Future functionalities of flight management system

Gerard Sainthuile

ABSTRACT
The availability of new Communication, Navigation and Surveillance technologies provides the basis to move towards advanced ATM concepts.
Some of these new concepts will impact the airborne flight management systems such as:
-at the strategic level of the flight time horizon, the weather datafusion, the enroute replanning, the air-ground 4D trajectory negotiation,
-at the tactical level of the flight time horizon, airborne separation with traffic, terrain and adverse weather.
They will impact obviously the flight management pilot's interface.
That is why SEXTANT, as a major avionics manufacturer, is leading research and development activities on these concepts and on the related future flight management functions.
The current R&D activities are dealing with:
- the air-ground trajectory negotiation in a project called TNP/MAGIC.
- the enroute replanning in a project called FINDER.
- the weather datafusion in a study called 4MIDABLE.
The further activities are dealing with:
-the airborne separation with traffic, terrain and adverse weather in a project called 3FMS.
The objective of this paper is to present the results of the current activities and the subject of the further ones. Its conclusion is a synthesis of the requirements to be applied to the human-machine interface of the future flight management and the corresponding issues.
Keywords
FMS pilot's interface, CNS/ATM impact on FMS.

INTRODUCTION
The availability of new Communication, Navigation and Surveillance technologies provides the basis to move towards advanced Air Traffic Management (ATM) concepts.
Some of them will impact the airborne Flight Management System (FMS) by introducing new functions at different flight time horizon.
In this scope, two main flight time horizon are defined:
The tactical flight time horizon is between 30s and 10mn ahead the aircraft current position. The airborne separation with traffic, terrain and adverse weather will be introduced in this time horizon as a tactical function.
The strategic flight time horizon is beyond 10mn ahead the aircraft current position. The weather datafusion, the enroute and the air-ground trajectory negotiation will be introduced in this time horizon as strategic functions.
The organisation of the associated future flight management system can be synthesised in the following scheme:

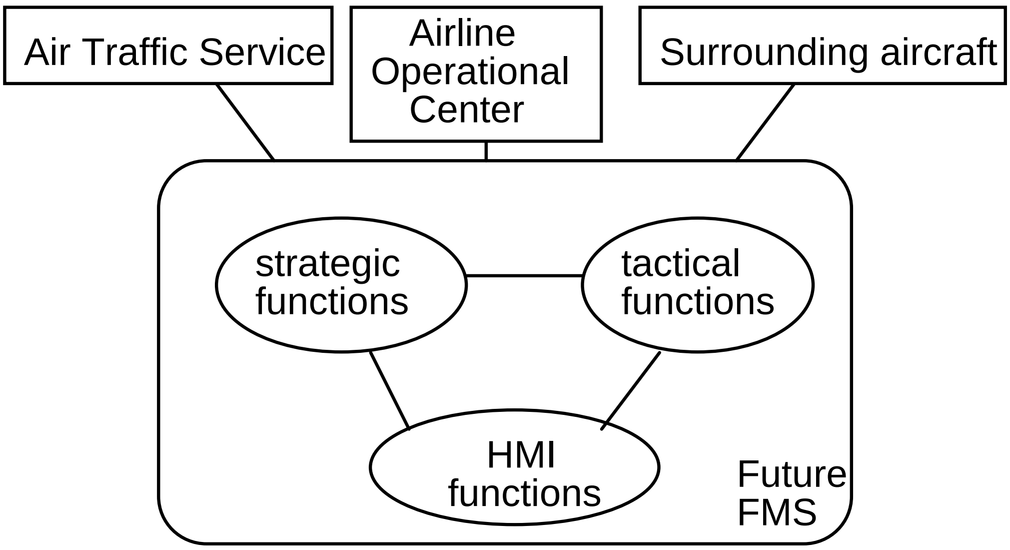

figure 1: future flight management organisation

The data to be displayed to the pilot for his flight awareness are function of the flight phase, the type of airspace and of the type of encountered situation.
Globally these data can be shared in function of their flight time horizon, and their topic as it is described in the following table.

In the cells are indicated the flight object that these data address.

	Traffic	Weather	Terrain	Perfor-mance
Strategic management	Flight plan	Flight plan	Flight plan	Preferred trajectory
Tactical management	separation manoeuvre	separation manoeuvre	separation manoeuvre	Allowed trajectory
Real-time safety nets	avoidance manoeuvre	avoidance manoeuvre	avoidance manoeuvre	flight envelope

SEXTANT as a major avionics manufacturer is leading research and development activities in the area of the ATM related airborne flight management functions. Their existing or expected findings in the area of the pilot's interface are described in the following-chapter.

ONGOING SEXTANT PROJECTS RESULTS

TNP/MAGIC project

The initial 4D-trajectory computed before takeoff has always to be updated in flight to take into account ATC (Air Traffic Control) constraints, changes in wind, weather or restricted areas. Also the objective of the TNP-MAGIC project (Trajectory Negotiation Process/Mock-up for Air-Ground Integration Concepts) is to demonstrate the potentialities of the air-ground trajectory negotiation assistance through datalink in terms of flight efficiency and traffic flow optimisation.
Between 1994 and 1997, CENA and SEXTANT developed a demonstrator of an air-ground trajectory negotiation comprising:
- a simulated part of the airborne segment with a pilot's interface for negotiation, the associated trajectory prediction and the protocol for air-ground communication.
-a simulated part of the Air Traffic Control including a Controller Working position, an Air traffic generator and the protocol for ground-air communication.
This demonstrator is designed as follows:

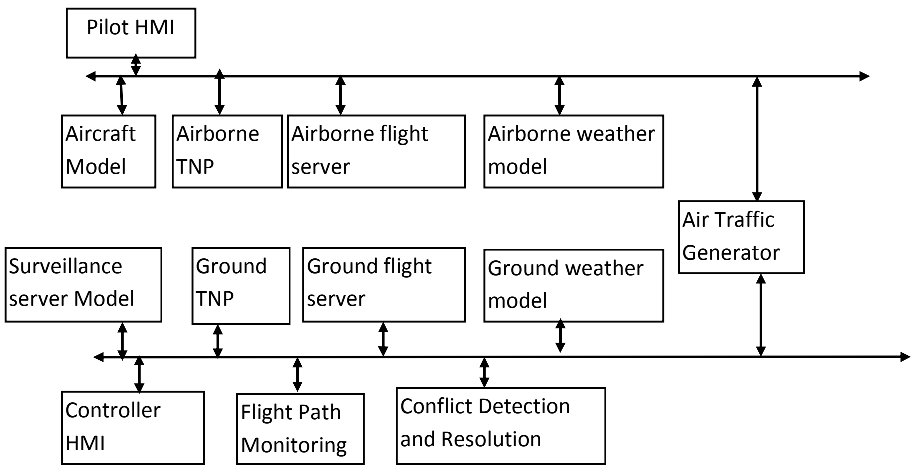

figure 2: TNP/MAGIC demonstrator architecture

Demonstrations have been performed for the benefit of pilots and controllers.
The main results of these demonstrations in the area of the pilot's interface, are the following ones:
- Only the trajectory beyond the 10 minutes just ahead the aircraft current position can be negotiated.
- Pilots and controllers prefer to manage speed constraints than time constraints.
- The pilot needs a graphic representation of the vertical profile in addition to the horizontal profile to have a complete understanding of the negotiated trajectory before acceptance as the active one.
- The trajectory negotiation is manageable onboard only when head down pilot's position is possible. It means that the enroute airspace with low or medium traffic density is the most suitable for such an application.

In conclusion, the airborne segment needs only moderate adaptations to be able to negotiate its trajectory efficiently. In fact, the most important requirement for modifications is on the ground segment where controller negotiation aids are to be developed for conflict detection and resolution assistance.

FINDER project

The manual head-down replanning of current FMS and the lack of airborne situation awareness for onboard aircraft operations are strong limitations of the current aircraft.
The objective of the FINDER project (Flight plan INteractive and Decision aiding system for Enroute Rerouting) is to demonstrate the potentialities of the onboard replanning decision aid functions through the associated technological improvement (increase of the computation power, good management of software complexity and implementation of an aeronautical telecommunication network) and an enhanced ground environment (weather databases, Air Traffic Control Centers (ATCC) automation and Airline Operational Communications Centers (AOCC) automation. The links of an onboard replanning aid with its environment are represented on the following figure.

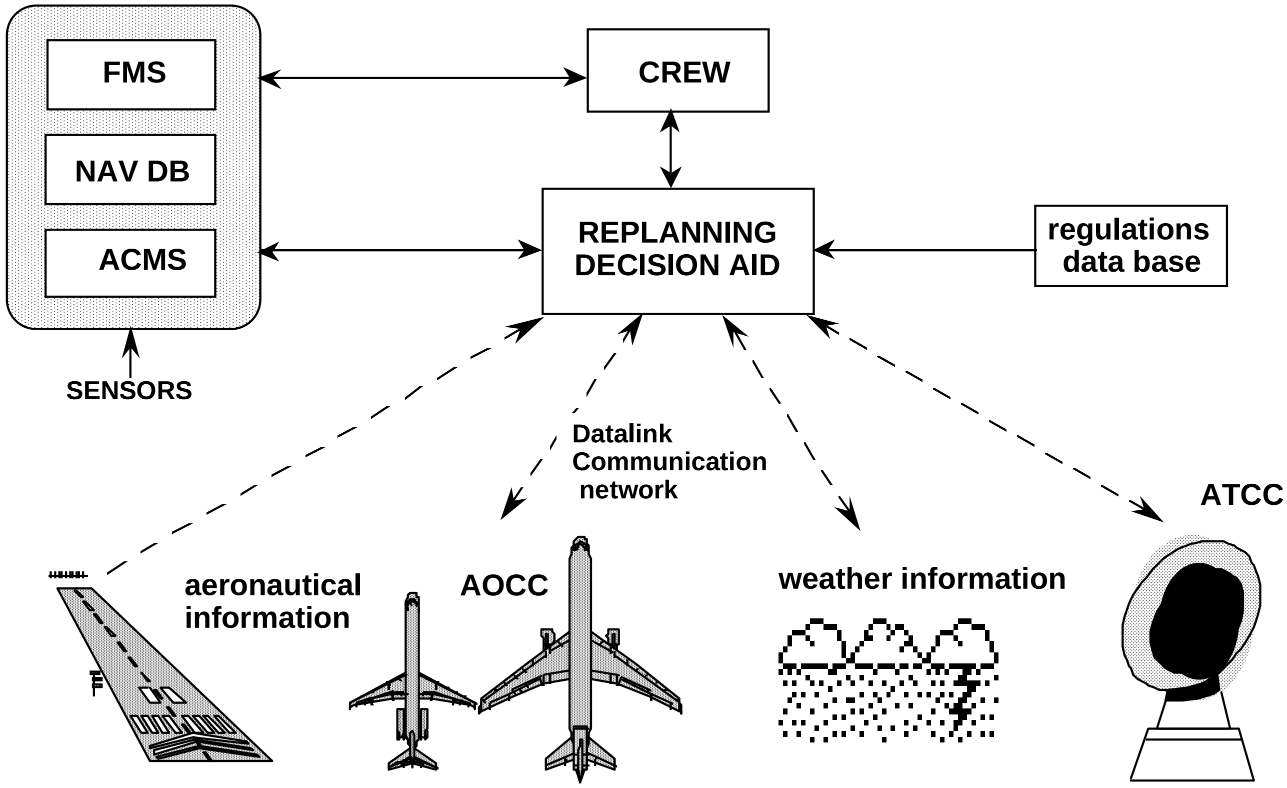

figure 3: replanning decision aid architecture

The FINDER project began in 1991 by the development of a mock-up of a diversion aid system based on the knowledge of the aircraft performance, the aircraft systems status, the airports weather conditions and the airways network. This mock-up was able to propose the optimal diversion flight plan for the 5 most convenient airports.
On this basis, SEXTANT developed between 1994 and 1997, a demonstrator of a replanning aid offering a diversion assistance in nominal and emergency conditions and a lateral area avoidance assistance for adverse weather or restricted areas. This demonstrator proposes on request explanations and comparisons.
All the data are displayed on a dedicated physical interface within a coherent graphical mode and with a good real time performance.
The demonstrator's functional organisation is the following one:

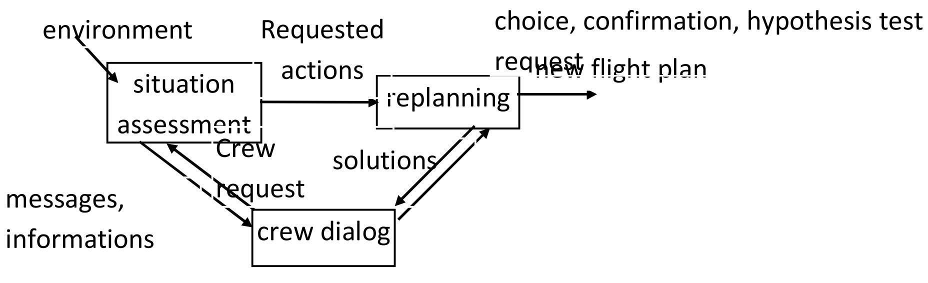

figure 4: Finder functional organisation

Airline pilots have specified and experimented it. The most important pilots requirements after evaluation were:
-The need of context data display used by the replanning aid such as weather data.
-The confirmation of the need for explanation data addressing the proposed solutions.

-The confirmation of the need for the pilot to test his own hypothesis.
The next step is to integrate the existing FINDER demonstrator in a more realistic environment to complete the evaluation.
The concepts implemented in this demonstrator are of interest for business aircraft where the inflight replanning is completely managed by the crew.
Free-flight operations for commercial aircraft are also a long term opportunity for these concepts.

4MIDABLE study

On one hand, weather forecasts rely on ground based datafusions of observations coming from many sources comprising the aircraft sensors. On the other hand, the aircraft are the main users of weather forecasts for their trajectory prediction. We see the common interest of all the actors to have a common and updated weather database.
Also the primary objective of the 4MIDABLE study (4d Meteorological Information DAtaBases Linked across Europe) was to specify the meteorological requirements for operational 4D prediction of aircraft position.
This study of the Commission of the European Union, led by the UK Met office, began in 1996 and finished in 1997. SEXTANT, as the airborne member of this study, provided recommendations and indications on display functions to be made available on board in order to assess the airborne side of the requirements/benefits of meteorological data utilisation.
The work is split into four parts:
1. investigates and analyses users requirements by way of a questionnaire to pilots and analysis of responses.
2. investigates the possible weather data display functionalities to be implemented on existing on-board display systems (such as Navigation Display (ND), Primary Flight Display (PFD)). This is done by reviewing the use of meteorological products by airborne users and the compilation of aviation user requirements for enhanced meteorological products as a background.
3. studies the possibility of enhancing weather display functionalities with regard to available displaying techniques, technologies and distribution.
4. provides qualitative and quantitative results on requirements/benefits dealing with meteorological data usage with the display functionalities specified in parts 2 and 3. The problem of ergonomics is specifically addressed.
The following figure illustrates the way weather data could be displayed on a ND.

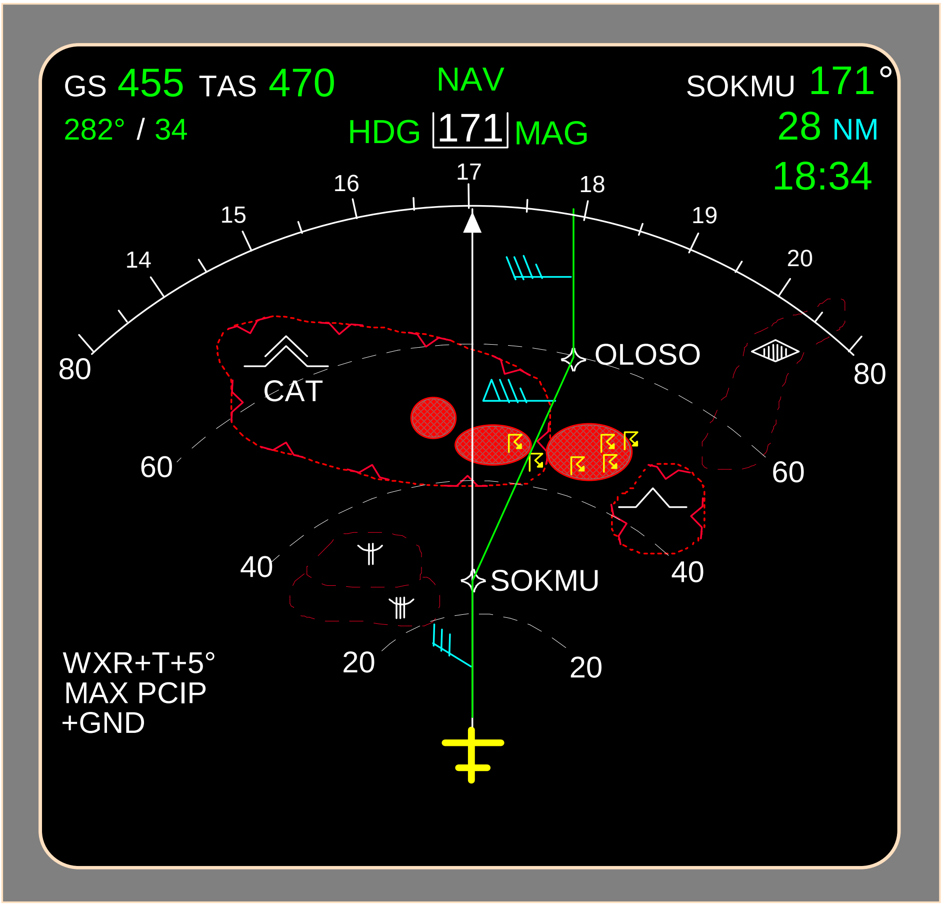

figure 5: weather data displayed on a ND

The figure 6 at the top of the next page illustrates the modern aircraft Human Machine Interface (HMI) and ergonomics challenge facing the modern aircraft cockpit display designer. It illustrates the ultimate challenge of delivering meteorological data to the flight crew of an airborne aircraft.

The main results are:
- the need for more accurate and reliable long range weather data.
- the need of an hazardous phenomena description for both flight optimisation and safety purposes.

Nevertheless, pilots do not seem very demanding, perhaps because they are trained for the current flying context, and partly because their margins are not very large in strict ATC regulated traffic. However, the forthcoming introduction of free-flight procedures will most likely change the current operating context. Furthermore, airlines should carefully analyse the benefits stemming from more accurate wind and temperature forecasts and forecasts of hazardous meteorological locations and time. There seems to be very significant gains in using more accurate and reliable data for flight preparation and flight progress.

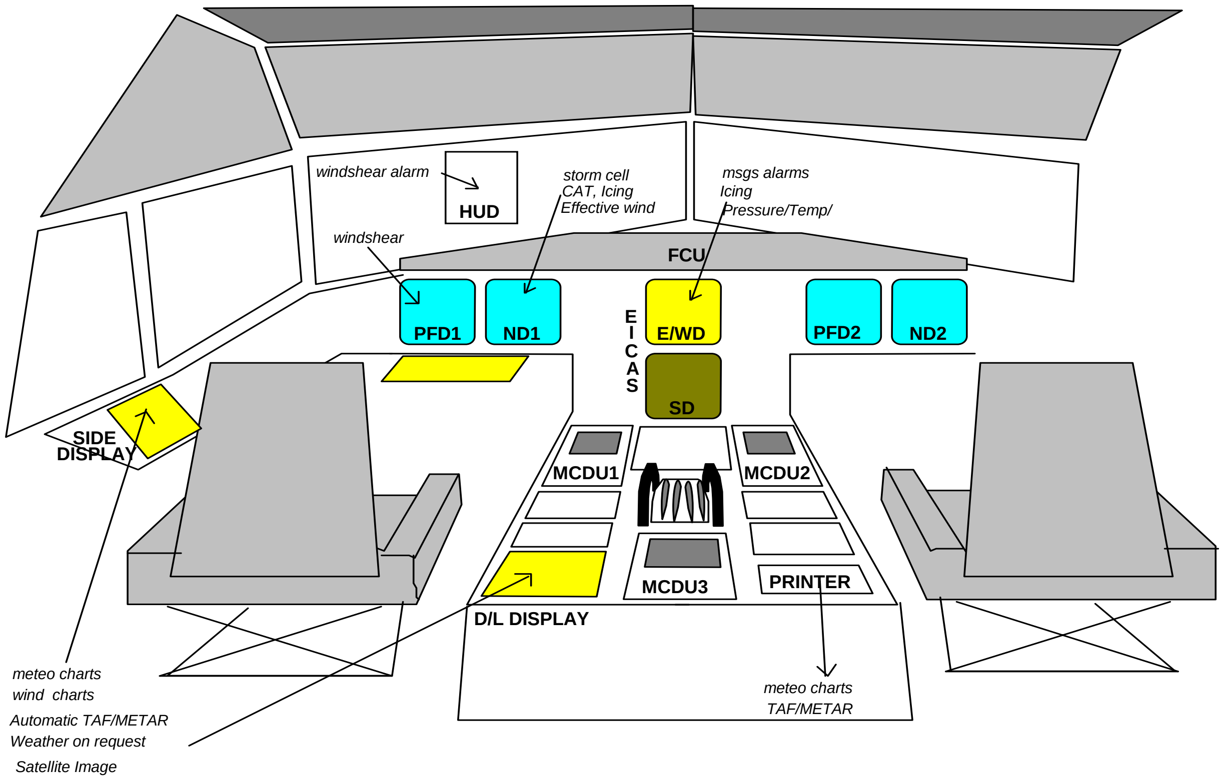

figure 6: Meteorological data distribution in a modern aircraft cockpit.

3FMS project

In the full free-flight concept, we can describe the aircraft as follows:

-Future aircraft will be able to monitor automatically, during all flight phases, their environment through sensors and datalink. They will be able to analyse automatically their flight situation, detect hazards and build new trajectories alleviating the hazards and insuring traffic separation.

-Future aircraft will automatically, through datalink, co-ordinate with ATC for tactical manoeuvres and will negotiate with the Air Traffic Flow Management (ATFM) for flight plan modifications.

This will normally contribute to reduce the air traffic separation in some airspaces and increase the airspace capacity and safety. It will help aircraft to fly closer to their preferred route.

That's why the Commission of the European Union launched the 3FMS project (Free-Flight Flight Management System), led by SEXTANT, with the objective to prepare an early functional definition of the European Flight Management System to operate the free-flight concepts.

This project began in January 1998 and is expected to finish at the end of the year 2000.

It will focus on the following onboard free-flight tactical flight management functions which are time-related to the Air Traffic Control:

- aircraft separation which consists of utilising the traffic information broadcast by surrounding aircraft to detect potential conflicts and to propose trajectory modifications,
- anticipatory terrain avoidance which consists of utilising terrain information within the FMS and correlating this with the flight planning functions (not including early ground proximity warning systems).
- weather management which includes the correlation of nowcast information with the flight planning functions to optimise the trajectory and future predictions.

and the associated Human Machine Interface (HMI) and decision aid functions.

The innovative approach is to see the aircraft as a proactive player of the future ATM system through enhancement of its ATM related flight management functions towards what is now called free-flight**.**

The 3FMS project will be based on the software core of the NEW FMS for AIRBUS (current FMS functionalities but with a great potential of growth) and will take into account the particular definition of an air transport AIRBUS cockpit.

The architecture of the 3FMS demonstrator will be in accordance with the following scheme:

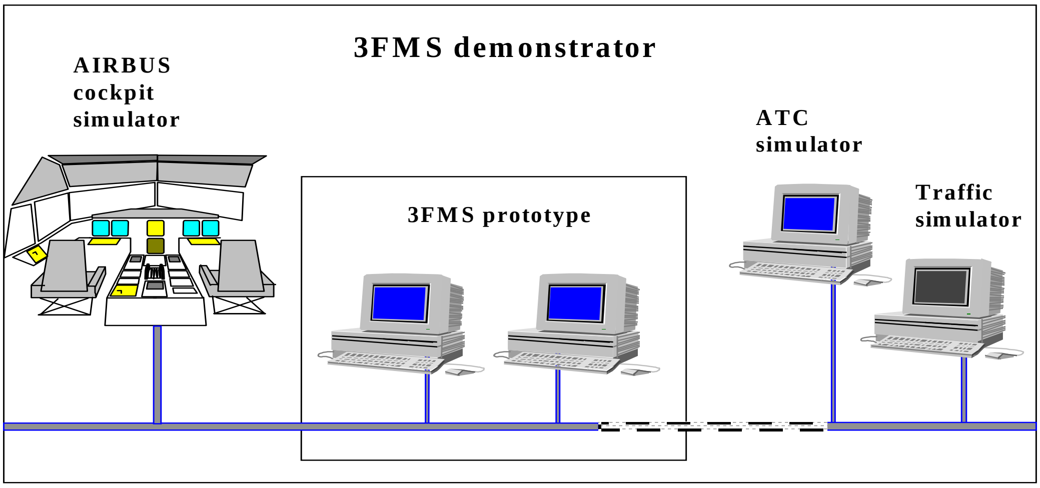

figure 7: 3FMS demonstrator architecture

The 3FMS prototype will be fully functional on an AIRBUS aircraft simulator. Flight test pilots and airlines pilots will be invited to evaluate the performances of the 3FMS demonstrator.
According to the project schedule, the functional definition of the 3FMS demonstrator will be available at the end of 1998 and the results of the pilots evaluation will be available at the end of 2000.

CONCLUSION

The air-ground communications media required for the strategic functions, like the 4D negotiation and the in flight replanning, are or will exist soon.
The modifications of the current FMS to be able of trajectory negotiation would be feasible. The introduction of the in flight replanning would probably require an additional on board computer less critical than the FMS one and a dedicated control and display device. But what requires much more time and energy is the enhancement of the ATCCs and of the ground based database management such as the weather database one.
For the tactical functions of separation, the required air-air communication media called ADS-B is under development. These functions are to be studied and developed according to a clear definition of ATM operational procedures and with respect of airborne HMI considerations. The corresponding issues are:
- the responsibility sharing during separation delegation.
- the influence of airlines competition on separation rules definition.
- the level of airborne automation of separation manoeuvres and its impact on the situation awareness.
- the integration of traffic, terrain and weather data on the same display.
- the compatibility with safety nets such as the TCAS or the GPWS.
- the risk of increase of intercrew communications.

REFERENCES

1. Regis LOURME (CENA)-Xavier CHICOT (SEXTANT)-(1997). Experimentations MAGIC/TNP: Resultats de la campagne d’évaluation menée avec des pilotes et des contrôleurs.
2. Guy DEKER Gerard SAINTHUILE (SEXTANT)-(1997). contribution to the 4MIDABLE project: Requirement/benefit definition study leading to 4D Meteorological Information Databases linked across Europe.
3. Genevieve EYDALEINE (CENA)-Gerard SAINTHUILE (SEXTANT). Air-Ground Trajectory Negotiation Assistance. First World-wide Communications Navigation and Surveillance Symposium, Reston Virginia, April 1993.
4. Guy DEKER (SEXTANT)-(1997). FINDER: Evaluation de fonctions d’aide à la décision pour aviation commerciale.
5. Gerard SAINTHUILE-Philippe JASSELIN (SEXTANT)-(1997) 3FMS project programme.
6. Vincent BITTERMANN, Myriam PERENNEC, Jean-Christophe MIELNIK Gerard SAINTHUILE (SEXTANT), Jean-Marie JUD (AIR-FRANCE)-(1992). FINDER: Flight-plan Interactive Negotiation and Decision-aiding system for Enroute Rerouting. 12th Conference Intelligence Artificielle, Systemes Experts, Langage Naturel, Avignon.