A HUMAN FACTORS PERSPECTIVE ON FREE ROUTING AND AIRBORNE SEPARATION ASSURANCE IN THE MEDITERRANEAN AIRSPACE

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This paper is compiled from the MFF real-time simulation Nº1 reports [12,13] written by Eurocontrol and ENAV experts (Barff, Modin, Schäfer, Scrivani, Waggitt, et al).

Abstract

This paper presents the results of real time simulations carried out in order to evaluate the potential application of the Free Route Airspace concept and Airborne Separation Assurance in the Mediterranean Airspace. The Mediterranean Free Flight Programme (MFF) is a pre-implementation program partly sponsored by the Commission of the European Community. The programme is managed by ENAV (Italy) and the partners of the project are EUROCONTROL, AENA (Spain), DNA (France), HCAA (Greece), MATS (Malta), NATS (UK) and SCAA-LFV (Sweden). MFF targets the evaluation of advanced ATM concepts in the Mediterranean through a series of fast-time simulations, real-time simulations, and flight trials. In order to do so, five applications have been identified and these will be evaluated in the course of MFF, thus paving the way for an implementation: the Free Route Airspace concept, Air Traffic Situation Awareness (ATSAW), Airborne Separation Assurance System (ASAS) Spacing, ASAS Separation, and Airborne Self Separation (Free Flight).

The MFF project is closely associated with the MEDUP Automatic Dependent Surveillance-Broadcast (ADS-B) network installation project. ADS-B using VHF Datalink (VDL) Mode4 technology is considered the primary enabler for the MFF ASAS concepts. The MFF programme includes full flight trials which will make use of the MEDUP ADS-B network.

The first in a series of large-scale real-time simulations within MFF was carried out in April and May 2002 targeted the evaluation of the Free Route Airspace concept and ASAS Spacing. This paper introduces the evaluation methodology and presents results of the real-time simulations from a human factors perspective.

Introduction

It is widely recognised that the present air traffic management system will not accommodate the growth of air transportation beyond a certain point that is predicted to be reached in the not too distant future. In order to meet society's expectations for safe and economic air travel, further capacity enhancements will be required that might only be possible through the application of new air traffic management paradigms.

The concept of Free Flight foresees that aircraft are responsible for maintaining a safe separation between each other and thus can choose and change their flight path in real time. Air traffic control services will execute 'control by exception', which means that controllers monitor the traffic and only intervene if strictly required.

The overall aim of MFF is to pave the way towards the Free Flight concept by the systematic evaluation of concepts that increase the autonomy of flight. The chosen airspace (the Mediterranean basin) is considered appropriate due to its location between the high density airspace of the core area of Europe to the north and the low density African airspace to the south. To achieve its aim, MFF has defined five applications that will be evaluated in detail [1,2]:

- Free Routing: Free Route (FR) airspace is defined as a specific airspace "within which users freely plan their routes between an entry point and an exit point without reference to a route network." [1].

- Air Traffic Situation Awareness (ATSAW): An enhancement of air traffic situation awareness can be obtained by displaying the traffic situation around the aircraft on adequate onboard systems, permitting the flight crew to identify aircraft that are relevant or even critical with regard to the own trajectory [2].
- ASAS Spacing: Airborne Separation Assurance System (ASAS) Spacing applications concern the delegation of spacing tasks to the flight crew. The delegation is limited in time and space [2].
- ASAS Separation: Whereas ASAS Spacing procedures concern the implementation of separations specified by ATM, ASAS Separation procedures go one step further. The delegated aircraft is free, within certain boundaries, to choose the most appropriate manoeuvre in order to avoid a separation violation with the target aircraft. Unlike ASAS Spacing applications, airborne separation minima apply for ASAS Separation procedures [2].
- Airborne Self Separation: Airborne Self Separation corresponds to the full delegation of responsibility for separation assurance to the flight crews of aircraft operating in specifically designated airspace – the Free Flight Airspace (FFAS). Compared to Managed Airspace (MAS) which comprises both Fixed Route Airspace and Free Routing Airspace, the roles and responsibilities of air traffic control services in FFAS are limited to supporting aircraft in distress ('control by exception'), the provision of information, airspace density monitoring, and assistance during the transition between FFAS and MAS [2].

The first in a series of ground-based real time simulations has been carried out in April and May 2002. MFF real-time simulation 1 (RTS/1) was concerned with the evaluation of Free Routing Airspace concept and ASAS Spacing. These two applications are hence discussed in some detail.

Free Routing

Historically, the navigation of aircraft has been based on flying between beacons; a flight thus took place along air routes connecting a number of beacons. Whereas modern aircraft are capable of navigating on arbitrary flight paths, air traffic procedures are still based on the route network. The difficulty that navigating on 'free routes' would inflict on air traffic control services is the dominant reason for the fact that route structures have been maintained up to date. However, in most cases, direct routings between origin and destination, are preferable for economic reasons. Permitting airspace users to choose their flight path freely and without reference to a route network is expected to result in positive effects on efficiency and capacity. Recent studies conclude that a reduction of about 3 percent in track miles and thus in fuel burn could be achieved through the application of free routing [3,4].

Whilst Free Routing permits flight crews to file flight plans along arbitrary routes, air traffic control continues to be responsible for the safe separation between aircraft. Free routing will be carried out in Managed Airspace (MAS) and flights will remain subject to air traffic control service, responsible for the separation of aircraft. Aircraft will enter and exit Free Route airspace via predefined entry/exit points along the boundaries encompassing one or more free route airspace sectors.

In a conventional route network potential conflicts between aircraft usually can be expected at merging points, i.e. the intersection of air routes. In Free Routes aircraft must be expected to navigate along almost any possible route which means that conflicts may occur at any point in the sector. Both the detection of conflicts and their resolution through control intervention are thus becoming geometrically more complex.

It is therefore anticipated that the controller needs to be supported by a conflict detection system that identifies any future loss of separation between two or more aircraft up to, say, 20 minutes ahead. Such tools as Medium-Term Conflict Detection (MTCD) system is presently under development and evaluation at EURCONTROL [7].

Conflict detection with a look-ahead time of 20 minutes depends very much on the availability of precise information about the aircraft's flight trajectories. The transmission of its intended flight path by every aircraft within the sector via digital data link will greatly increase the accuracy of trajectory information. The technological infrastructure proposed by MFF is intended to facilitate this.

ASAS Spacing

The aim of ASAS spacing is to increase the capacity of Air Traffic Control by delegating spacing tasks to the flight crew. The assumption is that delegation of spacing tasks will result in increased controller availability, which in turn will permit increased capacity. The delegation is limited in time and space.

The study done by MFF on ASAS spacing is mainly based on work and studies performed by Co-space [8] (former EACAC) within EUROCONTROL. Co-space is a project entirely dedicated to the study of ASAS concepts mainly in TMA environment.

In the development of the ASAS spacing concept and procedures, certain key principles were considered:

- The implementation of the ASAS spacing concept shall strive to minimise change in current roles and working methods of controllers and flight crew.
- Spacing tasks shall be delegated to flight crews *upon controller initiative* and the controller can resume conventional control at any time.
- The spacing tasks delegated to the flight crew shall be concerned only with "low-level" tasks (i.e. implementation and monitoring tasks) as opposed to "high-level" tasks (i.e. definition of strategy).
- The controller shall always keep the initiative and overall authority on traffic management throughout the whole ASAS spacing procedure.

The ASAS spacing concept is essentially dedicated to sequencing operations:

- In-trail (follow): The *delegated* aircraft is instructed to *follow* a *target* aircraft. The controller specifies the distance that the delegated aircraft should maintain to the target aircraft.
- Merging: The *delegated* aircraft is instructed to *merge behind* a *target* aircraft. The controller specifies the geographical point where merging should take place, as well as the distance that should separate the delegated and the target aircraft at the merging point.

Two levels of delegation are proposed to establish spacing: after issuing the heading, the controller might either issue the *resume* instruction when appropriate and then delegate the speed adjustment; or he may also delegate the *resume* instruction in advance.

The separation minima for ASAS Spacing manoeuvres are the same as those applicable for spacing by ATC. In addition ASAS Spacing does not require the 'target' aircraft to consent to the manoeuvre.

Human Factors Issues within RTS/1

The impact of the new applications 'Free Routing' and 'ASAS Spacing' need to be analysed carefully in order to ensure high standards of efficiency and safety.

The most significant change in Free Routing Airspace is the absence of a mandatory route structure. Therefore, conflicts between aircraft can no longer be expected to occur primarily at crossing points between air routes – the geometric diversity of the traffic pattern will increase. Abandoning the route structure comes with a number of issues that need to be investigated from a human factors perspective:

- Controller situation awareness: The fact that aircraft navigate on free routes instead of following a fixed route network may have an effect on the cognitive demands of maintaining a mental representation of the traffic situation
- Required ground tools for conflict detection: It may be expected that free route operations will lead to a smaller number of conflicts but that it may become increasingly difficult to detect conflicts. The introduction of Free Routing may need to be accompanied with an appropriate tool to counterbalance decrements in controller conflict detection performance.

- Sector Transition: The transition between Free Routing Airspace and Fixed Route Airspace takes place through sector entry and exit points. The additional workload this might cause for the controller needs to be considered.

- Controller workload: Both routine tasks such as R/T and cognitively more demanding tasks such as conflict monitoring and resolution contribute to controller workload and both factors may be subject to changes in Free Routing Airspace. Since controller workload is often a driving factor for sector capacity, potential increases in controller workload during situations of high traffic density as a consequence of free routes must be studied. It may be argued that the gradient of workload as a function of traffic density may be different in free routes and under route network conditions[1].

- ASAS spacing: During ASAS Spacing applications aircraft execute specific manoeuvres; the responsibility for separation assurance remains unchanged and lies with the controller. The controller is free to apply the manoeuvre whenever he considers it beneficial. Among other issues, changes need to be studied in the following fields:
  - R/T load and procedures: The application of spacing applications should not lead to an overall increase in R/T communication time.
  - Workload: When applying spacing manoeuvres, the controller first has to issue the spacing instruction and then monitor aircraft compliance with the instruction. It needs to be studied how this impacts on workload.

Method

Simulation Facility and Airspace

The MFF real-time simulation RTS/1 took place at ENAV CNS/ATM in Rome between April 22nd and May 24th 2002. The simulations encompassed four civil measured sectors each provided with executive and planning controller positions plus one military measured sector.

The participant controllers were seconded by ENAV (Italy) and MATS (Malta), plus military controllers from the Italian Air Force.

The airspace was based on existing sectors at Rome ACC which were slightly adapted to better match the objectives of the simulation and the Free Route flight paths.

The human-machine interface chosen for MFF is the result of the Italian Interface Project (ITI)[2]. This interface represents a sound basis for MFF as it has reached an advanced level of maturity and designed on EATCHIP guidelines.

The Medium Term Conflict Detection (MTCD) system, as presently developed by EUROCONTROL, was used during the simulation exercises. MTCD supports the controller in the detection of conflicts between two or more aircraft up to 20 minutes into the future. MTCD is primarily intended to support the planning controller, but conflicts with a shorter timeline, say five minutes, are equally displayed on the executive controller screen.

Simulation Setup

MFF RTS/1 was based on the qualitative and quantitative analysis of ‘measured’ exercises plus the mostly qualitative analysis of so-called ‘scenario-based’ exercises. In total 42 simulation exercises were successfully completed. 35 of these were the measured exercises and the remaining 7 were scenario-based exercises.

Including the training period of roughly one week, the participants in RTS1 spent almost 65 hours assessing the MFF applications.

Measured Exercises

The measured exercises were 75 minutes long. The simulation used the concept of “organisations” to achieve the majority of the objectives. Each

[1] It may be assumed that tasks such as coordination and R/T are roughly dependent on the number of aircraft in the sector. On the contrary, workload due to conflict monitoring and resolution depends on the number of aircraft and potential conflict complexities and can be expected to increase more than linearly with increasing traffic density.

[2] ITI – Italian Interface Project. A joint HMI study by EUROCONTROL and ENAV resulting in an advanced stripless EATCHIP compliant interface compatible with the current Italian FDP system and accepted by ENAV as the basis for the future ATC system interface in Italy.

organisation represented an airspace structure and set of procedures to be followed and was simulated with 7 traffic samples. In this way organisations could be statistically compared with each other with the minimum of variables affecting the comparison. The set of 5 organisations created for RTS1 allowed the impact of the various MFF applications to be measured against the baseline of Fixed Route without MTCD and also enabled a clear analysis of the different benefits that MTCD and Free Route may bring compared to the baseline. Each organisation was simulated 7 times.

- Org1: Fixed Route airspace without MTCD
- Org2: Fixed Route airspace with MTCD
- Org3: Free Route airspace without MTCD
- Org4: Free Route airspace with MTCD
- Org5: Free Route airspace with MTCD and ASAS Spacing applications

In Org 5 all the aircraft were equipped for ASAS spacing.

Questionnaires were completed both after each simulation exercise and at the end of the simulation period to obtain subjective feedback from the participants. Observer teams were formed, consisting of a human factors specialist and a subject matter expert (SME). The SME observers noted their observations following an observation guide. Team debriefings were conducted after the measured exercises.

Scenario-based exercises

The scenario-based exercises were about 45 minutes long and aimed at reproducing specific, often critical, or abnormal situations. The following is an example of a scenario that was simulated:

> Scenario2: *ASAS Spacing:*
>
> Description: *ASAS spacing exercise in which a shift changeover was simulated. Plus R/T failure of one aircraft involved in an ASAS delegation.*
>
> Objective: *Assess ASAS procedures: Target identification, in-trail and merging application, transfer of control (hand-over) and ASAS termination.*

The scenario-based exercises aimed at testing if the events could successfully be dealt with and, if not so, which difficulties controllers might encounter. The critical interaction analysis model (CRIA) provided the theoretical framework for the exercises [11].

Scenario-based exercises provided a rich source of information through observations, questionnaires, and debriefings. Scenario-based exercises were video-taped but no statistical analysis was performed.

The video and audio recordings were transcribed and analysed using the CRIA. The analysis mainly consisted in the following steps:

- analysing the scenarios execution on the base of the video-recording,
- analysing interactions among liveware, hardware and software components involved in each scenario (see SHEL categories below),
- answering the CRIA questions table [11],
- highlighting critical interactions,
- comparing these results with the results from other methods.

The output of this analysis is a list of critical interactions emerging from the execution of the activities.

Observations recorded through Human Factor (HF) and Subject Matter Expert (SME) observers were organised in tables and classified according to SHEL [14] categories in order to highlight at what level the problem occurs and which interactions between system components should be redesigned to solve them. The SHEL categories are Liveware (humans), Software (rules, procedures, practices etc), Hardware (tools, manuals, telephone etc), Environment (socio-cultural and organisational environment).

Results

In the following the impact of free route and ASAS spacing on human factor issues will be discussed.

Free Route impact on human factor issues

Workload and task allocation

ISA: Analysis of Instantaneous Self Assessment (ISA) ratings, recorded through the simulations, suggest a workload difference between the organisations. Scenarios with Free Route Airspace organisation without MTCD lead to the lowest overall workload ratings (-10%) against the 'baseline conditions' Fixed Route Airspace organisation without MTCD, followed by Fixed Route with MTCD (-7%) and Free Routing with MTCD; the latter provided no significant difference to the baseline. Free Routing with MTCD and ASAS Spacing lead to an increase in workload (+2%).

It would seem that in fixed route the addition of MTCD reduces workload while in free route the opposite effect occurs. This may be due to the fact that in fixed route the relevance of an MTCD alert may more easily be evaluated 'at a glance', since the routes and crossing points are known to the controller. In the more unpredictable environment of free routes the evaluation of an MTCD alert may take more effort.

NASA TLX provided no significant differences between the organisations, neither for the combined rating nor for any of the subscales.

R/T Loading does not change significantly throughout the organisations.

Task allocation between Planning (PLC) and Executive controllers (EXC). Observations, debriefings and ISA results suggest that the EXC had a slightly higher workload than the PLC. However anecdotal evidence suggests that the controllers were comfortable with the task distribution and that the task distribution was flexible enough to allow them to work in collaborative manner.

Route Management

Need for reference points in Free Route Organisation: One of the most effective methods for re-routing aircraft is via waypoints as observed during scenario-based exercises specifically designed for this assessment. But the Free Routes tools implemented for RTS1 only allowed re-routing using heading or using a subset of waypoints (those already in the flight plan). Evidence suggests that the absence of a network of waypoints in Free Routing conditions causes problems.

Track Conformance monitoring: Compared to Fixed Route, in Free Route it is harder to tell at a glance if an a/c is deviating from its assigned track. A track conformance tool would be very helpful, as noticed especially in re-routing situations, and it is already foreseen.

Re-routing: Re-routing for weather and avoidance of military areas proved to be one of the most critical tasks during the simulation since this task was not adequately supported by the tools and because the Free Routes environment makes re-routings harder to foresee. Since aircraft do not follow a route structure, each aircraft has to be checked individually whether its route is clear from segregated areas or bad weather areas. This also has an impact on coordination with adjacent sectors. Since it is more difficult to anticipate which aircraft requires re-routing it is also more difficult to ask for another sector's agreement.

Resuming own navigation: After a deviation from the current route, for example due to an avoidance procedure or bad weather circumnavigation, the controller needs to instruct the aircraft to resume normal navigation. It is not obvious how to do this in Free Routes since there is an ambiguity about the term 'Resume Own Navigation' as depicted in Figure 1. Since no route structure is available in Free Routes, "resume own navigation" can mean 1) moving back to the trajectory prior to the deviation, or 2) going straight from the actual position to the Free Route airspace exit point. In the first case the aircraft might be routing direct to a point outside the current ATC sector so that it will enter the next sector at a totally different point.

Conflict Management

STCA: A reduction in Short Term Conflict Alert (STCA) events was noticed when MTCD was used. This effect was observed both for Fixed Route and Free Route airspace organisation.

Conflict detection in Free Routes: As mentioned above, conflict detection proved more demanding in Free Routing conditions. In Fixed Routes aircraft can be expected to enter the sector at specific points and follow certain routes which allows for a better planning and easier conflict detection - conflicts are more likely to happen at certain critical points. Questionnaires and debriefings suggest that the perception of controllers is that aircraft in Free Routing Airspace "come from everywhere".

Conflict Resolution in Free Routes: Even if controllers did not consider conflict resolution more difficult in Free Routing Airspace compared to Fixed Routes, they felt they had less conflict resolution strategies available to them. This may be caused by the fact that in Fixed Routes controllers solve many conflicts by simply giving a "direct", but in Free route airspace routes are already direct which means that this conflict resolution strategy is not applicable.

MTCD: MTCD seems to be required but needs improvement. Overall the usage of the tools, especially MTCD, was lower than expected. Moderately complex traffic samples were successfully dealt with and without MTCD. Observations, debriefings and questionnaires suggest that the following points needs extra attention:

- The MTCD used in the simulation displayed some false and not relevant alerts and failed to display a few potential problems. Therefore controllers lost time whilst evaluating the relevance of a MTCD alert.
- The MTCD alerts are pre-dominantly displayed in a separate window (PPD). This is not optimal since it draws the controllers' attention away from the main radar display.
- A "*conflict*" (between 2 a/c) is shown by the PPD as the primary entity, while controllers seem to think more in term of "*track of an a/c*" (intersecting other tracks). If an aircraft is in conflict with a number of aircraft this is for the controller still only one problem requiring one resolution strategy. However in the PPD the same situation is represented as separate problems where the connection in between them is not immediately clear.
- The MTCD algorithm seems to be most efficient in the time frame of circa 5-13 minutes ahead. A longer look ahead gives unreliable data, and below circa five minutes the impact of a particular design feature would become critical; a potentially dangerous Cleared Flight Level (CFL) input would not always trigger an MTCD alert.

Military operations

Civil-Military Conflicts*:* Potential conflicts between civil and military aircraft are more difficult to anticipate in Free Routing Airspace because it is harder for controllers to predict the evolution of the civil traffic. These conflicts can be critical because the aircraft are on different frequencies. A similar problem could be observed in relation to potential conflicts between civil aircraft on different frequencies.

Segregated area activity*:* During the measured exercises, it was observed that scheduled segregated area activity has little impact on workload in a Free Route environment due to the fact that aircraft have already flight planned to avoid notified areas. This is potentially safer than in Fixed Routes: giving a direct in Fixed Routes involves checking the direct route to be sure it is clear from segregated areas. Nevertheless, the eventuality of a route change that could incorrectly lead the aircraft into a segregated area must be taken into account. This case was observed during the simulation: the controller had issued the wrong clearance and did not immediately

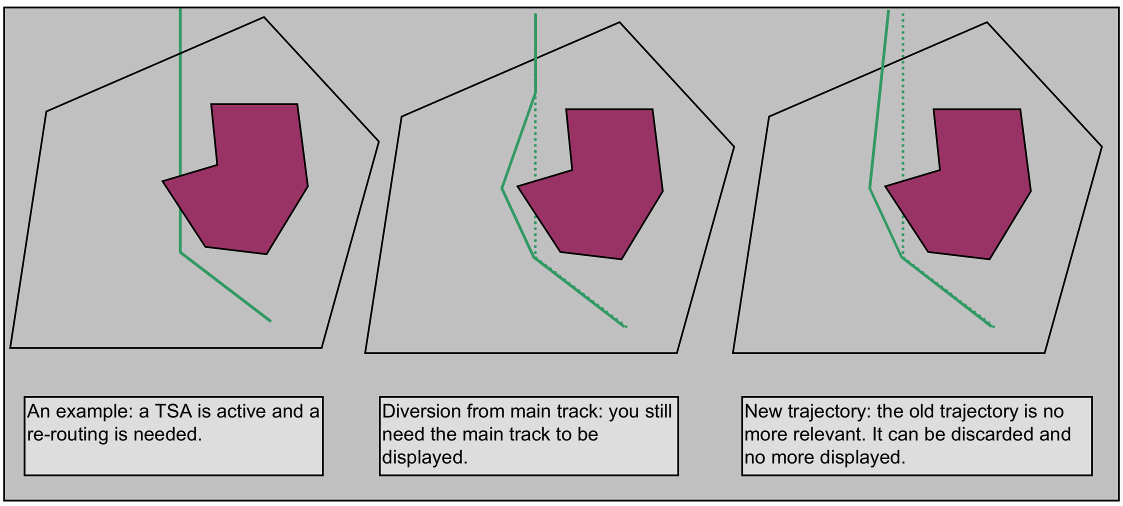

Figure 1 Resume own navigation around TSA.

notice the possible segregated area infringement because the segregated area was in the next sector. In those cases a warning would be helpful.

Unscheduled/late notification of segregated area activity has a large impact on workload in a Free Route environment, but this was also affected by limitations of the simulated system. The main problem is related to the re-routing procedures that have to be applied when the planned routes are not clear of the segregated area.

General

Transition Fixed Routes – Free Routes: Controllers did not find it more difficult to transfer aircraft between Fixed and Free Routes sectors. The transition from Free Routes to Fixed Routes was done through fixed exit points, therefore there is no great departure from the present transition procedures between Fixed Route sectors as presently applied.

SART showed no significant difference between organisations. The Situation Awareness Rating Technique (SART) [10] was used in order to investigate the effects of Free Routing, MTCD, and ASAS Spacing on Situation Awareness. No statistically significant effects were detected.

ASAS Spacing impact on human factor issues

ASAS Spacing – Procedures: The results of MFF RTS1 indicate that with appropriate procedures and appropriate tools these are strong benefits that can be achieved by the use of ASAS spacing. ASAS spacing is essentially made for sequencing (arrival) streams of aircraft in terminal areas (extended TMA). In the simulated free route environment it was expected that ASAS spacing would additionally be useful for sequencing aircraft on the exit points from free route to fixed route. However no conclusive evidence could be extracted from the simulation results. This was mainly due to the fact that RVSM provided for sufficient airspace capacity to resolve situations without the application of ASAS Spacing. Additionally the traffic samples did not include many arrival streams suitable for ASAS spacing, but was rather composed of overflying traffic. Evidence also suggests that maybe controllers did not have enough time to fully familiarise themselves with the ASAS Spacing procedures as only 20% of the simulation was dedicated to ASAS.

ASAS Spacing Workload*:* ASAS Spacing procedures imply initial extra work to establish a pairing. The controllers may therefore benefit from a “workload saving” only after the spacing has been established. In addition controllers found that the phraseology for ASAS spacing was not concise enough and thus prone to misinterpretation.

ASAS Spacing – Delegation*:* Another key aspect of ASAS spacing is the “partial delegation” of responsibility to the pilot. This means that the controller delegates an action (in this case speed adjustment) but not the full responsibility for monitoring. Issuing an ASAS spacing involves a greater level of trust in the pilot, compared to issuing a speed restriction, since there is more discretion: the pilot is delegated to make his own judgement about speed, but the controller is responsible for that judgement.

ASAS Spacing tools: In the simulated HMI the difference between ASAS target aircraft and delegated aircraft is not immediately understandable, especially when more than 2 aircraft are involved in a delegation. All the information needed to decide if to apply ASAS spacing is not available in a unique tool. Therefore the controller has to seek this information in different locations, making the procedure more time consuming and less straightforward.

Use of ASAS spacing: Simple speed adjustment was preferred to the use of “heading then merge” which was likely to take the delegated aircraft on a heading of indeterminate length, further increasing the monitoring task of the controller.

Conclusions

Free Route impact on human factor issues

The conclusion that may be drawn from MFF RTS1 is that free routing seems to be a feasible concept in the simulated airspace. The balance of workload between PLC and EXC seems acceptable. The task allocation offered a dynamic workload allocation, compensating for any unbalanced workload.

In addition current practices in the study airspace involve extensive direct routings meaning that there were no major differences between Fixed and Free Route final flight profiles. This is another reason why free route was well accepted by the controllers.

Nevertheless it was noted that when 'traffic became busy' some controllers felt as if the traffic 'was coming from everywhere'. In free route traffic does not necessarily enter the sector through well defined entry points which means a higher effort for the controllers to assess future traffic patterns and potential conflict points. This potential loss of situational awareness had already been foreseen before the simulation and measures had been taken to support the controller's planning task.

One of these measures was MTCD. The utility of MTCD could not be evaluated with any definite results due to certain problems; 'context[3]' traffic was not displayed by the MTCD tools and the rate of false and missed alerts was too high. Nevertheless, anecdotal evidence suggests that a tool such as MTCD seems necessary in free route. An important result of the simulation was indeed several good ideas to improve MTCD. For example there is a strong case for developing a new MTCD tool designed to specifically aid EXC controllers in the Free Route environment taking both Cleared Flight Level (CFL) and tactical speed control into consideration.

ASAS spacing impact on human factor issues

Evidence suggest that controllers did not have enough time to familiarise themselves with ASAS spacing procedures for mainly two reasons; there was not enough training and the traffic samples did not offer an abundance of situations in which ASAS Spacing would have been reasonably applicable. Due to RVSM several flight levels were available and a level change was often the preferred resolution strategy of the controllers in the enroute environment. As a result no conclusive evidence may be drawn from the results regarding ASAS spacing. Nevertheless one of the major problems observed is related to the lack of trust towards pilots that controllers showed, and this aspect should be further investigated. If controllers do not trust a system[4], its introduction may result in extra workload as the controllers feel the need to double check the information/actions presented. Giving the controller more information about what precisely the pilot is actually doing and seeing (climb rate, air speed, etc.) might reduce resistance towards delegation (the ADS-B technology foreseen by MFF targets at exactly this).

Scheduled segregated area activity has little impact on workload in a Free Route environment. Unscheduled/late notification of segregated area activity has a large impact on workload in a Free Route environment. The performance of system functionality to support re-routing is critical in this respect.

Future

Based on the results of RTS1, these are some examples of issues that need further investigation:

- <u>Controllers situational awareness in free route</u>. To further investigate the impact of free routes on controllers situational awareness of the traffic it is recommended to place the simulated sectors inside a large free route area where the controller will not be able to 'see' the entry/exit to fixed route. This is assumed to be a realistic scenario in the future. In addition the utility of MTCD should be further assessed upon the availability of a new version.

- <u>Critical dependencies on tools</u>. The changes introduced in a Free Route environment can have great impact on safety in case of system failure. It is a common feeling that Free Route procedures make tools' support even more essential than in Fixed Route. It is therefore recommended to validate specific emergency procedures for system failure in Free Route environment.

- <u>Trust</u>: The use of shared representations can improve the mutual trust between pilots and controllers. An example of this can be a re-routing issued by a controller with a partial delegation[5] supported by tools with some datalink features, allowing both controller and pilots to see consistent graphical route data and

[3] Context traffic is traffic that is not in direct conflict with the subject aircraft, but that constrain the movements of the subject aircraft.

[4] 'System' is here defined as the combination of human agents; hardware, procedures, environment etc.

[5] In case of military area avoidance it could be a clearance like this: "TSA (n) is active, remain 5 miles clear. After passing cleared direct RP (n)".

avoiding any doubt about where the a/c should be routed.

As MFF RTS1 was the first of a series of simulations within the MFF project there will be ample opportunities to investigate these and other issues in upcoming simulations. More specifically the next MFF simulation will further investigate Free Route, ASAS Spacing and ASAS Crossing[6].

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[6] It should here be noted that ASAS crossing will be simulated as a 'spacing' application meaning that the controller maintains the responsibility during all of the crossing operations. Radar separation minima will be applied.

Key words

Free flight, airborne separation, ASAS, ASAS spacing, free route, human factors, delegation, MTCD, medium term conflict detection, scenario, scenario-based exercises, CRIA, SHEL, real time simulation

Biographies

Dirk Schäfer is presently employed by the EUROCONTROL Experimental Centre in Brétigny, France, where he is responsible for human factors experimentation. He is managing the EUROCONTROL Human Factors Lab and advises a number of research projects on human factors issues. Prior to working for EUROCONTROL Dirk was employed by the German Aerospace Center in Braunschweig, where he led the ATM simulation group and was also working on a range of projects including automated speech recognition. Dirk holds a Diploma in Aerospace Engineering from the University of Aachen and a Doctor Degree in Aerospace Human Factors Engineering from the German Armed Forces University.

Elisabeth Modin has a degree in Master of Science in Engineering Physics from the Royal Institute of Technology (KTH), Stockholm, Sweden. She has a specialization in computer science with a focus on human computer interaction. She has gained further practical experience though her thesis study at the university of Siena, Italy, and through her current position as a human factor researcher and interface designer at Eurocontrol Experimental Center in Brétigny, France.