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SIMULATED FREE ROUTING OPERATIONS IN THE MARSEILLE UIR: RESULTS AND ISSUES FROM A HUMAN FACTORS PERSPECTIVE

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Abstract

Human performance considerations are expected to be central to the efficiency and safety of advanced Air Traffic Management (ATM) systems, while increases in traffic and advances in available technologies are projected. Free Flight (FF) and Free Routing (FR) proposals to relax airspace and give greater autonomy to aircraft represent applications of possible new air traffic management paradigms.

Relaxing route and part of altitude restrictions within a specific airspace is allowed by Free Routing (FR) operation. In FR airspace, users freely plan their routes between an entry point and an exit point without reference to a route network.

This paper exclusively concerns Free Routing, and presents the main results of a study conducted by the DSNA as a participation in the Mediterranean Free Flight (MFF) program. The DSNA carried out extensive experiments in the third series of MFF large-scale real-time simulation (RTS3), with the objective to acquire results on the Free Route concept in a busy Mediterranean area. The obtained results complement those coming from the first and second series of MFF real time simulations, as well as the other simulations in the RTS3. The DSNA simulation trials, denominated RTS3/FR in the rest of this document, took place in January and February 2004 in the experimental facilities of its research center in Toulouse.

For the RTS3/FR, controllers were provided with an original set of tools designed to assist them in dealing with Free Route traffic, according to operational requirements specifically defined for FR.

Eleven controllers from the Marseille air traffic control centre (including two subject matter experts), two military controllers, and six pseudo-pilots participated in the simulation trials. These trials consisted of eighteen measured exercises, including two exercises only exploited for safety scenarios.

The main lesson of this specific RTS3/FR is that Free Route as simulated is not adapted for high levels of traffic load. In case of sufficiently low traffic, the concept would be usable on condition that sector design is improved, and that controllers' tools can be made perfectly reliable.

The paper examines FF and FR cognitive implications, then introduces the experimental set up, gives information on the main aiding tools, and presents the main results of the simulations from a human-factors perspective.

Introduction

Background

The Mediterranean Free Flight Program is a European project led by ENAV in partnership with AENA (Spain), DSNA (formerly DNA, France), Eurocontrol, HCAA (Greece), MATS (Malta), NERL (UK), NLR (NL) and SCAA-LFV (Sweden). The main objectives of MFF are focused on Communication Navigation Surveillance / Air Traffic Management (CNS/ATM) technologies, Free Route, and Airborne Separation Assurance System (ASAS) applications.

Thanks to the foresight and funding provided by the European Commission, MFF was an effective exercise in international co-operation that developed European consensus on new innovative ATM techniques. It enabled experts from all over Europe to co-operate in overcoming the operational and technical hurdles in defining and evaluating future concepts and led to the development of advanced simulation facilities and techniques. The first hurdle for MFF was to structure its scope and the partners agreed to focus on a series of increasingly innovative and challenging applications. Because of its wide scope MFF has produced detailed results concerning the feasibility of a large range of applications leading towards user-preferred flight trajectories, redistribution of tasks between controllers and aircrew and making use of the possibilities offered by Automatic Dependent Surveillance Broadcast (ADS-B) technology.

Free Flight and Free Route

It seems essential to define what we are calling Free Route in comparison with Free Flight, because the distinction between both concepts may not be universally accepted.

Within FR and FF environments, pilots would be granted greater authority to choose their own trajectories, according to the most economical and efficient flight plans. FF implies that the responsibility for separation of traffic is partly delegated to the air side, according to various conditions and for limited duration. FR is one of the applications included in FF, in which controllers would remain responsible for traffic separation at all times, while aircraft would proceed on freely planned trajectories in a given airspace.

Although FF implies to supply ATM systems with advanced technologies, the problem to deal with it mainly resides on human factors issues.

Authority distribution between the cockpit and the ground system may have been the main issues discussed so far. There exist a great deal of studies on FF however, that give evidence about various topics of interest, on the cockpit side or the ground side. We are going to recall the main points which are called into question from a human factors perspective, more specifically those concerning the ground side.

On the Cockpit Side

Considering the cockpit, studies examine the pilot decision making for manoeuvres choice in FF, showing fundamental stereotypes and individual tendencies [1]. The design of Cockpit Display of Traffic Information (CDTI) is explored, comparing several kinds of formats, 3-dimensional display being among the display versions [2]. In both cases, a relationship appears between the format of display of information and the pilot's manoeuvres efficiency.

On the Ground Side

On the ground side, researchers have focussed on the distribution of tasks between the cockpit and the ground air traffic control (ATC). They underline that there exists a risk for controllers to move from active control to passive monitoring, according to the extent with which the responsibility for separation is transferred from controllers to pilots [3]. This study [3] shows that it took significantly longer to detect conflicts in the passive monitoring condition under high traffic. To conclude, the authors recommend keeping separation authority with the controller in the future systems for air traffic management.

Free Route in Air Traffic Control

At lower frequency, under FF designation, some studies are conducted with a view to analysing the effect of removing the route network on the predictability of traffic development for controllers [4] [5] [6].

Since users can freely choose their routes, controllers may deal with a great deal of diverse and variable routes patterns that could possibly lead to a given destination point.

The issue is of interest and fully warranted since the chosen automation philosophy is to keep controllers in the decision loop. So, the future system may allow controllers to maintain conflict detection and resolution capabilities.

Within this context, Nunes and St-Cyr [5] report results about the effect of a trajectory extrapolation tool usage in a Direct Routing environment. In their study, twenty ATC controllers were asked to anticipate pilots' requests for deviation from their current trajectory, and to determine whether a conflict could occur under that request. It had been observed that traffic load had more impact in case no aiding tool is available to controllers. Nevertheless, the use of the tool seemed to affect the controller's underlying mental model of the traffic.

Results from another study conducted by Nunes [6] suggest that controllers with more experience in conventional environment took longer to detect conflicts than their novice counterparts in an experiment on an environment without any route structure. Furthermore, an interaction between traffic load and experience was highlighted, increases of traffic load magnifying the adverse effect of experience.

Endsley [4] indicates that direct routes induce a decrease in situation awareness for controllers, on aircraft location, conformance to clearances, next sector for aircraft and other variables. These effects were all the more clear as pilots were not required to inform ATC of their intentions before they deviated, that was one of the conditions presented in that study.

As regards workload in Free Routing, results do not converge entirely. A Eurocontrol report [7] establishes that, compared to route structured airspace, there was no clear change in controller's workload as measured by instantaneous self-assessment in FR. According to that same report, the peaks of workload where the controller was overloaded decreased within FR. However, no workload reduction was observed in subsequent studies [8] [9] [11].

Within the MFF project, the first real-time simulations [10] [11] point that the introduction of a Medium Term Conflict Detection (MTCD) tool, and of ASAS procedures in FR tended to increase the workload of the controllers compared to a route structured environment. In the second series of MFF real-time simulations, it is said that ASAS raised workload in FR [12].

According to the mentioned studies, FR furthermore modifies working methods and makes conflict detection more complex.

The experiments we have just referred to, introduced new tools (ASAS, MTCD) that may have driven the objectives of the study and consequently may have mitigated the specifics impacts of FR. In addition, laboratory studies like those we mentioned above do not encompass the operational requirements in sectorisation, real traffic, realistic interactions or simulation exercise duration.

The particular features of the study carried out by DSNA [13], is to underline the FR impacts on controllers activity, using a system supplied with aiding tools which had been developed by the research center of DSNA, while aiming at simulating an environment as close as possible to the operational one.

The RTS3/FR Operational Concept

The Free Route Airspace in this series of experiments was defined as a zone in which aircraft operators may plan any route between an entry and exit point, without reference to any published route network, but with possible references to published or lat/long waypoints. Entry and exit points were published waypoints chosen so that the flight could be above the floor of the FR airspace between them.

The objectives of introducing Free Route Airspace initially announced in the MFF Operational Concept [14] were:

- To increase airspace capacity. - On the basis of model-based simulations, it was expected that an increase in capacity would occur as a result of a reduction in the number of conflicts and the wider use of the whole airspace.
- To enhance the flexibility of operations. - Freed from the need to plan routes within a fixed route structure, aircraft operators were supposed to be able to take advantage of greater freedom in the planning of their flights.
- To create operational and hence financial benefits for the airspace users. – The hypothesis was that the ability to fly a preferred route enhances operational freedom and, as a result of the shorter distances flown, enables a greater utilization of aircraft and a reduction in operational costs.

The RTS3/FR focused on the first point and called into question this supposed advantage of FR, initially stated in preliminary MFF Operational Concept [14].

The RTS3/FR trials actually applied Direct Routing, which may be considered as a special case of Free Routing. The reason of that choice is that one may suppose that users would be especially interested in minimizing flight times through the Free Route airspace. Direct Routing was implemented in the FR airspace, by planning the flight as a direct route from the entry point to the exit point.

The main aiding tools that supported controller's activity in FR are presented in the next section.

The FR Tools in the RTS3/FR

The control units were provided with a set of aiding tools, which mainly were related to a trajectory editor, and the DSNA approach of an MTCD that involves basic and simulated filtering functions, and a tasks scheduler. Additionally, the simulator introduced electronic inter-sectors co-ordination tools, and controller-pilot datalink communication (CPDLC) services. We only describe here the FR tools most related to the presented results.

Filtering Functions

Filtering a flight reduces, by dimming non-relevant flights, the number of flights to be analyzed with respect to the reference flight. The algorithms of the filtering function are based on two main modules. The first defines the range of usual behavior patterns for each aircraft. The second, starting from these default behavior patterns for each aircraft, and the pilots' and controllers' habits, associates a set of flights pertaining to each aircraft.

The basic filtering function processes the progress of a reference flight according to its flight plan. The simulated filtering function considers that the reference flight has received level or route clearance.

All filters can be accessed by the planning controller (PlC) and the executive controller (ExC) separately, from the radar label and from other access points.

The filtering functions had been re-designed from fixed-routes requirements to include in the range of the analysis an Area of Common Interest (ACI) that extends in all the dimensions the boundaries of the current control unit. There is thus an overlap in the ACIs of two adjacent units.

Trajectory Editor

The trajectory editor enables controllers to graphically edit the route of a flight in order to view, modify, test, propose or validate a planned route. The trajectory editor allows:

- The insertion of published, or non-published points (lat-long) that constitute new waypoints,
- The deletion, or the modification of existing waypoints.

The connection of the trajectory editor with the transfer via datalink minimizes the usage of voice radio channels when routes are edited. Datalink also ensures that airborne systems are updated with information consistent with that of the ground systems

An edition session is entered simply by clicking on the graphic route of the flight. During an edition, there is a facility that eases the selection of any published points. Hence, the interaction means tend to ensure that the relevant actions are readily perceivable, in a view to obtaining a highly usable tool.

The Tasks Scheduler

The tasks scheduler provides information about the future workload, displaying problem labels on the interface. It also distributes the tasks schedule labels between the PlC and the ExC, according to their resolution time and according to whether or not coordination inter-units would be required.

The tasks scheduler presents the PlC and the ExC with task scheduler labels that they can adapt to their mental representation of the traffic and to their needs, using the edit functions (modify, reschedule, transfer, delete or create).

The algorithms of the tasks scheduler are based on filtering functions results, taking into account the Area of Common Interest to two adjacent units.

Placing the cursor on the label displays the routes of the aircraft involved in a problem. These aircraft are highlighted on the radar image, at the time specified by the controller, otherwise at the resolution time set by the system.

Objectives of the RTS3/FR

Although controller's activity in FR comprised out main concern, we also evaluated how the proposed new FR tools could support representations updating and decision-making.

Among the high-level objectives of RTS3/FR [13], one was to assess whether the simulated Free Route concept will allow controllers to effectively perform their mission, and the fitness of the tools proposed to the controllers. This objective was split into several detailed objectives.

The present paper focuses on 3 aspects of FR among all of the detailed objectives investigated:

- Integration of flight and memorization,
- Conflict detection,
- Controllers workload.

Method

There were simulation exercises in 2 phases: the training periods (which lasted a total of 11 days), and the trials that lasted 10 days. This section gives information about the experimental protocol, and conditions of testing for the RTS3/FR experiments.

Sectorization and Traffic Samples

Airspace below flight level 285 (28500 feet) was conventional, fixed-route airspace. Airspace above flight level 285 was all FR airspace in the simulated area.

Each control position, whether it was measured or not, was responsible for the control of one control unit, that is to say a group of connected sectors.

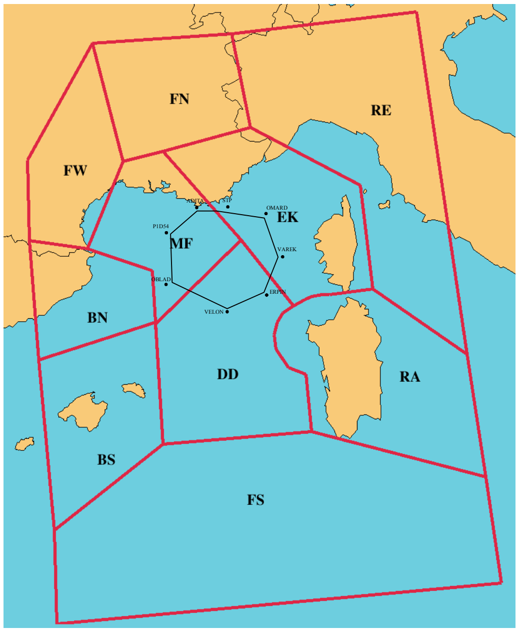

Figure 1: Free Route Sectors and Military Area

The experiments consisted of 16 measured exercises, and 2 additional exercises dedicated to safety scenarios (out of the focus of the present paper). All the traffic samples had a nominal duration of 90 minutes.

Traffic data was obtained from the Central Flow Management Unit (CFMU) before regulation. The traffic load was extracted from periods chosen during busy days of 2002 for the Marseille ATC Center. All the flights in the traffic demand samples entering the simulated area were retained in the process of generating the FR scenarios, including those related to the non-measured units: all the traffic flows were preserved in order to inject a traffic as realistic as possible from the point of view of the measured units. These choices were deemed appropriate in a view to providing controllers with a realistic operational traffic situation.

Two military controllers from the Nice CDC[1] manned a military position integrated in the simulator. The dynamic activation of the military area was simulated according to two different activation configurations, and a traffic sample that consisted of three military flights (Operational Air Traffic - OAT) was injected in three exercises.

The simulation exercises differed according to traffic load, sector design, availability of datalink or not, and activity status of a temporarily segregated military area.

Participants

Nine experienced controllers from the Marseille ATC center participated in the present study. They were all volunteers and the final group was the result of a selection by their peers, according to criteria coming from DSNA. They were 7 males and 2 females, and ranged in age from 29 to 54 (mean = 39.8). The experience in terms of qualification as a "first class controller" in the Marseille ATC center ranged from 1 to 29 years.

For each exercise, 4 of the controllers, i.e. 2 PlC and ExC pairs, manned the measured units in strictly planned rotations, while 4 more manned the non-measured units responsible for the management of the adjacent airspace. The remaining controller was a spare.

Furthermore, two additional experienced controllers played a function of subject matter experts. As they were involved in the FR project since its very beginning, they were required to participate to the training and the observations gathering. Later, they reviewed the report and gave comments on results.

Measures and Observations

The analysis was performed on the basis of all the information collected, observed and measured during the simulation trials. Quantitative and qualitative data were analyzed: these two types of data are complementary and were generally crosschecked. Most of the quantitative data were automatically recorded. Qualitative data were collected through individual interviews, questionnaires, observations and collective debriefings.

The individual interview was performed at the end of each exercise. It consisted in collecting the cognitive components of the controller's activity, in particular flight integration, conflict detection and resolution, traffic monitoring and situation awareness, plus others.

1 CDC: Centre de Détection et Contrôle (DIRCAM)

Two types of questionnaires were used:

- The post-exercise questionnaire was filled in by the controllers immediately after each measured exercise and mainly provided data on workload,
- The post-simulation questionnaire was filled in by each controller at the end of the two week simulation trials; its purpose was to gather subjective data on FR acceptance, training, and various aspects of the trials period.

Results

Controller's activity was split up into several tasks for their analysis: conflict detection, resolution of conflicts, anticipation, integration and memorization, and co-operation. A further analysis was conducted for the FR tools: their usage and usability. Both results either initially separated for presentation purposes, are tightly related. Through the presented results, the paper is giving back some evidence of this existing connection between cognitive activity and aiding tools.

The section presents results for integration of flight and memorization, conflict detection and workload.

Integration of Flights and Memorization

Interviews with controllers showed that FR operation had a major impact on flight integration:

- The place where a flight would enter a unit was unknown,
- There were flights tangential to units (in their ACIs), that had to be integrated or not, depending on trajectory editions in previously crossed units, or on traffic configurations,
- Simultaneous calls from flights on unregulated trajectories in the same direction (e.g.: parallel, or slowly converging routes) were received, whereas in a conventional environment, aircraft arrived separated in one direction and on several levels.

Eight controllers were in total agreement or in agreement that difficulties existed due to aircraft not following conventional routes. They developed that statement with various comments:

- Absence of stable markers,
- Difficulty in spotting slow horizontal deviations of FR trajectories,
- Aircraft at the edges of sectors,
- Multiplication in points of conflict.

Difficulties encountered in integrating flights originated from:

- Interference with processing caused by simultaneous calls from flights,
- Lack of knowledge of points on the flight plan that were too far from the sector as there were no waypoints between the entry and the exit of the FR area,
- Possibility of having to integrate flights that were announced late due for instance to a trajectory edition,
- Possibility of having to integrate flights passing close to the edges of the sector without entering the sector.

FR modified the processes in "getting the picture" of traffic when integrating flights, as the integration of a flight could no longer work based on the cognitive expectations that formed part of the skill-based processing of controllers in a conventional environment. For instance, in the conventional environment controllers know the entry point in the controlled sector, when considering a particular departure to a particular destination.

Our hypothesis was that forming a mental picture of traffic when integrating a new flight should be aided in FR by the basic filtering function. The analysed data lead to the fact that the filtering function was not perfectly suitable for supporting flight integration in FR. For instance, the following table shows the proportion of basic filtering requests before assume status for all the flights for which filtering was requested at least once (the rows are cumulative, for example, the 9% includes the 6.8%):

Flights with basic filtering	PlC	ExC
Before assumable status = announced status	6.8%	2.6%
Before the "assume" status = assumable status	9%	14.6%

Hence, when the controllers display the filter 10 minutes before an aircraft enters the sector, the tool provides them with too much information, without focus on conflicts that occur at the boundaries of the sector.

The principle of a filtering function for assisting analysis was nevertheless well liked by controllers in the FR environment. Controllers deemed that the filtering function could be a useful tool providing them with the relevant traffic context for a reference aircraft, throughout every traffic analysis while being responsible for a given aircraft.

In FR, stable aircraft do not enter the sector flying over published points that are known by controllers. It is why, in FR, the filtering function did not succeed in decreasing the difficulties encountered for flight integration. Controllers were not provided with a powerful enough aiding tool that could allow them to first know, at the right time, which aircraft would enter the sector, and above all, the place where they would enter. Especially in heavy traffic load situations, controllers experimented difficulties in acquiring this kind of information; their anticipation of traffic evolution and their mental picture were damaged. The dissolution of the route structure adversely affected the controller's mental model, in agreement with [5].

Regarding memory processes, controllers carried out compensatory strategies like repeated consultation of information, which aimed at reducing the demands on memorisation. Given that FR trajectories may be diverse and may vary over time, memorizing them came at a cost that was incompatible with the performance of other tasks. The reason is that in FR, trajectories do not constitute a stable network of points well known by controllers.

Conflict detection

All controllers expressed difficulty in identifying the point of conflict, in other words the place where the aircraft will be closest to one another:

- Points of conflict are not known in advance,
- Points of possible crossing are numerous and are not marked,
- Convergence can be varied: several aircraft, many different directions,
- Monitoring has to cover aircraft flying along the boundaries of the sector.

The controllers indicated that the management of climbing and descending flights was much more dangerous and difficult than in fixed route operation. Many climbing or descending flights were face to face due in particular to the choice of flight level 285 as the FR floor.

The following graph, showing the number of clearances per aircraft in each of the measured control units, is one of the results that illustrate the handling of climbing or descending flights. Indeed, intermediate CFLs in the management of the important flows to and from Barcelona and the Balearic Islands partly explain the higher number of these clearances in the MF2 and MF23 volumes.

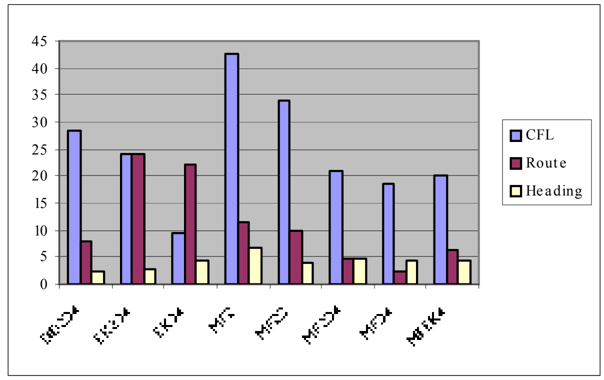

Figure 2: Clearances per Aircraft in Each Unit Volume

Eight controllers deemed that, in principle, the task scheduler was useful or essential for controlling traffic in a Free Route environment. Such a result was also stated in RTS1 [11] and RTS2 [12].

The task scheduler was liked as a tool to help detect conflicts, when the labels were deemed relevant by the controllers. In such cases, they confirm or give advance information on a conflict that has not yet been detected.

The task scheduler was not operational when, on sectors with dense climbing or descending flows, numerous levels represent potential conflicts that were obviously seen and processed. The PlC was not comfortable with the management of these labels: he may have felt that transferring them to the ExC was not useful.

Furthermore, on some occasions when the controller noted that a label relative to a "definite" and detected conflict was missing, he had a tendency to lose trust in the tool.

In principle, the controllers appreciated the task scheduler, but it did not appear to be efficient in high workload situations, and in particular when controllers had to deal with traffic complexity.

As a recommendation, the task scheduler must earn the trust of the user, by performing relevant and reliable operations.

Workload

Controllers were asked to rate their perceived workload and traffic load for each of the exercises. For 56% of the exercises, the traffic load was deemed high or very high, whereas the perceived workload was high or very high for 47% of the exercises.

Various conditions determined the perceived workload in FR. It increased with the following factors:

- The traffic load - this seems to be the main variation factor,
- The activation of temporarily segregated areas,
- The intermittent non-optimal operation of tools,
- The traffic configurations: face-to-face and climbing or descending flights on opposite trajectories increased the workload. Units with a small vertical extension were more difficult to manage because they required more clearances to be given for levels that did not belong to the unit.

For all exercises, the perceived workload by the PlC and ExC increased overall with the measured hourly traffic load during the exercise (high correlation of 0.755). The 64 workload measurements for the 16 runs can indeed be plotted as follows:

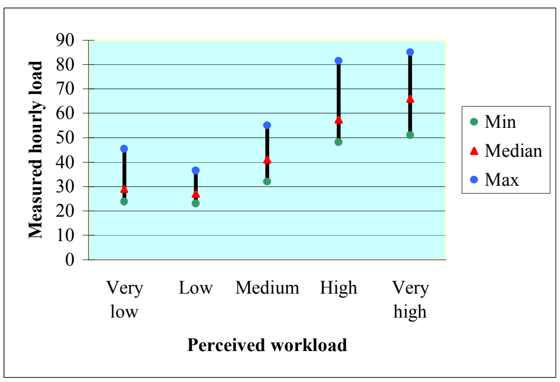

Figure 3: Perceived Workload and Measured Hourly Traffic Load

Verbal data collected during individual interviews stated that controllers had difficulty for estimating real traffic load and its variation in FR environment. Furthermore, the feeling of not being in control of traffic and being behind in resolutions meant that controllers were working in poorer conditions.

We can understand these results as an inability for controllers to maintain their workload at a satisfactory level by working at a skill-based behaviour level [15]. This level of behaviour could not be achieved, as traffic situations encountered in FR remain diverse and unfamiliar. In the model of Rasmussen, potential errors depend on the type of behaviour, so that would need to be carefully tested to determine potential errors recovery in FR.

Regarding risk perception, Free Route as simulated in RTS3 (sector design, tools, traffic load) has systematically generated a feeling of insecurity with the PlC and the ExC, starting from a particular level of traffic load. Controllers actually judged that the level of safety was not satisfactory in 39% of their responses. There was no distinction between PlC and ExC in this result. The controllers gave no response on safety in a minority of cases because they judged these unrealistic to some degree.

Conclusions

The main lesson of the RTS3 is that even though the controllers closely co-operated to be deeply involved in these Free Route simulations, this does not mean that they accept the concept as proposed: this one is not adapted for high levels of traffic load. In case of sufficiently low traffic, the concept would be usable on condition that the design of sectors and controllers' tools are improved.

The memorization of routes and conflicts proved to be difficult in FR. Controllers had to compensate by getting recurrent and continuous data, which resulted in the increase in the requirement level of the tasks to be undertaken, and the workload. The traffic load damaged the construction and update of the mental traffic representation, as well as memorization.

Another main problem consists in identifying the point of conflict and the deviation of a flight from its trajectory. In a traffic situation that included more than one conflict to be detected, no automatisms using geographical reference frames could be used to speed up the decision processes. The detection of conflicts was processed in a systematic and recurrent manner. The detection of conflicts and the resolution in FR are within the scope of expertise of the controllers, but the processes lose their effectiveness as the traffic increases.

FR did not generate the feeling that safety was satisfactory, sometimes even in exercises with a light traffic load, but where other load factors were involved. As simulated in the RTS3/FR, FR does not maintain the workload of the controller within acceptable limits, except in exercises where the load was lightest and without any military activity.

Under real conditions, such as those simulated in RTS3/FR, the FR concept could not be operational.

The RTS3/FR highlighted several factors that must be taken into account in feasibility studies of FR: traffic load, sectorisation, military activity and the tools.

- Traffic load is a limiting factor. FR could not be an option in heavy traffic without jeopardising flight safety. When considering implementation, little-used areas of airspace and/or quiet periods should be targeted.
- Sector design as set up for the RTS3/FR showed a number of deficiencies. When considering implementation, the floor level of the FR area should be raised in order to exclude climbing and descending aircraft as much as possible from FR, the number of flight levels should be reduced, and horizontally broad sectors should be chosen.

The question of sectorisation cannot however be settled by simply making ad-hoc corrections. Suitable boundary definitions for controlled airspaces should be found, based on real requests from users. RTS3/FR results would suggest that this definition should be flexible and dynamic, and guided by some type of multi-sector planning scheduling body, processing flights upstream of the control unit.

Under the experimental setting of that evaluation, and considering the set of tools provided in RTS3/FR, our conclusion is that there exist fundamental restrictions to be clearly addressed before putting FR into the operational context: traffic loads restrictions, airspace and traffic flows management, design and reliability of aiding tools for controllers.

References

[1] Wickens, C.D., Helleberg, J., Xu, X., 1999, *Maneuver choice in free flight*. Proceedings of the 1999 World Aviation Conference (1999-01-5591). Anaheim, CA.

[2] Alexander A. L., Wickens C. D., 2001, *Cockpit display of traffic information: the effects of traffic load, dimensionality, and vertical profile orientation*. Proceedings of the 45th Annual Meeting of the Human Factors and Ergonomics Society, Santa Monica, CA: Human Factors & Ergonomics Society.

[3] Metzger, U., Parasuraman, R., 2001, *The role of the Air Traffic Controller in future Air Traffic Management: an empirical study of Active Control versus Passive Monitoring*. Human Factors, Vol. 43, No 4, pp. 519-528.

[4] Endsley, M. R., 1997, *Situation Awareness, Automation & Free Flight*. Proceedings of the 4th USA/Europe ATM1997 R&D Seminar

[5] Nunes, A., St Cyr, O., 2002, *Predictive aids and mental models under Free Flight: proceed with caution*. Proceedings of the 12th International Symposium of Aviation Psychology, Dayton, OH.

[6] Nunes, A., 2004, *An empirical investigation of the effects of controllers experience on conflict detection ability under Free Flight*. Proceedings of the 48th Annual Chapter Meeting of the Human Factors and Ergonomics Society, New Orleans, LA, USA.

[7] Eurocontrol Experimental Center, 1999, *Eight-States Free Routes Airspace, 1st Small scale real time simulation*.

[8] Eurocontrol Experimental Center, 2000, *Eight-States Free Routes Airspace, 2ndt Small scale real time simulation*.

[9] Eurocontrol Experimental Center, 2000, *Eight-States Free Routes Airspace, 3rd Small scale real time simulation*.

[10] MFF D442A, 2003, *MFF RTS1 Real Time Simulation N°1 Report*.

[11] Schäfer, D., Modin, E., 2003, *A Human Factors Perspective on Free Routing and Airborne Separation Assurance in the Mediterranean Airspace*. Proceedings of the 4th USA/Europe ATM2003 R&D Seminar.

[12] MFF D451B, 2003, *MFF RTS2 Real Time Simulation N°2. Ground Human Factors Analysis*.

[13] MFF D451C Part 3, 2004, *MFF RTS3 Ground Human Factors in Free Routing (A1) Simulation Trials*, Toulouse, Released edition1.1, July 19th 2004.

[14] MFF D210, 2002, *Concept and requirements.*

[15] Rasmussen, J., 1983, *Skills, rules, knowledge: signals, signs and symbols and other distinctions in human performance models*, IEEE Transactions: Systems, Man and Cybernetics, 13, 257-267.

Key-words

Mediterranean Free Flight, Free Route, direct routing, human factors, aiding tools, real time simulation.

Glossary

ACI Area of Common Interest (common to a control unit and the adjacent control units)

ASAS Airborne Separation Assurance System

ATC Air Traffic Control

DSNA Direction des Services de la Navigation Aérienne (formerly DNA).

ExC Executive Controller

FF Free Flight

FR Free Route

MFF Mediterranean Free Flight

MTCD Medium Term Conflict Detection

PlC Planning Controller

RTS3 Real Time Simulation n°3 (MFF)

Biographies

Philippe TROUSLARD is the deputy chief of the E4 department, which studies Concepts for Evolution in the En Route Control, at the research center of DSNA (Studies and applied Research directorate - formerly CENA). He is furthermore the project manager of the DSNA participation in the MFF programme. He first fully qualified as an air-traffic controller before choosing to change the course of his career and graduating as an engineer. He was previously in charge of the study section at the Reims air traffic control centre, and afterwards, of the Air Navigation Service at the Directorate of Civil Aviation for the South region, based in Toulouse.

Thomas KIRCHER has an engineering degree in aeronautics. Since he joined the research center of DSNA, he worked first on studies related to the standardization of the Aeronautical Telecommunication Network, and later joined a team responsible for ATC validation and simulation environments in the E4 department. He was in charge of the technical co-ordination of the RTS3/FR trials.

Nicole BOUDES received a Ph.D. in Ergonomics from Toulouse University, where she studied cognitive ergonomics, psychology and linguistics. She has co-authored a number of scientific papers on cognitive activity in Air Traffic Control, and evaluations of ATC performance in new environments. She was in charge of the Human Factors GFI-Consulting team working for the MFF-REFLEX project at the research center of DSNA.

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