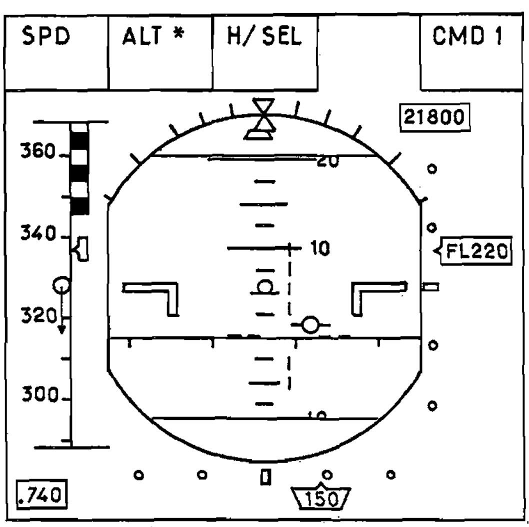

Fig. 5- P F D

One may object that too much information is displayed on this little area but it is necessary to understand that colour, phase adaptation, symbology ease the clarity of the presentation. This is the conclusion of many airline pilots.

<u>Navigation Display</u>

Two main modes can be selected :

- The rose mode which is in fact the same presentation as the present electromechanical Horizontal Situation Indicator (HSI).
- The map mode which is a presentation of the real horizontal situation.

  In map mode the following information is displayed:
  - aircraft position relative to flight plan

  the active flight plan is represented by a line between the various way points. One can have the active flight plan plus alternate destination or offset or engine out SID. The flight plan procedures are also displayed such as curved path transition for the active leg, holding pattern procedure turn, origin/destination airports.

The symbology is in accordance with the range selected.

- Heading and track
- Miscelleaneous information in digital format ground speed, true airspeed, wind direction and value.
- The vertical deviation relative to the profile required by the Flight Management Computer.
- The submodes of the Flight Management Computer.

Six scales (of the map) can be selected from 15NM to 240 NM. One can superimpose the weather radar navigation at the same scale with colour coding which eases the corellation between the route and perturbations. It is also possible to select complementary indications :

On Navaids
Waypoints
Airports
General reference points

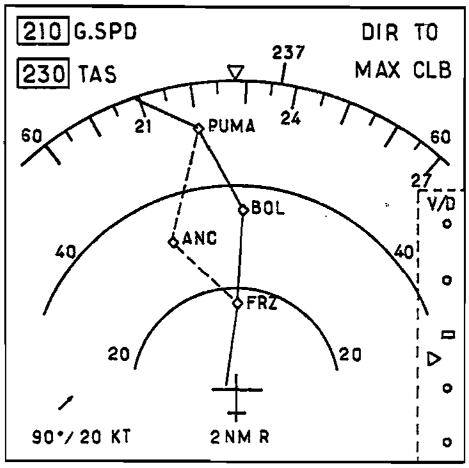

Fig.6- ND MAP MODE

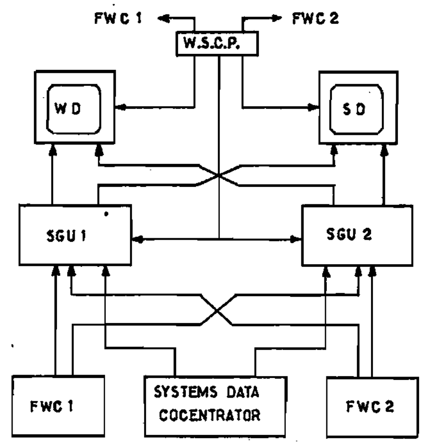

Fig. 7- ECAM SYSTEM ARCHITECTURE

E C A M

The Electronic Centralized Aircraft Monitoring (ECAM) is composed as said earlier of two CRT's which are located on the central panel :
They are used for :

- System monitoring in normal flight phases
- Presentation of a clear situation in the event case of warning or caution
- Advisory information in the event of parameter deviation.

They are mainly used with automatic modes but always with manual access to the information.

System Architecture

The system is composed of two interchangeable CRTs, and two identical symbol generator units (SGU). Each CRT is driven by its own SGU, but each SGU has the possibility to generate all necessary functions provided by both CRTs in the event of failure of the other SGU. When there is a CRT failure it is also possible to have all the same information, but multiplexed in time on the remaining CRT in a mode called Single Display. The two SGUs receive data generated by two Flight Warning Computers(FWC) and a System Data Analogue Converter (SDAC) which acquires all data on the aircraft (200 discretes 150 analogue).

ECAM modes of operation

When there is no failure on the aircraft systems the left hand CRT is in the Memo mode that gives the crew information on some systems temporarily ON such as APU running, Anti ice on, seat belt, ...
This is a sort of reminder of the aircraft configuration principally for systems that can be forgotten
The right hand CRT is in automatic flight phase presentation. It gives system data which is necessary depending on the flight phase:for example APU parameters when starting the APU, Engine secondary parameters when starting Engines, brakes temperature antiskid signal and spoilers when landing etc ...
At each time it is possible to select manually any other system among :

Hydraulic
Electricity - AC
Electricity - DC
Air bleed
Air conditioning
Pressurization
Fuel
APU
Doors
Brakes
Flight Control
Engines (secondary)

This information is presented on synoptics with a considerable improvment in the comprehension of the system operation.

When a parameter deviates from its normal value the advisory mode draws the crew's attention to it by automatically selecting the corresponding system.

When there is a failure, a warning or caution message is presented on the left hand CRT and the associated system is shown on the right CRT.

The left hand CRT shows

the system which is concerned by the failure
the nature of the failure
the list of corrective actions.
Colour coding is used to differentiate warning (red) and caution (amber).

Two types of failures are distinguished :

- independant failures with no consequences
- primary failures with consequent secondary failures.

In the event of a primary failure the origine and the consequence are indicated clearly. Such as an engine failure, or a bus bar failure, or an hydraulic failure...
On the right hand CRT the associated system synoptic is represented indicating clearly the location of the failure by using colour coding :

green for safe operation, amber or red for a failed system.

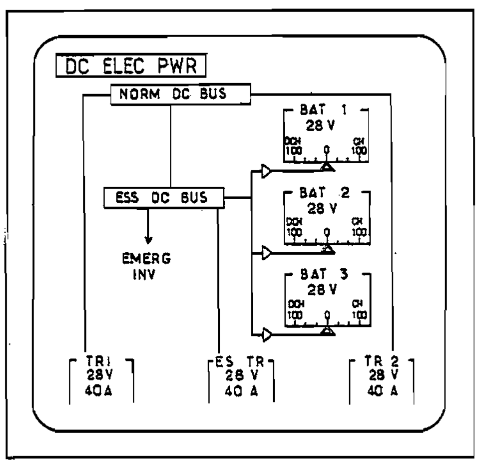

Fig. 8- ECAM DISPLAY

CONCLUSION

As stated earlier the next generation of civil aircraft will see the introduction of new technologies which lead to important improvments in the man machine interface.

A big step has been made by introducing CRTs on the flight deck. They have considerable flexibility of data presentation and one can envisage future growth capability. To day the symbologies defined are in a continuation to the previous world principally to avoid training problems but new features are introduced to ease the crew workload.

The following generation will certainly be totally equipped with CRT's deleting more and more conventional instruments. But the second step in cockpit revolution will be with the fly by wire controls with a mini stick in stead of the present control column.