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THE MI-38 AVIONICS - A NEW STEP TOWARDS SAFETY

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1. FOREWORD

Flight safety in extreme operating conditions has become an absolute priority for helicopter manufacturers.

The great experience gained in producing a range of aircraft designed to operate in particularly harsh environments such as the North Sea storm-lashed offshore oil rigs, the Middle East desert areas, the South American jungle, the Canadian Far North and Central Siberia have largely contributed to MIL's and EUROCOPTER's worldwide reputation.

The MI 38 systems have particularly been designed in this view in order to meet the needs of the most demanding customers and by even being forward of the most stringent regulations required by the various certification bodies.

The purpose of this contribution is to present the main characteristics of the aircraft basic system by focusing on the safety aspect of our design which will permit to propose, in the very early 21st century, an advanced aircraft suited to the world most rigourous weather conditions and particularly to the strongly contrasting climate in central and northern Euro-Asian regions.

2. FUNCTIONS AND ARCHITECTURE OF THE MI 38 BASIC SYSTEM

The basic system selected for the MI 38 aims at symplifying the pilots' task thanks to :

- a more synthetic data display,
- a dual-dual automatic flight control system,
- assistance in case of problems,
- preventing some mechanical damage that was so far unpredictable.

Moreover, this system aims at providing a significant support to maintenance and an appreciable reduction of operating costs.

The following three subsystems answer the above criteria :

- Integrated Flight Control System : IFCS,
- Vehicle Monitoring System : VMS,
- Aircraft Recording and Monitoring System : ARMS.

2.1. Integrated Flight Control System (IFCS)

The IFCS is an integrated piloting aid system which allows automatic flight control with a high safety and reliability level.

The IFCS is made up of two identical and independent semi-systems with cross-monitoring.

Each semi-system is made up of three subsystems :

- the Primary Reference System (PRS) whose core is the Flight Data Computer (FDC); it processes data from various sensors (pressure, temperature, heading sensors), and delivers information to the other two subsystems. Moreover, it ensures hybridization with external navigation equipment such as Doppler, GPS, ...

- the Automatic Flight Control System (AFCS) which performs :
  * automatic flight control after AFCS engagement (basic stabilization and upper modes),
  * processing of flight envelope and power margin data,
  * some sensor monitoring functions.

  It includes a four-axis digital computer which activates four series-mounted hydraulic actuators and four parallel electrical trim actuators acting on the yaw, roll, pitch and collective channels.

- the Display System comprising two Smart Multimode Displays (SMD) which display flight and mission data on color screens, 6 x 6 inch wide.

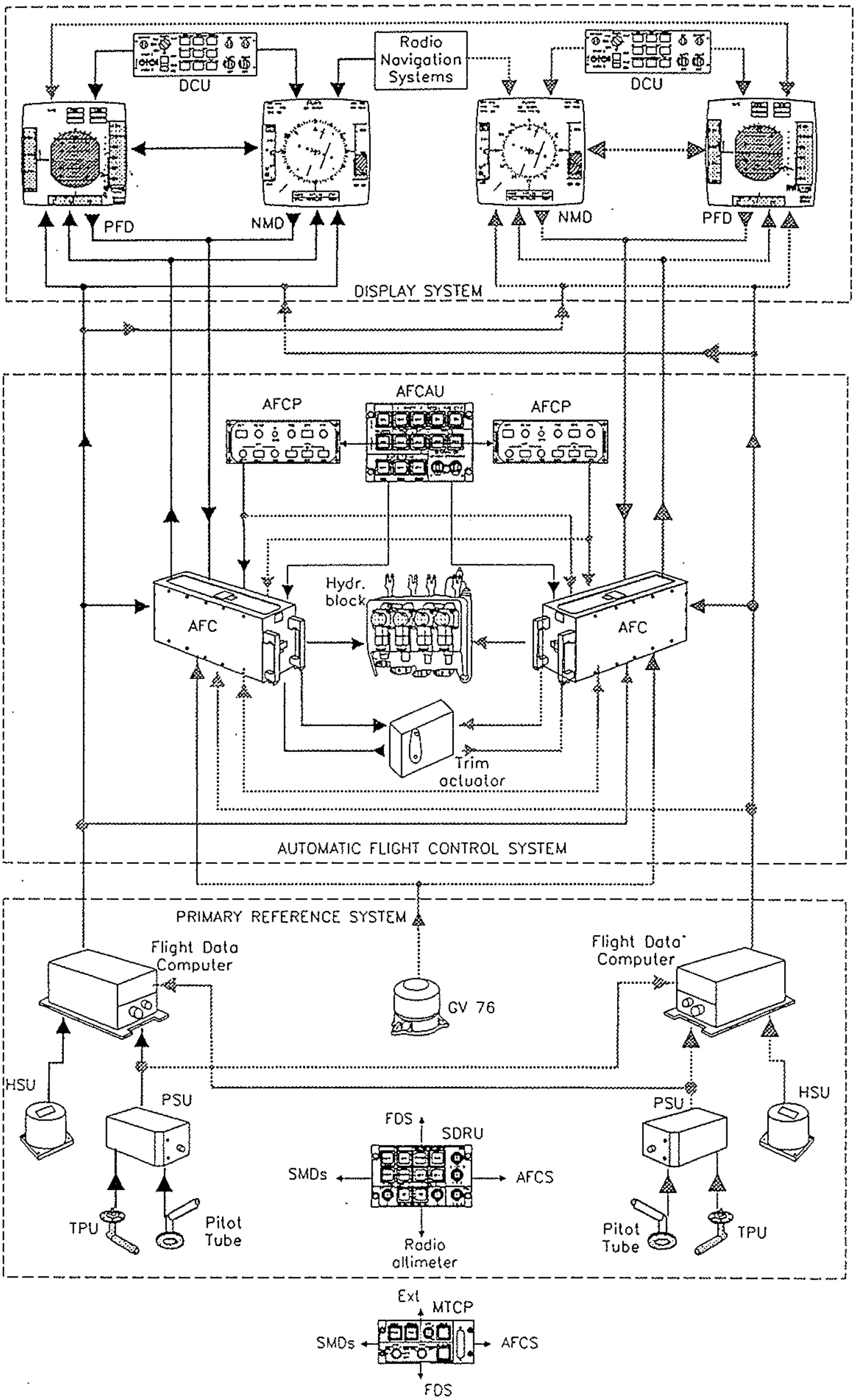
  Each screen, which contains its own processing and symbol generator ressources, receives all data available on board and provides display with the desired symbology at all times. They also concentrate data from external navigation system such as VOR, DME, radio-altimeter, and transmit them with a high degree of reliability to the other sub-systems. Moreover, they permanently monitor the system by storing the failure events during flight.

A Maintenance and Test Control Panel (MTCP) can report more than 90 % of the system failure causes to the technician.

The interconnection between the different units is ensured by an ARINC 429 data link.

The following picture shows the general block diagram of the IFCS.

MI 38 IFCS


DCU
Radio Navigation Systems
DCU
PFD
NMD
NMD
PFD
DISPLAY SYSTEM
AFCP
AFCAU
AFCP
Hydr. block
AFC
AFC
Trim actuator
AUTOMATIC FLIGHT CONTROL SYSTEM
PRIMARY REFERENCE SYSTEM
Flight Data Computer
Flight Data Computer
GV 76
HSU
PSU
FDS
SDRU
HSU
PSU
SMDs
AFCS
TPU
Pilot Tube
Radio altimeter
Pilot Tube
TPU
Ext
MTCP
SMDs
AFCS
FDS

2.2. Vehicle Monitoring System (VMS)

The VMS functions are to provide the crew members with all the parameters necessary for controlling the engines and the various vehicle systems :

- in normal configuration, by improving crew availability and eliminating the need for frequent scanning of the various helicopter systems,
- in case of system failure detection, by providing guidance for corrective actions.

The VMS is made up of :

- 2 color displays, 6 x 6 inch wide, of the same type as those used for the IFCS, located on the central instrument panel,
- 1 dedicated VMS Control Unit (VMCU) which forms the dialogue interface between the crew members and the VMS,
- Dual digital, analog and discrete data concentrators used to concentrate all parameters received from the different aircraft sensors on specific digital ARINC 429 lines.

In order to increase the display safety, both screens are connected to each other via an ARINC 429 HS digital link so called "cross talk".

The basic functions to be performed by the VMS display system are as follows :

- Monitoring and display of the engine parameters,

  NG, T4, TQ, NR, NF, oil pressures and temperatures, P2 tapping, de-icing, air intake, oil levels, ...

- Monitoring and display of the vehicle parameters,

Fuel system	:	Fuel quantities, fuel flow, pressures, heating indications, transfer indications, ...
Transmission	:	MGB, IGB, TGB oil temperatures, oil pressures, ...
Hydraulic system	:	Fluid pressures, fluid levels, ...
Electrical system	:	Voltage on bus-bars, AC and DC output generators, battery voltage and temperature, APU indications, ...
Miscellaneous	:	Outside air temperature, GMT time, doors, ...

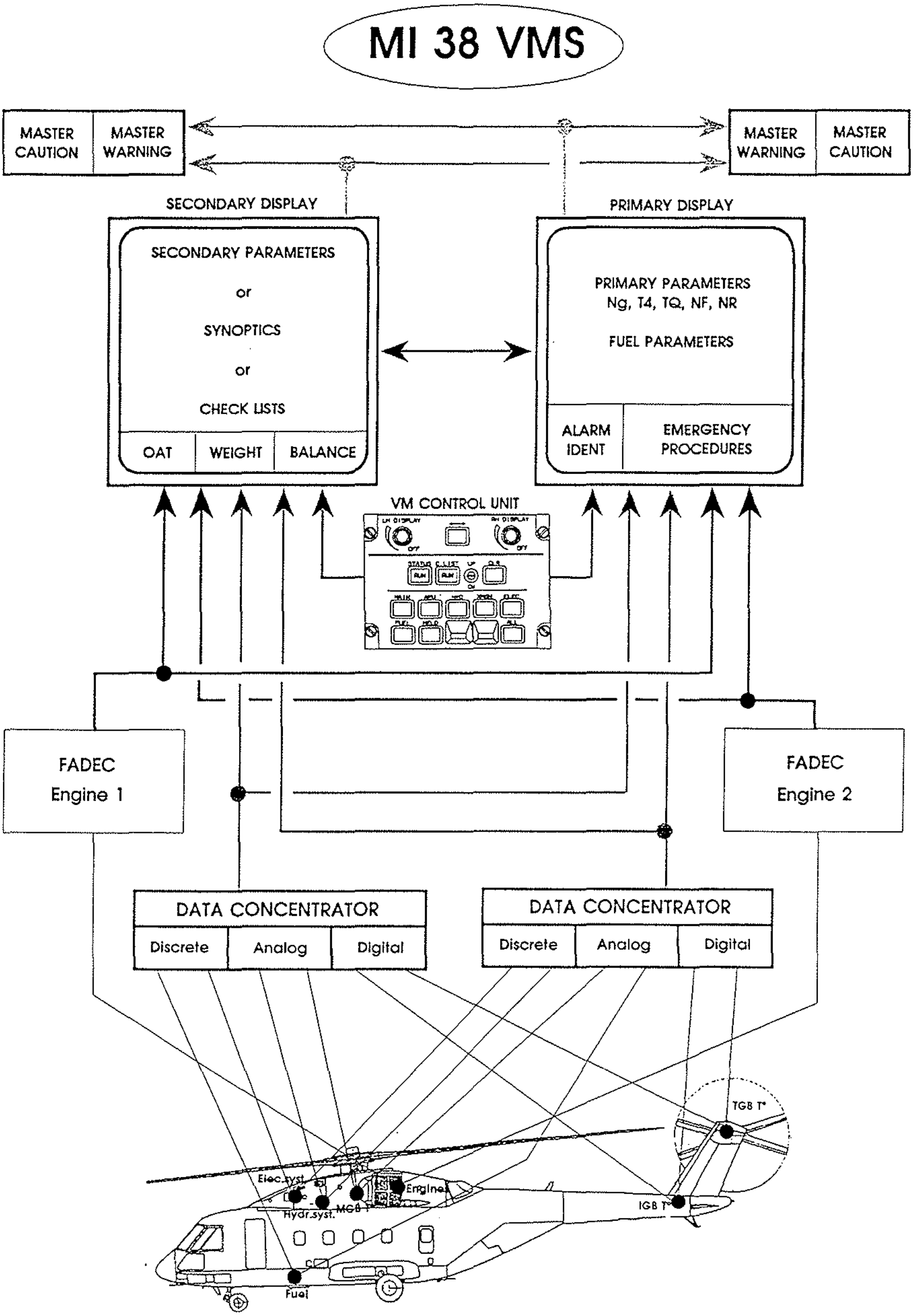
- Aircraft weight and balance calculations and display of current aircraft weight and center-of-gravity,

- Failure and alarm management and display according to criticality.

  * Level 1 : warning + flashing red master warning,
    + warning audio alarm, where applicable,
    + steady red indication on central warning panel,
    + warning identification on display with adequate symbology,
    + presentation of the associated emergency procedure.

  * Level 2 : caution + flashing amber master caution,
    + caution identification on display with adequate symbology,
    + presentation of the associated corrective procedure.

  * Level 3 : advisory + advisory identification on display with adequate symbology.


MI 38 VMS
MASTER CAUTION
MASTER WARNING
MASTER WARNING
MASTER CAUTION
SECONDARY DISPLAY
PRIMARY DISPLAY
SECONDARY PARAMETERS
or
SYNOPTICS
or
CHECK LISTS
OAT
WEIGHT
BALANCE
PRIMARY PARAMETERS
Ng, T4, TQ, NF, NR
FUEL PARAMETERS
ALARM IDENT
EMERGENCY PROCEDURES
VM CONTROL UNIT
FADEC Engine 1
FADEC Engine 2
DATA CONCENTRATOR
Discrete
Analog
Digital
DATA CONCENTRATOR
Discrete
Analog
Digital
TGB T°
IGB T°
Elec.syst.
Hydr.syst.
MGB T°
Engines
Fuel

2.3. Aircraft Recording and Monitoring System (ARMS).

Mechanical faults could have catastrophic consequences on helicopters due to their criticality. Among the causes of technical failures besides engines, mechanical failures are the main ones.
Safety improvement is one of the aircraft manufacturers and Certification Authorities common concern. Consequently, preventing such risks has led to select for the newly certified aircraft, a helicopter health monitoring system.

Eurocopter met this new requirement by fitting such a system on its Super Puma.

EC and MIL are preparing a new generation able to monitor a wider range of functions on the MI 38.

This system called ARMS, mainly allow through vibrations analysis, potential damages to critical parts to be forecast and as a consequence to know the condition of the helicopter.

ARMS also allows the rotors to be tuned, hence to reduce the level of vibrations and to trigger off a warning through an abnormally increased vibration level.

Besides, ARMS can record the engines operation time and the possible exceeding of operation limits.

ARMS acts as well as a crash recorder.

ARMS is based on the following main functions :

- Health monitoring

  A permanent vibration analysis of major components (engines, gears, transmission, ...) and oil debris monitoring will allow to detect an incipient damage directly on the part before a significant damage is generated.

- Usage monitoring

  The counting of operating time, taxiing time, flight time, engines cycles, exceedance of limitations (Nr, Tq, T4, Ng, Nf, ...) will be performed.
  This monitoring will help optimize maintenance actions by computing damage to the major mechanical items.

- Status monitoring

  The acquisition of the on-board system failure indicators will help enhance the knowledge of failure modes of the parts. This knowledge of the failure cases will be used to improve diagnostics, and reduce the false removal rate.

- Accident recording

  Crew voices and mandatory flight data parameters will be recorded in a crashworthy box. In case of accident, this information may be replayed again to help determining the cause of the accident.

The ARMS will include the following components :

on aircraft

- The Cockpit Voice / Flight Data Recorder (CVFDR) : That is a crash protected memory red box where flight data and pilots voices are continuously and automatically recorded.

- The Voice Recorder Control Panel : It allows the recorder testing and also the listening and erasing of the recorded voices but can only be used on the ground.

- Aircraft sensors : Accelerometers for mechanical parts vibration parameters acquisistion, tachometers, chip detectors,...

- Dual data concentrators designed to collect data from the sensors and send them to the Aircraft Monitoring Computer through ARINC 429 HS lines.

- The Aircraft Condition Monitoring Computer (ACMC), the heart of the system is a computer which receives the data from the concentrators. Processing is carried out by this unit.

- An ARMS Control Box used to initialize the system before flight, initiate a health engine analysis or main and tail rotors track and balance parameters acquisition processing and display an analysis result.

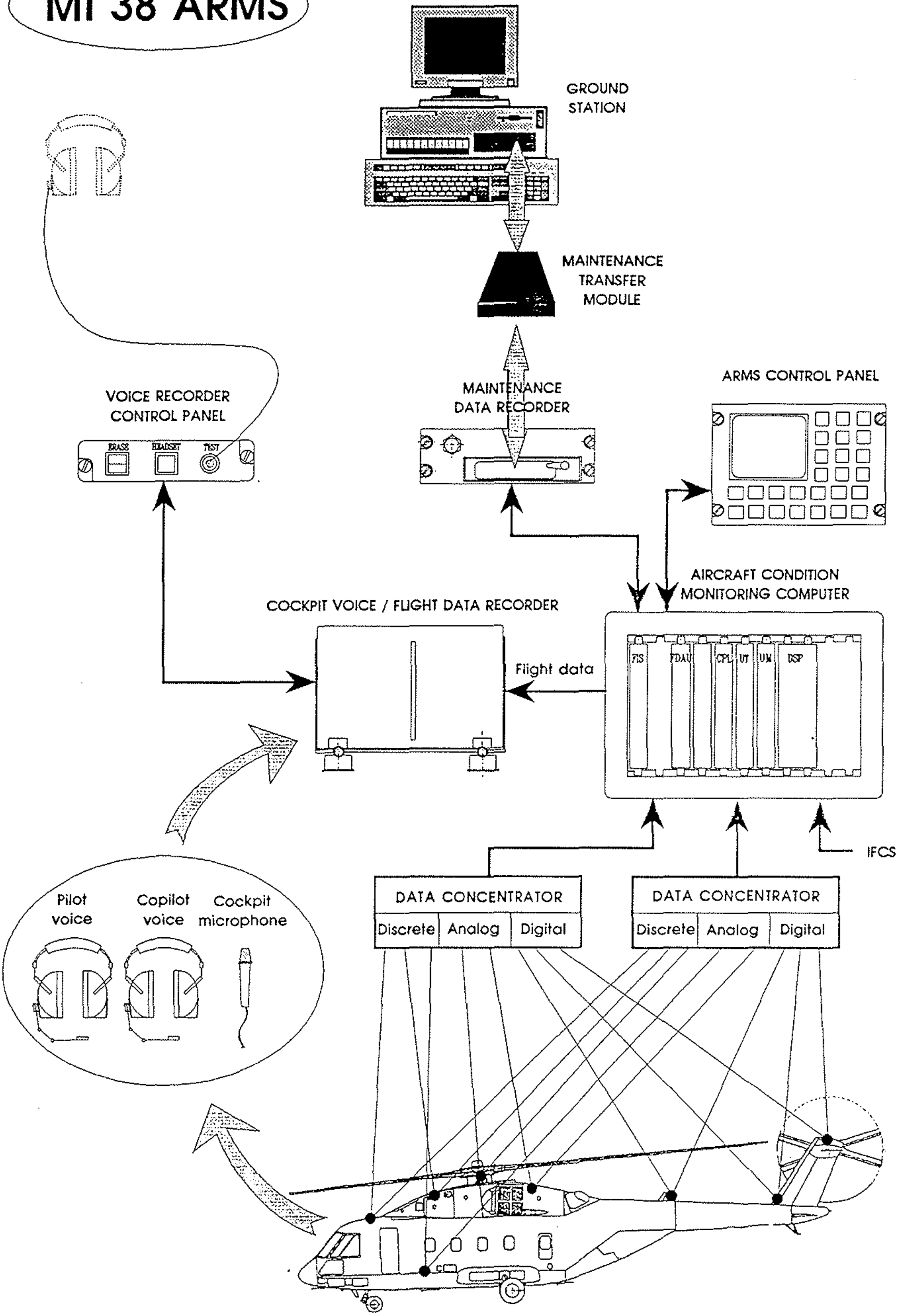
- A Maintenance Data Recorder (MDR) which makes the parameters storage on a Maintenance Transfer Module (MTM) for transfer between aircraft, and ground station.

on the ground

- A Ground Station allowing :

  * analysis of the flight collected data,
  * flight report establishment,
  * helicopter maintenance management,
  * coherence with the fleet management,
  * aircraft configuration status.

MI 38 ARMS


GROUND
STATION
MAINTENANCE
TRANSFER
MODULE
MAINTENANCE
DATA RECORDER
ARMS CONTROL PANEL
VOICE RECORDER
CONTROL PANEL
ERASE
HEADSET
TEST
AIRCRAFT CONDITION
MONITORING COMPUTER
COCKPIT VOICE / FLIGHT DATA RECORDER
Flight data
FDAU
CPL
UT
UM
DSP
IFCS
DATA CONCENTRATOR
Discrete
Analog
Digital
DATA CONCENTRATOR
Discrete
Analog
Digital
Pilot
voice
Copilot
voice
Cockpit
microphone

3. MAN-MACHINE INTERFACE

3.1. Design criteria

Anthroprometric data including western and Russian population have been used for the design of the cockpit.

The general principles governing the definition are :

- a maximum external visibility,
- an excellent accessibility for pilot and copilot to the instrument panel with their harness locked, in order to be able to use the IFCS control panel,
- a good accessibility to the pilots' seats through the central aisle.

Because of the western certification requirements for two pilots in IFR and a single pilot in VFR, the cockpit should provide the same possibilities to each crew member in order to allow the copilot to control the machine in the same way as the pilot.

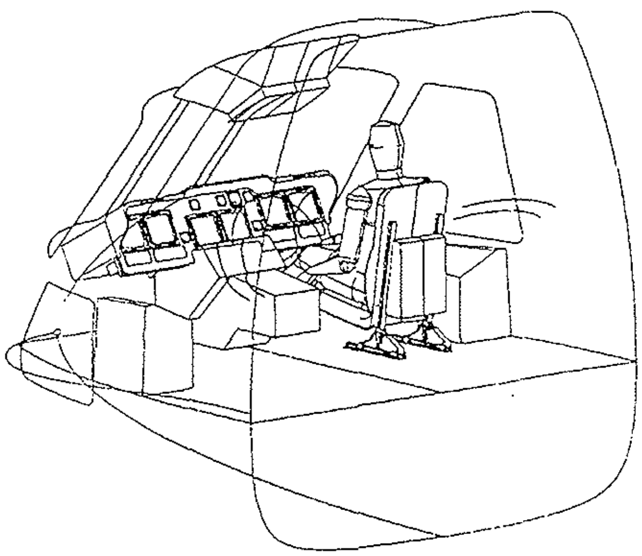
3.2. Information display

Recent analyses have demonstrated that in most helicopter accidents, human factors are deeply involved. An erroneous decision taken by a pilot in a stress situation is a frequent case of accident.
The MI 38 man-machine interface concept is designed to reduce the sensitivity to these human factors.

For this purpose, thorough ergonomic studies were carried out to provide the crew with the necessary information for the current phase of the flight with an appropriate symbology.

- In normal operation, reduction of the workload is obtained through a more synthetic information display, more forecast and assistance-oriented than on monitoring.
- In case of a failure, the VMS screens will assist the crew by providing the relevant emergency procedures and systems synoptics.

The feedback we got from Super Puma MK II commercial use with IFDS system in the North Sea with our customer Helikopter Service has been very useful.



4. SAFETY FEATURES.

A very particular care was taken on the safety aspect when designing the MI 38 systems.

The system architecture proposed results from a very accurate risk analysis and, the missions can therefore be achieved after a major subsystem failure with a high safety level.

To assure this safety level, a dual / dual configuration including two computing units, each with two processors, enables the AFCS to remain totally operational in all modes following a single failure.

In the event of a single failure of the VMS control unit, an "ALL" command, separately wired to the displays, allows to gain access to each vehicle page through a circular permutation process.

Redundant data concentrators provide dual links between vehicule sensors and VMS displays / ARMS computer.

The ARMS will provide an early detection of a mechanical defect which could lead to an accident and will guarantee that the maintenance is in accordance with the helicopter usage (no exceedance omitted).

The following devices and means were introduced to improve the system safety.

- Development of level 1 software in accordance with DO 178 B.

- Feedback for critical parameters display.

- Input parameters refresh control by the use of ARINC lines.

- Reconfigurations capability. Architecture is dual / dual and in case of failure, the system will be reconfigured.

- Red gun supervisor to assure the reliability of the displayed alarms.

- Fan supervision for reliability of equipment using forced ventilation.

- Built-in test : preflight tests, post and cyclic tests, maintenance tests.

Complying with all these constraints will contribute to improve the safety of the MI 38 system, the efficiency of the maintenance actions and facilitate the certification with the various authorities.

5. THE RUSSIAN ENVIRONMENT

As opposed to Western Europe where the severe cold of the frozen North can only be felt in far Lapland, practically no region of the ICS is really spared the cold.

About one third of the country is subjected to an arctic climate with polar night and violent snowstorms (purga) comparable to the Canadian North blizzard for about 8 to 9 months followed by short thaw periods where mud makes any land circulation impossible.

Though in January the average temperature in Moscow is around -10°C, the average temperature throughout the country is -30°C for the same month.

South-east of the peninsula, Vladivostock's harbour which is at the same latitude as Florence takes advantage of the milder effect of Pacific but is however icebound for 4 months a year because of the proximity of the Oyashio, a cold stream from the Bering strait.

The Siberian weather, a typical example of the continental climate, features an annual temperature range that may reach 70°C. There are practically no intermediate seasons and in few weeks the weather shifts from a freezing winter to a suffocating summer broken with stormy showers.

The MI 38 helicopter is designed to be operated in this particularly hostile environment and to be used under these extremely harsh weather conditions, especially in low temperature and strong wind conditions.

The aircraft intended to be operated in such an environment will be equipped with deicing systems (rotors, windshields, air intakes) and self-contained navigation systems so that they can be flown far from any ground infrastructure with a great accuracy.

For some specific missions, landing on unprepared ground will be made possible thanks to an automatic all-weather blind landing system.

The aircraft is intended to be operated down to an extreme temperature of -60°C. An operational procedure will be applied for starting up the aircraft at such extreme temperatures and an avionics bay heated prior to takeoff, will make the systems operational in a very short time.

6. CERTIFICATION ISSUES.

The MI 38 is the first helicopter in the world designed to meet from the early design stage, both the latest AP 29 Russian regulation and the JAR 29 European regulation.

A detailed study of these regulations has therefore been performed between MIL and Eurocopter.

This analysis has taken into account the passed experience of both helicopter designers in order to build a common interpretation of regulation able to cope with Aviaregister and JAA requirements.

This implementation has been started and will go on in detailed design, test and substantations.

More specifically for avionics, complementary special conditions are forecast and taken into account.

Two are particularly important for safety : lightning and EMI effects.

It implies complementary studies and protection on vehicle and electronic equipment.

The MI 38 will be the first Russian certified helicopter to meet these requirements.

7. PROGRAMME'S PARTNERSHIPS.

The whole programme activities will be conducted and managed by the EUROMIL joint venture created in September 1994 and based in Moscow, between the following four companies :

- Eurocopter,
- Kazan Helicopter Plant,
- Klimov Plant in St Petersburg,
- Mil Moscow Helicopter Plant.

25 % of shares belong to each partner.

Euromil will have an extremely wide authority, since the programme belongs to it.

Euromil will be in charge of organizing all exchanges between the four partners, in terms of development, industrialization and series production.

The main activities of the partners have been agreed upon, under the wing of Euromil, in a cooperation framework agreement.

- Thus, MIL, which is still an engineering department and employs high level engineers and technicians, has been tasked with developing the future helicopter. MIL is in charge of the design, prototype manufacture, ground and flight tests.

- KLIMOV PLANT has been declared in charge of developing, finalizing and industrializing the TVa 3000 engine. This engine whose contingency power is near 4000 Shp will be the first one to be provided with a full authority digital electronic controller (Fadec).

- The KAZAN HELICOPTER PLANT (KVZ) located at Kazan, is one of Russia's largest helicopter manufacturers. Among other helicopters, it produces the MI 8, MI 17 line.
  KVZ will be in charge of industrializing and productionizing the helicopter components developed by MIL, together with customizing and commercializing the aircraft intended for the C.I.S. countries.

- EUROCOPTER will be responsible for developing a modern avionics system together with electronic piloting, navigation and radio-communication equipment, required for the most varied missions. Eurocopter will rely on its partners, SEXTANT AVIONIQUE and SFIM, especially to satisfactorily design the modern multi-function system, which is the scope of this paper.
  The collaboration of Russian companies is being discussed so as to widen the cooperation links in this first extended Franco-Russian programme.

8. CONCLUSION

The success of the MI 38 programme is for us a true challenge intended to propose to our future customers, a greater safety, lesser maintenance aircraft for a particularly hostile environment.

The introduction of advanced technologies based on digital displays and computers will make the most complex missions successful.

The design of the MI 38 systems will provide a support to piloting, flight and vehicle management, resulting in a significant reduction of standard aircraft monitoring tasks performed by the crew.
Moreover, the prevention against still-possible mechanical damage will give the pilot the comfort and peace of mind required to cope with the hardest missions.

The maintenance teams also will have less workload thanks to the automatic failure diagnostics preventing any tedious troubleshooting, and thanks to data exceedance records intended for a better adapted and more economic maintenance or aircraft fleet follow-up.

Finally, the especially warm and cordial spirit in the Franco-Russian relationships, within the framework of this programme, generates a strong technical synergy between the partners which augurs well for the success of this new aircraft.