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MODERN STRAPDOWN SYSTEM FOR HELICOPTER

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ABSTRACT

The Flight Data System (F.D.S.) is a dual redundant system, chosen to fit the AEROSPATIALE AS 332 MK 2 Helicopter and which provides all the informations necessary for the
flight : attitudes, heading, velocities, air data, etc...

To fulfil this mission, CROUZET, the supplier of the F.D.S. (also called Primary Reference System), has chosen optimized solutions, in order to meet :

- The high safety level required for the basic information (also called "primary reference information)

- The high accuracy required for optional navigation functions

- The low-cost requirements for the whole system.

1. INTRODUCTION

This paper describes the AS 332 MK 2 Flight Data System, designed to provide the aircarft with all the basic flight information :

- Attitude and Heading Data,
- Air Data,
- Ground Velocity.

The System is currently being developed by CROUZET and will be included within the INTEGRATED FLIGHT and DISPLAY SYSTEM.

The development of the Flight Data System lies upon a strong experience of CROUZET in the techniques which are necessarily used in such a system :

- Air Data sensors and algorithms, including low airspeed flight envelope
- Magnetometers and self-compensated magnetic heading measurement
- Strapped-down inertial systems
- Navigation systems, specially for helicopters
- Avionics hardware and software experience.

In addition to the basic functionalities of the system, original options can be provided, such as :

- Doppler Navigation
- Low Airspeed synthetic computation
- GPS service, by integration of a GPS receiver inside the AHRS.

2. DESCRIPTION OF THE SYSTEM

The basic mission of the Flight Data System is to provide the aircraft with the following information :

- Magnetic Heading
- Roll and pitch
- Angular rates
- Specific accelerations
- True Airspeed, Indicated Airspeed and Vertical Airspeed
- Standard pressure altitude
- External air temperature.

The FDS can also be connected to a Doppler Radar, in order to provide a filtered ground speed information.

The FDS is composed of the following equipments :

- A Flight Data Computer (FDC)
  This strapdown unit is an AHRS comprising the inertial sensor, the processing unit and the interfacing unit of the system
- A Heading Sensor Unit (HSU), with is a 3 axis static magnetometer
- A Pressure Sensor Unit (PSU), including 2 pressure sensors, connected to the external pneumatic probes and to the TPU
- A Temperature Probe Unit (TPU), enabling the measurement of the external air temperature.

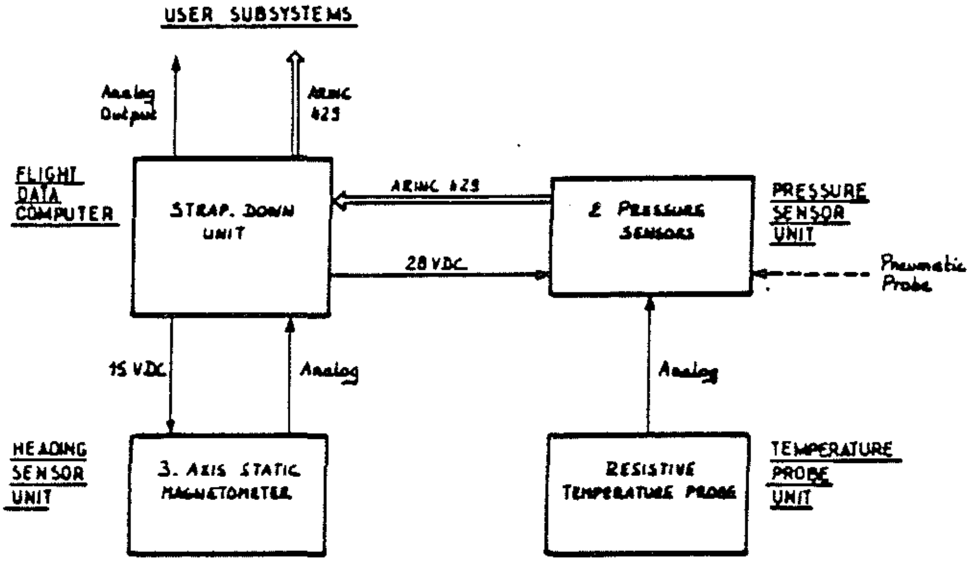


Figure 2.1 : FDS Architecture

The system includes also a Back-up Battery Unit (BBU) enabling a specific back-up power supply of the FDS.

External links include ARINC 429 lines and analog output for heading indication on a RMI.

For safety reasons, the FDS is fully redunded in the Integrated Flight Data System, and no liason is left between the two FDC's.

General architecture is as follows :

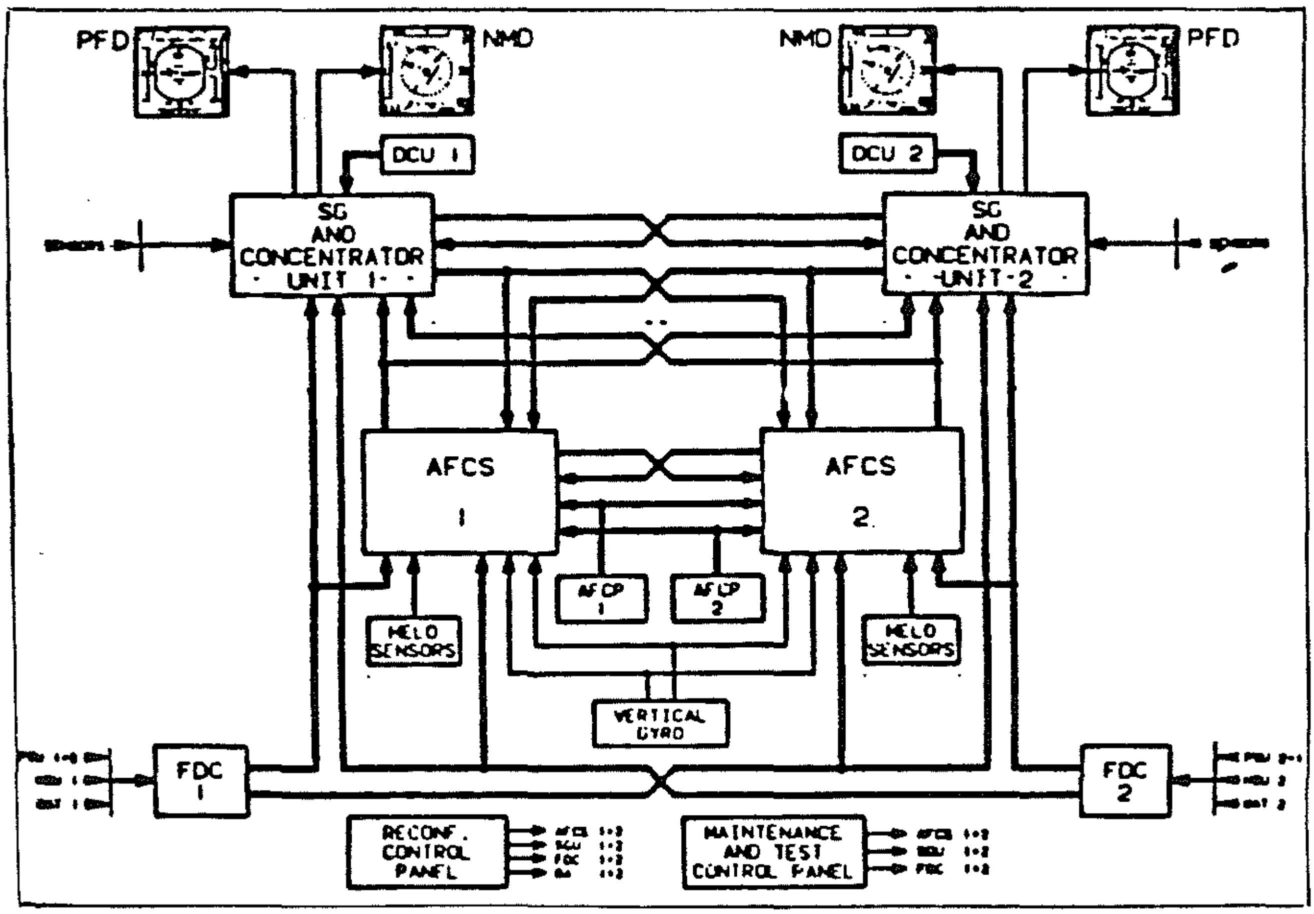


Figure 2.2 : IFDS Architecture

3. DESCRIPTION OF THE LRUs

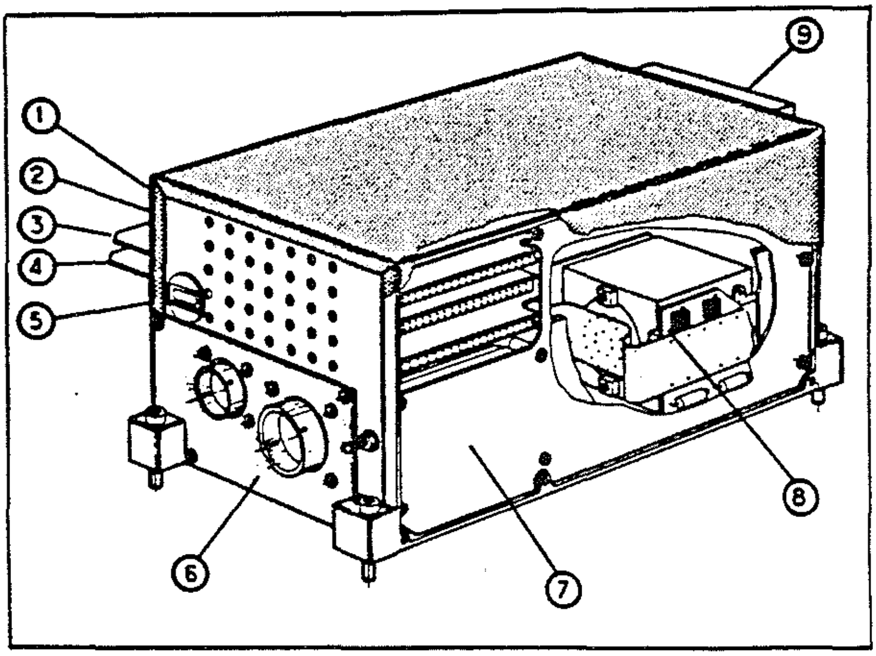
The main LRUs of the FDS are described below :

3.1 Flight Data Computer (FDC)

The FDC has been designed to be as compact and light as possible, in order to save volume and weight as much as possible.

It basically includes :

- Two 2 axes Dry Tuned Gyros DTG 2000 made by SMITHS INDUSTRIES, and their electronics
- Three Accelerometers 3152 made by CROUZET
- Three cards performing data acquisition from the sensors, central processing unit and I/O
- Two Spare Slots for additional functions
- A power supply
- A chassis, including interconnection and lightning protection



1. Spare
2. Spare
3. I/O
4. CPU
5. IMU Acquisition
6. Connection/Protection Block
7. Power Supply
8. Gyrometer
9. Ventilator

Figure 3.1 : FDC description

The design is fully modular, each subassembly exchanging its information through a standard communication bus, and each of the electronic cards being equiped with a MC 68000 processing unit. The cards can be inserted at any of the 5 Slots, without any damage, which eases maintenance operations.

The intertial sensors have been chosen for their proven robustness and reliability : more than 5000 3152 force balanced accelerometers have already been manufactured by CROUZET and used in aircraft and missiles.

The DTG 2000 is a new high reliability Dynamically Tuned Gyro from SMITHS INDUSTRIES.

It has been chosen after a worldwide request for proposal, because of its best performance reliability/cost ratio in the world.

It uses assembled flex pivots, which provides performance, and gas bearings, avoiding ball bearings which generally considerably degrade reliability.

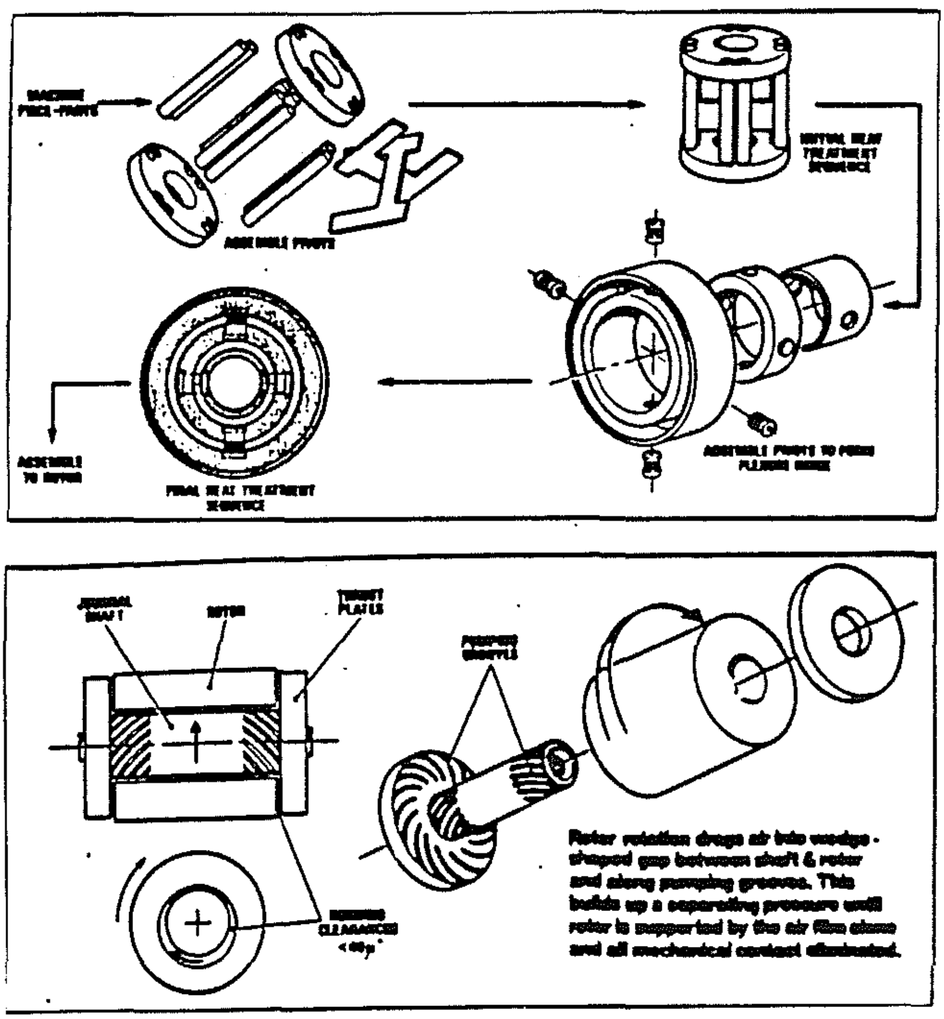
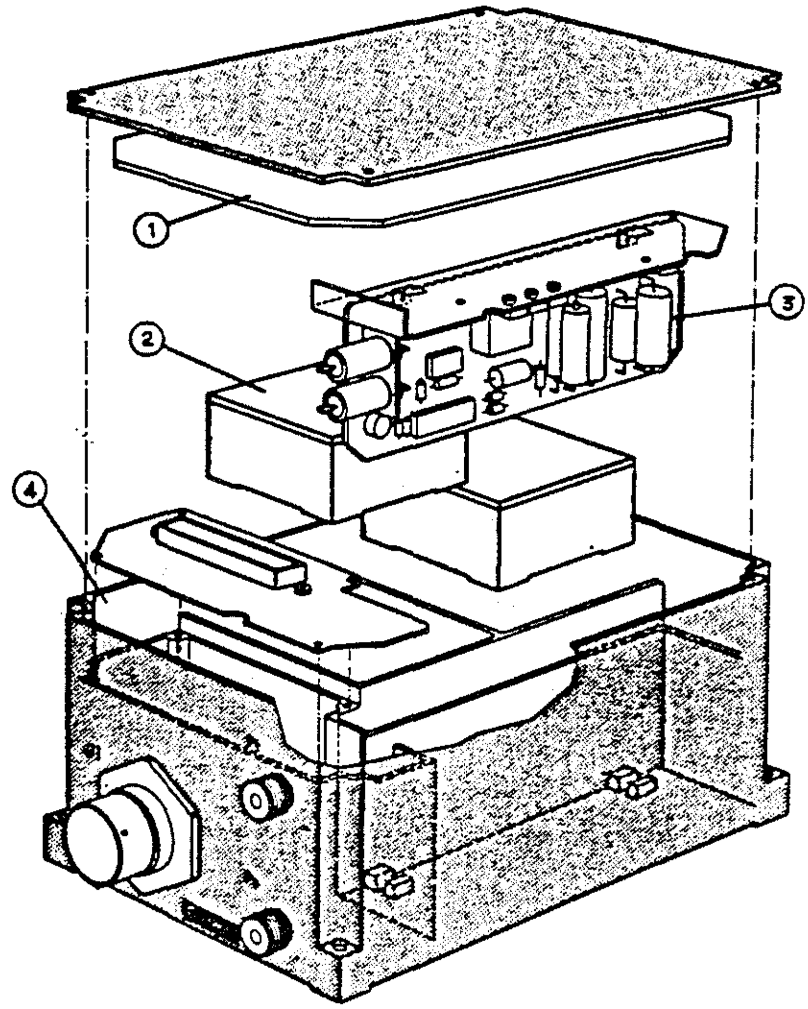


Figure 3.2 : DTG 2000

3.2 Pressure Sensor Unit (PSU)

The PSU is a unit specified for helicopter, with an optimum performance/cost ratio.

It includes two pressure sensors, one for absolute static pressure and one for differential dynamic pressure, and one electronic board. Both sensors are of the solid state type. This provides excellent reliability altogether with high accuracy. The PSU is TSO ed C 10b and C 2C.



1. Electronic board
2. Sensors
3. Power Supply
4. Chassis

Figure 3.3 : PSU description

The PSU is associated to a Temperature Probe Unit using a platinium sensing element.

3.3 Heading Sensor Unit (HSU)

The HSU is a 3 axis static magnetometer, which measures the three components of the local Earth Magnetic Field.

In addition to its very light weight, this unit affords the advantage of a possible software compensation of the carrier magnetic disturbances.

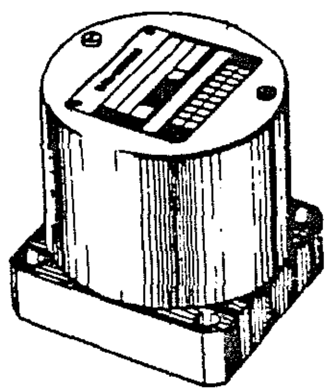


Figure 3.4 : HSU

Total weight of the FDS System is approximately 6.5 kg (including FDC, PSU and HSU)

Total power consumption is less than 60 w.

4. SPECIFIC CHARACTERISTICS

The Flight Data System is of the most recent design, relying upon :

- A choice of rugged and reliable components

- An effort to minimize volume, mass and cost

- A choise of solutions complying with the performance requirements for any modern helicopter primary reference and navigation information

- A choice of additonal options which offer wide possibilities of evolutions to the system designer.

4.1 Performances

The basic performances of the FDS comply to the AEROSPATIALE's requirements for the SUPER PUMA MK 2.

4.2 Flight Safety

The FDS will be certified within the AS 332 MK 2 certification programme and will be complying with :

- FAR 29, Amendment 16
- Special condition "Lightning protection" from DGAC (1)
- FAA (2) 12/15/1978 requirement concerning IFR Navigability Criteria.

According to the RTCA DO 178 A guideline, the FDS is classified in category "critical". The software of the FDC and of the PSU are of the "Level 1" type.

In order to achieve these requirements, a specific organization has been set up in CROUZET :

- General "Project" organization

- Special inspection meetings between CROUZET and AEROSPATIALE have been planned in order to check hardware and software development quality insurance conformity matrix.

- A complete and detailed documentation set has been produced and approved, in conformity with RTCA DO 178 A

- The configuration is managed in conformity with the rules of RTCA DO 178 A

- A specific modification management procedure has been followed. It includes the use of "Technical Data Sheets" and of "Modification Data Sheets" during all the integration and flight tests period. This method had previously been successfully experimented between CROUZET and AEROSPATIALE (Ref. 1).

Detailed analyses have been conducted concerning Failure Mode occurence, MTBF prediction and flight safety analysis. They all comply with AEROSPATIALE's requirements for the SUPER PUMA MK 2.

(1) : DGAC : Direction Générale de l'Aviation Civile
(2) : FAA : Federal Aviation Agency.

4.3 Self compensated Heading Computation

The method of heading computation in the FDS relies upon a strong experience of CROUZET, and on many flight tests.

It consists in measuring the components of the Earth's magnetic field with a 3 axis static magnetometer, and then in computing the magnetic heading by projection in across and along axes.

The main problem is to correct the magnetic disturbances due to the metallic mass and to the magnetic fields created by local electrical currents.

CROUZET has developed and experienced an original method to achieve that. It mainly relies on modelisation of the carrier magnetic ellipsoïd, through an automatic in flight procedure of 4-5 minutes (Cf. Ref. 2).

This friendly procedure has been successfully flight tested since 1982, and is strongly appreciated by operational users.

Accuracies better than 0.5° (95 %) can be achieved using this method.

4.4 Options and evolutions

The design of the FDS is basically modular so that, in addition to the standard basic definition described above, different options are offered strenghtening the ability of the FDS to fulfil any mission requirements of the AS 332 MK 2. These functions are added, in option, to the system, without changing its basic definition and operation.

4.4.1 Doppler Navigation

The use of a Doppler Navigation Radar can bring better performance in the hybridization algorithm, and then, better accuracy in pitch, roll and heading computation.

A smoothed ground speed information, a wind information and a ground position can thus be delivered and the FDS becomes a cost efficient self-contained navigation system, for military missions of the carrier.

Different types of Doppler can be used coming from different Doppler Radar manufacturers, but the standard installation shoud be with the ESD RDN 85 BA.

4.4.2 Low Airspeed : $CLASS^R$ option

CROUZET has a 40 year old experience in Air Data Systems for all types of airplanes, and has been developing a whole flight envelope Air Data System for helicopters since 1980.

This system use the $CLASS^R$ (1) principle, based upon flight mechanics analysis at low airspeed, taking into account the across and along cyclic pitch, the acceleration information, the collective pitch, the tail rotor pitch. This principle has been already described in previous conferences (see ref. 3).

The $CLASS^R$ algorithm derives from the initial $VIMI^R$ (2) System which has been operated for 15 years at the French Flight Test Center of BRETIGNY and ISTRES, and at AEROSPATIALE MARIGNANE. A lot of improvement has been performed, and the $CLASS^R$ has been flight tested on a PUMA helicopter at the French C.E.V., in a helicopter Air Data Computer (HADC).

This HADC (Figure 4.2) is a 2 MCU box including 2 sensors and a processing unit. The $CLASS^R$ algorithm is hybridized with classical anemometry in order to provide a complete flight envelope air data information.

A better than 3 kt (1.5 m/s) accuracy was performed during flight tests, which were conducted very carefully by the French Flight Test Center, using a specific method to calibrate properly the system (see Ref. 4).

The $CLASS^R$ option can be added to the FDS of the AS 332 MK 2 by two ways :

- Either by connecting an external HADC to the FDC
- Or by integrated a $CLASS^R$ function inside the FDC, which is a better solution in terms of mass, but which states a certification problem.

(1) $CLASS^R$ is a Registered Trademark and patented product of CROUZET. It stands for "CROUZET Low Airspeed System"

(2) $VIMI^R$ is a Registered Trademark of CROUZET, standing for "Vitesse Indiquée par Moyens Internes".

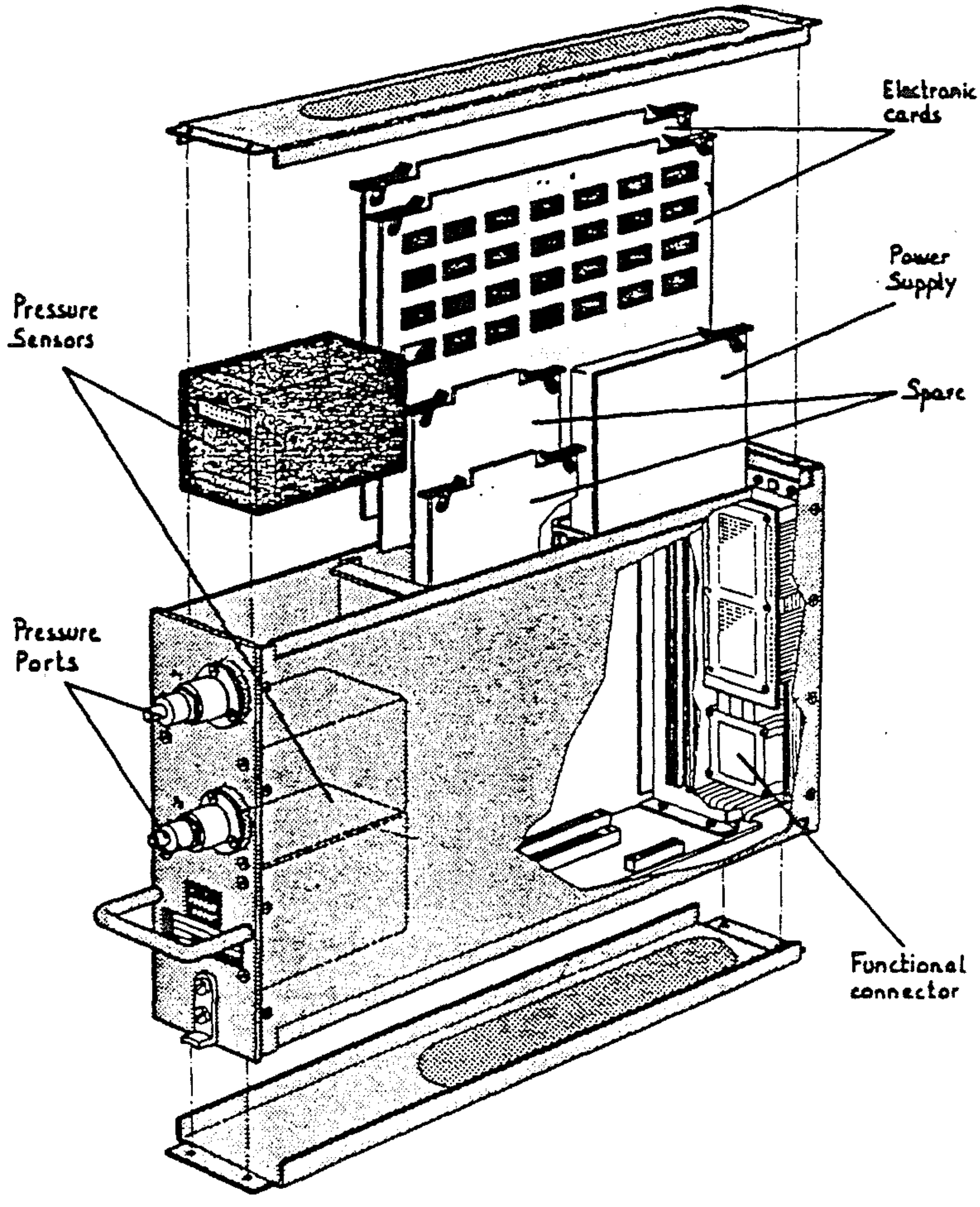


Figure 4.2 : Helicopter Air Data Computer

4.4.3 GPS Coupling

The satellite based NAVSTAR-GPS Global Positioning System will provide an all weather, worldwide positioning services as soon as 1990, for civil and military users.

Position accuracies of 100 m are expected in Standard Service and of 20 m in Precise Service, available for a few countries. The system will provide also a Velocity information (altogether with a Time information).

A great interest can be expected in the coupling of this system to an AHRS, for the following reasons :

- An AHRS/GPS set provides the equivalent of pure inertial systems data (attitudes, heading, velocities, accelerations, position), with much better accuracy and with less cost and weight

- The two systems are complementary, and help each other perfectly :

  . the AHRS can help the GPS loops to keep locked on, especially during high dynamics manoeuvers,

  . the AHRS can replace temporarily the GPS positioning service in case of satellite masking or GPS jamming configurations.
  This is particularly efficient when a Doppler Navigation Option is used.

  . vice versa, the GPS, which provides excellent velocity and position information, which can be used to help the AHRS :
  . by updating the AHRS/Doppler position information
  . by using the GPS ground speed information in the speed hybridization algorithm of the virtual platform.
  A common benefit and a large improvement in the performance level is then expected to be obtained.

CROUZET, whose know-how in Radio Navigation Systems comes from a 15 year old experience in OMEGA receivers, is currently developing a family of GPS receivers, specially designed to be integrated within avionics systems, and to be coupled to AHRS's.

For the AS 332 MK 2 Flight Data System, the GPS option could be realized by 2 ways :

- Either by coupling an external GPS receiver (GPS sensor) to the FDC, using ARINC 429 links

- Or by integrating a GPS module inside the FDC, which like the CLASS^{R} option, states a certification problem, but which offers the best performances, weight and cost.

Possible integration of GPS and CLASS^{R} options are illustrated in Figure 4.3 and 4.4 below.

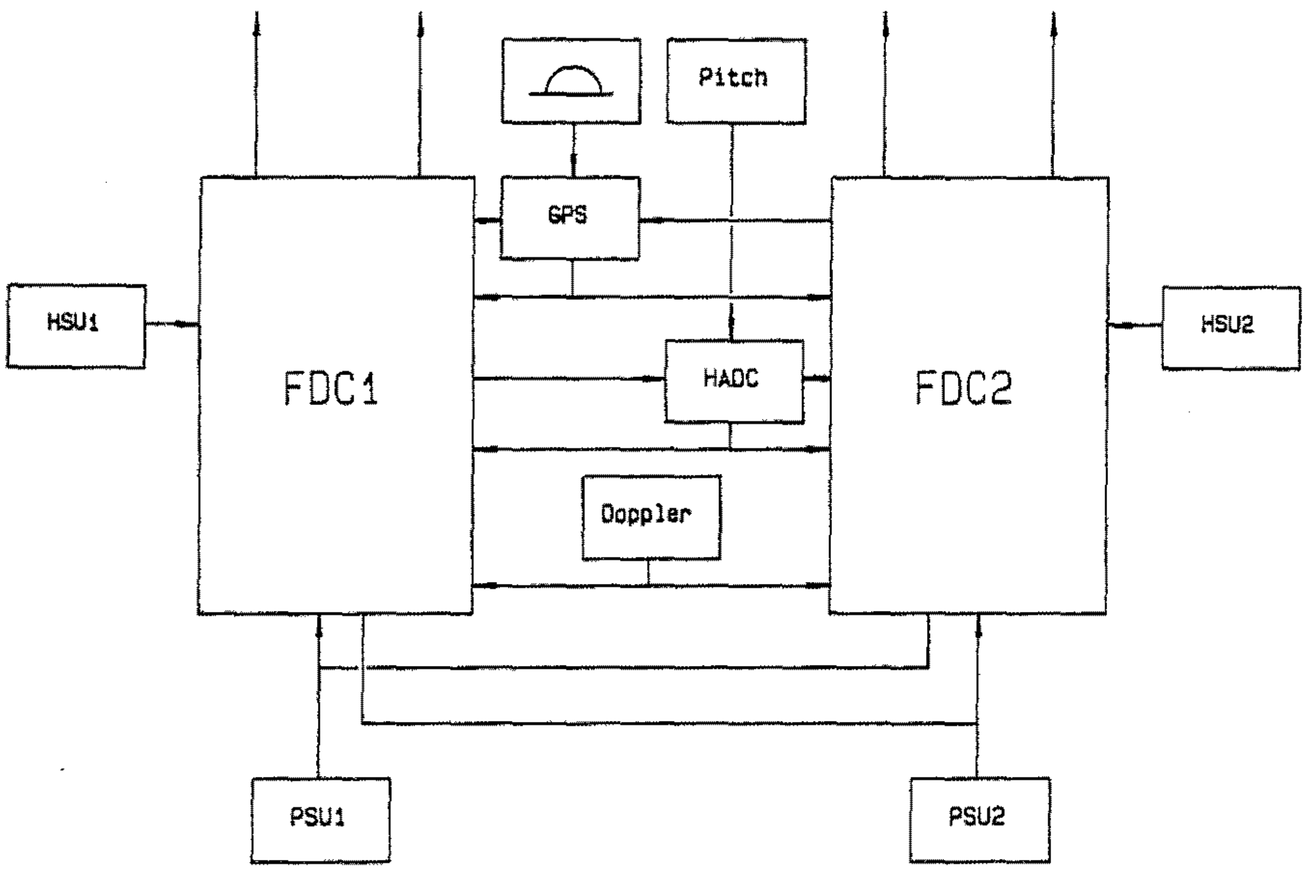


Figure 4.3 : GPS and CLASS^{R} options integration - Solution 1

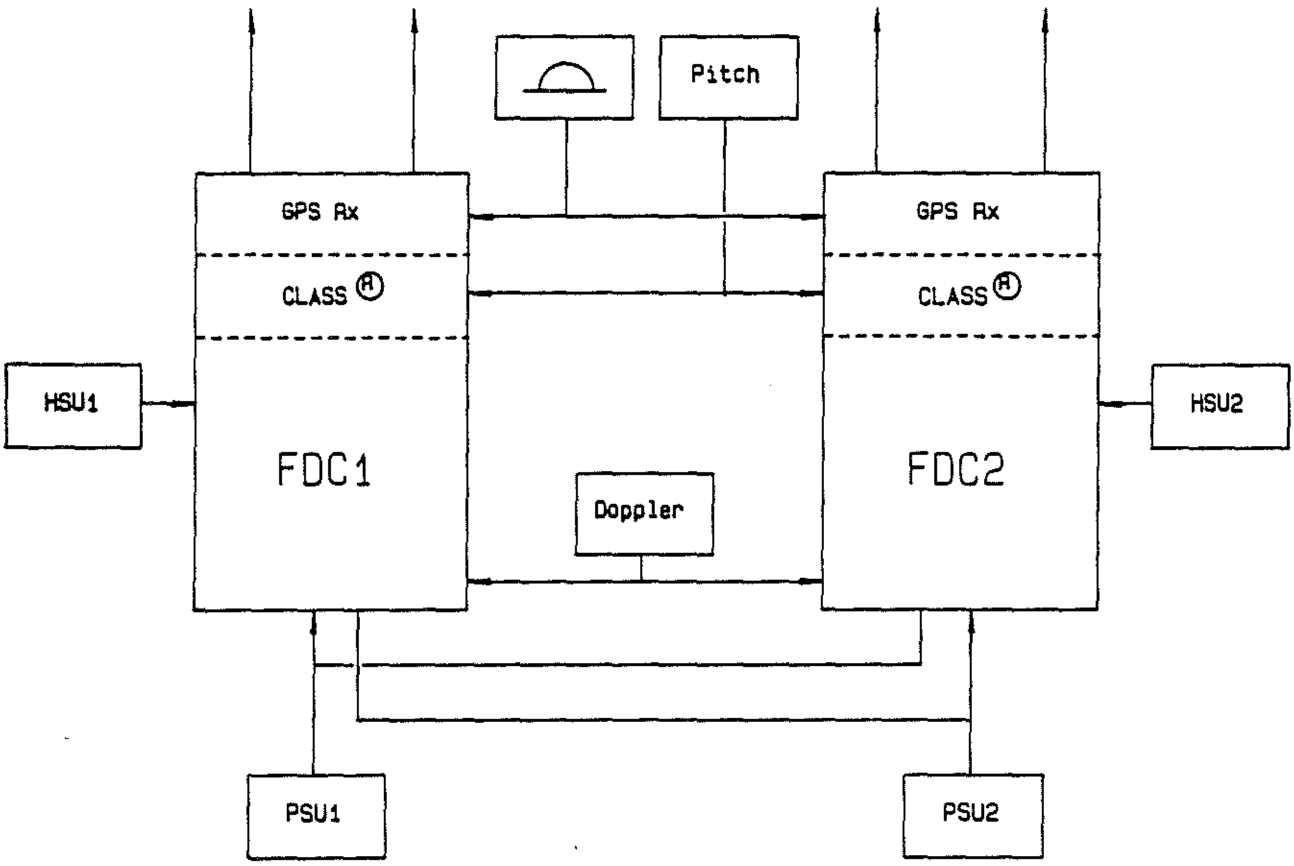


Figure 4.4 : GPS and CLASS[R] options integration - Solution 2

5. CONCLUSIONS

The basic configuration of the SUPER PUMA MK 2 Flight Data System has been described ; a special emphasis has been put out quality and safety insurance of the system.

Additional options have been described including Doppler Navigation, whole flight envelope air data computation and GPS coupling.

This underlines the modular and open-ended design of the system, which, in addition to its basic primary reference system functionalities, is likely to provide navigation data for any civil or military mission of the carrier.

6. REFERENCES

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