TRANSITIONS BETWEEN FREE FLIGHT AND MANAGED AIRSPACE

A CONTROLLER'S PERSPECTIVE

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Abstract

The predicted growth of air traffic over the next decade has started many activities and projects in the area of free flight. Introducing free flight requires free flight airspace (FFAS), which in turn leads to boundaries between managed airspace (MAS) and FFAS. The implications of transitioning these boundaries will be discussed in this paper.

Transitioning from MAS into FFAS and vice versa induces a shift of separation responsibility from ATC to the cockpit crew and, after re-entry into MAS, from the crew to ATC. In this paper, two transition concepts are described, that have been prototyped at the NLR ATC Research Simulator (NARSIM). The concepts are based on using a transition zone or layer for either vertical or horizontal transitions.

During the autumn of 2001, real-time experiments were conducted at NLR to get a first insight in the feasibility and controller acceptability of transition procedures between FFAS and MAS. These were controller in-the-loop experiments, focussing on their tasks and procedures.

Controllers indicated that the simulation reflected a realistic working position and a realistic traffic situation. Regarding the transitions, the most important comment was that the entry and exit should be made more flexible both in entry and exit position as well as the moment an aircraft could be cleared free flight or taken under control. Another important remark was that the task of the planner controller would change significantly and would require development of tools for supporting this new task.

Some of the controllers indicated that the transition into FFAS would be more flexible than current sector hand-over since no contract was required with the next sector.

Feedback provided by the controllers showed that the proposed concept is promising and will, together with the recommendations, be used for future experiments.

Biography

Collin Beers graduated in 1998 in Aerospace Engineering at the Delft University of Technology and has been employed by the National Aerospace Laboratory (NLR) since 1998. He has worked on different national and international ATM R&D projects since, amongst others Airborne ATM System (AATMS), Free Flight FMS (3FMS), and Evaluation of Area Conflict Detection (ACOD) at the Amsterdam Area Control centre.

Hans Huisman graduated in 1991 in Avionics at the Delft University of Technology. He has been active in the field of flight deck HMI design and evaluation since 1991 while working in the Human Factors Department of the National Aerospace Laboratory, NLR in Amsterdam. His activities on flight deck HMI design have mainly been conducted in ATM related topics, amongst others the 4D trajectory negotiation philosophy from the Programme for Harmonised ATM Research in Eurocontrol (PHARE), flight planning topics including data link application and free flight concepts.

Introduction

Over the last decades, the European civil aviation has increased by approximately 5% annually. In 1999, 25% of the total delays were caused by (lack of) en-route ATC capacity. In addition, this (lack of) en-route ATC capacity triggers part of the reactionary delays. Reactionary delays are built up by a number of primary delay causes and add up to 41% of the total delays [4]. Therefore, in order to decrease the total delay an increase of en-route capacity is of paramount importance. The Reduced Vertical Separation Minima (RVSM) program can offer a short-term solution. As a next step, direct routings with Medium Term Conflict Detection (MTCD) and eventually Free Flight Airspace (FFAS) can be introduced.

NLR participates in various Free Flight related projects, including Free Flight FMS (3FMS, consortium lead by Thales, partly funded by EC DGXII), More Autonomous Aircraft in the Future ATM System (MA-

AFAS, consortium lead by BAE Systems, partly funded by EC DGXII), Mediterranean Free Flight (MFF, consortium lead by ENAV, partly funded by EC TEN-T) and the NASA/NLR Free Flight project [2 and 3].

When introducing FFAS, a new problem arises. Currently, it seems unlikely that FFAS will be practical around an airport. At least the Terminal Area (TMA) will remain Managed Airspace (MAS). This will lead to the need for transition procedures between FFAS and MAS. The transition from one type of airspace to another involves different issues due to the differences in airspace structure, procedures and separation responsibility.

There are two transitions, which are inherently different. The first one is the *Vertical Transition*. This transition will be used when FFAS is positioned above MAS. The second one is the *Horizontal Transition*. This transition will be used when FFAS and MAS are adjacent.

In addition, there will be a need for a sort of evolution, namely to change some MAS sectors into FFAS sectors over the years. It can be envisaged that initially there will only be upper airspace that will be partly FFAS. Next, this airspace can be extended and eventually lead to total FFAS outside the TMA.

Defined Concepts

Transitioning between MAS and FFAS assumes that FFAS sectors will not only exist in remote, low traffic density areas but also in radar covered, high traffic density areas. It is further assumed that all traffic in FFAS is equipped with Automatic Dependant Surveillance – Broadcast (ADS-B), Airborne Separation Assurance System (ASAS) for conflict detection and resolution, a Cockpit Display of Traffic Information (CDTI) and Area Navigation (RNAV) capability.

Between MAS and FFAS a transition layer or zone is created which is solely reserved for aircraft which are in transition from one airspace type to the other. This transition layer or zone is introduced to avoid possible loss of separation between free flight and controlled aircraft.

The purpose of the transition zones is to serve as a safety buffer. Aircraft coming from MAS are only allowed to enter these zones while cleared by ATC, while aircraft coming from FFAS have to request and obtain approval from ATC (to enter). Inside the transition zone, aircraft are required to perform self-separation while maintaining an assigned flight level, but ATC controls the number of aircraft allowed in this zone.

Concept of Horizontal Transition

Horizontal transitions can exist within different airspace definitions. An example of such a concept is the situation where some sectors within upper airspace will be FFAS and other sectors remain MAS (see figure 1).

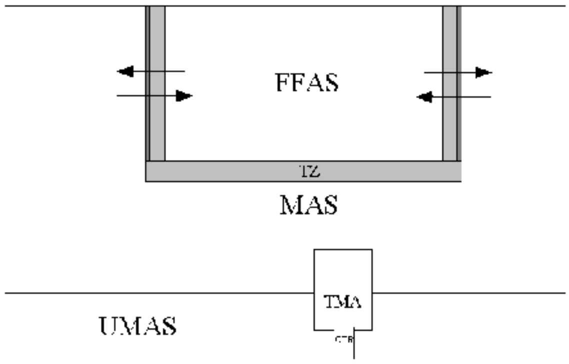

Figure 1: Airspace structure for horizontal transition

Another airspace definition could use the total airspace, except the TMA, for FFAS (see figure 2).

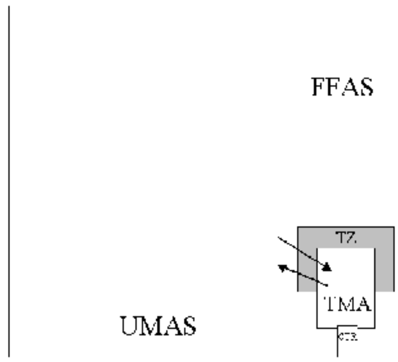

Figure 2: Airspace structure for horizontal transition

The different airspace definitions imply different controller procedures and possibly an adapted ground HMI.

When the TMA is the only MAS sector surrounded by FFAS, a number of MAS entry and exit points are defined. Aircraft will cross the entry points with a published track, time constraint (if necessary), cleared speed and altitude. These entry points resemble the currently used initial approach fixes (IAFs).

All aircraft entering the TMA via the same entry point should be separated, which implies a certain sequence at the entry point. Current day arrival managers assist controllers in achieving a sequence. Future experiments could assess to what extent arrival management support tools could benefit the transitions between FFAS and MAS.

When MAS is not restricted to a TMA but is just one of the en-route sectors, the situation is slightly different because the number of entry points is less restrictive compared to the previously described situation. In addition the altitude range for which an entry point can be used is far less restrictive.

Depending on whether the MAS sector to enter is capable of free routing, the entry points can also be flexible in their position on the MAS boundary.
For both situations the entry points are located on the boundary between MAS and the transition zone. Transitions will use specific entry and exit points. In the experiment described here the nature of these points can differ depending on the route with which they are connected:

- There will be separated entry and exit points, if these points are connected with a one-way route. Aircraft entering and exiting FFAS are laterally separated.
- There will be combined entry and exit points, if these points are connected with a two-way route structure.

In both cases entering and exiting traffic are vertically separated.

In the experiments, a separation area of 5NM between MAS and FFAS is defined. This separation area is introduced to avoid possible intrusions of protected zones between free flying and controlled aircraft. It is not allowed for any aircraft to enter this separation area (see figure 3).

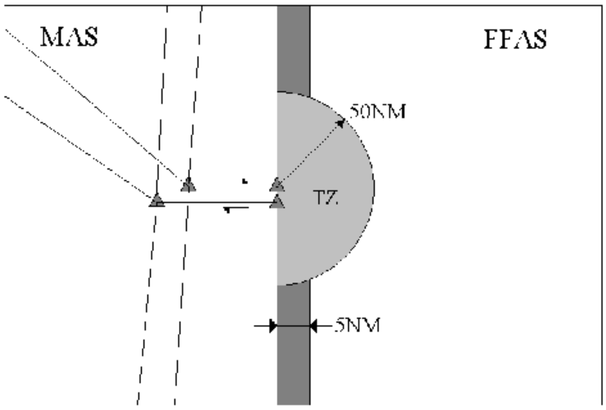

Figure 3: Entry and exit point for horizontal transition

Around the MAS exit point, within FFAS, a circular transition zone with a 50NM radius is defined. This transition zone is introduced to prevent conflicts between MAS exiting and MAS entering aircraft close to the MAS exit point. To prevent conflicts, vertical separation is assured through flight level assignment for aircraft either entering or exiting MAS.

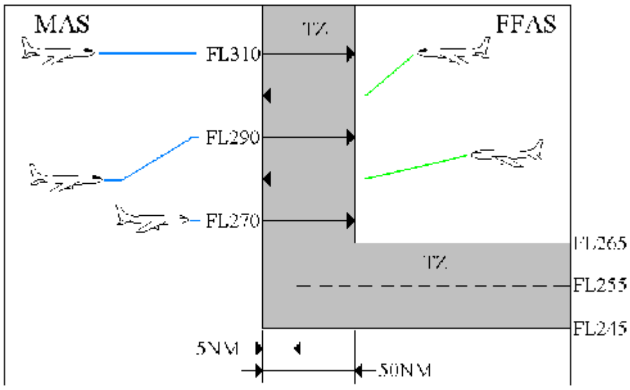

Figure 4: Vertical separation for horizontal transition

Within the concept, as shown in figure 4, the lowest FFAS entry flight level will be FL270 and the lowest MAS entry flight level will be FL280. The flight levels FL250 and FL260 shall be dedicated for vertical transitions.

MAS to FFAS horizontal transition
The tactical controller (TC) clears the aircraft to pass the MAS exit point and instructs the crew to expect free flight operation some time (about 10 minutes) before the MAS exit point will be reached. The crew then prepares to enter FFAS by switching on their ASAS (in case it was not already switched on). When passing the MAS exit point the aircraft enters the transition zone. Within this transition zone no immediate conflict should occur because the traffic in the transition zone, coming from MAS, is still separated since it was separated in MAS. Traffic coming from FFAS is separated from traffic coming from MAS by different altitude levels assigned for MAS exiting and entering traffic.

While residing in the transition zone, the crew of the aircraft intending to enter FFAS has to assure separation with traffic within the transition zone and traffic in FFAS. While residing in the transition zone only lateral manoeuvres are allowed since the level above and below are reserved for MAS entering traffic. After having entered FFAS both lateral and vertical manoeuvres are allowed.

A typical transition would look like this:

- TC: instruct crew to expect free flight operation at MAS exit point;
- Crew: affirm to ATC and activate ASAS function if not yet activated;
- TC: assign flight level to maintain in transition zone;
- Crew: affirm to ATC;
- TC: hand over separation responsibility to flight crew at MAS exit point;
- Crew: accept separation responsibility and continue flight via the separation zone into FFAS.

R/T

TC: *"(CALLSIGN), expect FF at DEXIT"*
Crew: *"Roger, (CALLSIGN)"*
TC: *"(CALLSIGN), climb FL (XFL)"*
Crew: *"Climbing FL (XFL), (CALLSIGN)"*
TC: *"(CALLSIGN), cleared for FF, monitor 136.465"*
Crew: *"Cleared for FF, monitoring 136.465, (CALLSIGN)"*
(DEXIT was the defined MAS exit point in the experiment.)

FFAS to MAS horizontal transition
Aircraft wanting to enter MAS will contact the planner controller (PC) of the MAS sector about 15-20 minutes before reaching the transition zone. The PC will assign a flight level to be reached before entering the transition zone and a required time of arrival (RTA) to be met at the MAS entry point. Since the PC planned the incoming traffic in such a way that it will be sequenced and separated when reaching the MAS entry point, the conflicts that might occur in the transition zone should be minimal. While flying in the transition zone approaching the MAS entry point, the PC will hand over the aircraft to the tactical controller (TC).

A typical transition would look like this:

- Crew: contact planner ATCo to request MAS entry;
- PC: assign flight level and RTA at MAS entry point;
- Crew: affirm flight level and RTA;
- Crew: monitors traffic in transition zone and solves conflicts if required with other inbound traffic;
- PC: hands over the crew to the TC;
- TC: takes over separation responsibility from the crew when passing the MAS entry point;
- Crew: affirms change of responsibility and switches off ASAS function if desired.

R/T

Crew: *"Maastricht Radar, (CALLSIGN) approaching DENTRY maintaining FL (NFL)"*
TC: *"(CALLSIGN), cancel FF"*
Crew: *"Cancelling FF, (CALLSIGN)"*
(DENTRY was the defined MAS entry point in the experiment.)

Concept of Vertical Transition

The first region where Free Flight is implemented will probably be an upper airspace area, for example above flight level 245. Flying at high altitude has a clear economic advantage for cruising aircraft. Another advantage of this method is that it allows a gradual implementation of free flight by lowering the altitude limit, similar to the National Route Program in the US, making it more acceptable when introduced [1].

Below flight level 245 will then be managed airspace and the area between flight level 245 and 265 will be defined as the transition zone (see figure 5 and 6). This transition layer avoids predicted conflicts and possible intrusions of protected zones between free flying and controlled aircraft if no transition zone would be used.

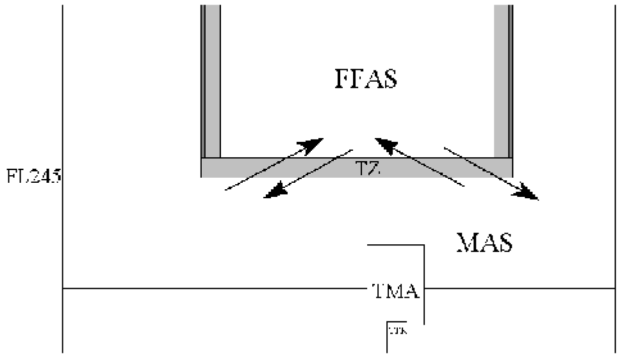

Figure 5: Airspace structure for vertical transition

MAS to FFAS vertical transition
While operating in MAS, the ASAS system is switched on to prepare the FFAS entry. The crew ensures a conflict free transition zone entry and requests ATC to leave MAS. The TC clears the aircraft into the transition zone, assuring no immediate conflict occurs after entering the zone and ASAS is operative on board.

Once the aircraft has entered the transition layer it may continue its climb on own separation responsibility using ASAS. Inside the complete transition layer the flight crew is responsible for separation assurance.

Whenever the flight crew intends to climb to FFAS, the ASAS module containing conflict detection and resolution algorithms should be switched on well before entering the transition layer because as soon as the transition layer is entered, the crew is responsible for the separation assurance.

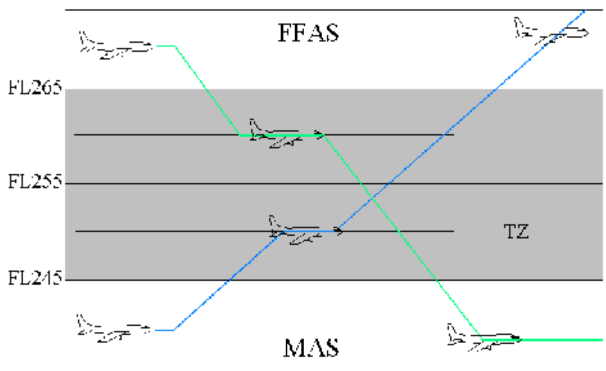

Figure 6: Use of Transition Layer for vertical transition

While still operating in MAS, the ASAS system is only switched on to prepare for FFAS operation because ATC is still responsible for separation assurance at that moment.

A typical transition would look like this:

- TC: instruct crew to expect free flight operation when crossing lower transition layer level;
- Crew: affirm to ATC and activates ASAS function if not yet activated;
- TC: assign flight level into the transition layer;
- Crew: affirm to ATC;
- TC: hand over separation responsibility to flight crew when crossing the lower transition layer level;
- Crew: accept separation responsibility;
- Crew: monitor traffic and initiate climb out of the transition layer into FFAS.

R/T

TC: *"(CALLSIGN), Expect FF after crossing FL245"*
Crew: *"Roger, (CALLSIGN)"*
TC: *"(CALLSIGN), Climb to FL250 and expect FF"*
Crew: *"Climbing to FL250, (CALLSIGN)"*
TC: *"(CALLSIGN), cleared for FF, monitor 136.465"*
Crew: *"Cleared for FF, monitor 136.465, (CALLSIGN)"*

FFAS to MAS vertical transition

The crew requests ATC to enter MAS while flying in FFAS. ATC clears the aircraft on a certain heading (or underlying airway), speed and altitude for MAS entry. Having received this clearance, the crew is allowed to descend into the transition layer coming from FFAS taking into account the constraints to enter MAS. At this moment the crew is still maintaining self-separation. Time constraints may be used for the moment or position of descent.

After entering MAS, the crew may switch off the ASAS functionality upon the crew's own discretion, in order to avoid nuisance alerts.

A typical transition would look like this:

- Crew: contact planner ATCo to request MAS entry;
- PC: assign constraints for MAS entry;
- Crew: affirm constraints if feasible;
- Crew: monitors traffic in transition layer and descents into the layer and solves conflicts if required with other inbound, but also outbound traffic;
- PC: hands over the crew to the TC;
- TC: clears aircraft down into MAS;
- TC: takes over separation responsibility from the crew when passing the lower boundary of the transition layer;
- Crew: affirms change of responsibility and switches off ASAS function is desired.

R/T

Crew: *"Amsterdam Radar, (CALLSIGN) approaching transition leg maintaining FL260"*
TC: *"(CALLSIGN), descend to FL240 and cancel FF"*
Crew: *"Descending FL240 and cancelling FF, (CALLSIGN)"*

Experiments for evaluation of ATCo tasks

During the autumn of 2001, real-time experiments were conducted at the NLR ATC Research Simulator (NARSIM) [6] to get a first insight in the controller acceptance and feasibility of transition procedures between FFAS and MAS. These were controller in-the-loop experiments, focussing on their tasks and procedures.

The transition concepts used in these experiments defined the upper airspace Coastal sector as FFAS. This definition was chosen because it is most likely that FFAS will initially be implemented as part of upper airspace. During the experiments two types of transitions were simulated. Firstly the horizontal transition, this is the transition between FFAS (Coastal sector) and UAS (Delta sector) and secondly the vertical transition, this is the transition between FFAS (Coastal sector) and ACC north. The controllers, who participated in the trials, were all familiar with the current operational procedures for these sectors. The airspace used during the trials is shown in figure 7 and figure 8.

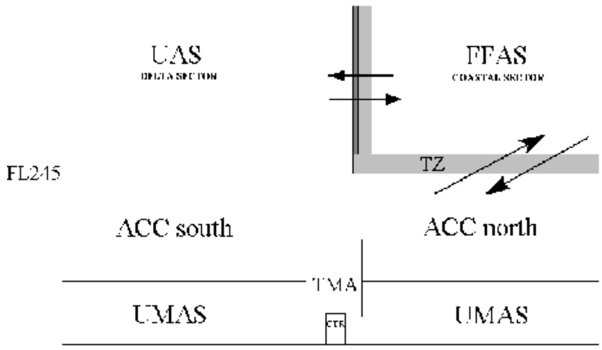

Figure 7: Used airspace for experiments

Aircraft indicate via their filed flight plan whether they are ASAS equipped. In case their requested route (lateral route and cruise level) uses FFAS, the planner controller assumes this aircraft will leave or enter the sector on the MAS to FFAS boundary.

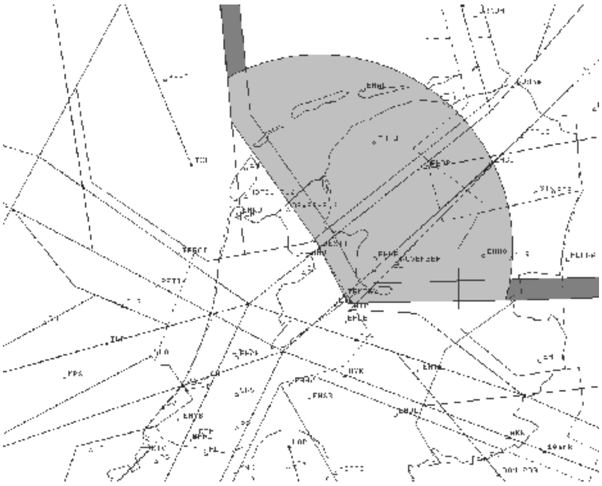

Figure 8: Used airspace for experiments (part of the Dutch FIR)

Experiment environment

Only one controller working position of NARSIM was used in the experiment. Depending on the session this was the tactical controller working position of an UAC sector or an ACC sector.

Figure 9: Controller working position

The planner controller was simulated by providing the tactical controller with a well planned inbound traffic stream. The aircraft in the experiment were controlled by two blip drivers. Each blip driver was able to fly 20 aircraft in the simulation. Communication between the controller and the blip drivers was performed by R/T

Figure 10: Blip driver working position

Experiment definition

Four controllers (ACC Amsterdam and UAC Maastricht) participated in the experiment, each performing three 30-minutes sessions as UAC controller and one as ACC controller.

In three sessions a controller performed the task of UAC controller using horizontal transitions. The first session started with only outbound traffic followed by the second session with only inbound traffic, while the third session consisted of a mixture of inbound and outbound traffic. In one session a controller performed the task of ACC controller using vertical transitions. This session consisted of a mixture of outbound and inbound traffic.

After each session, controllers were asked to fill in a questionnaire. In addition, a questionnaire was used before the start of the experiment and one after completion of all sessions. Each controller therefore filled in a total of six questionnaires. During the sessions, subjective workload was assessed using the ISA (Instantaneous Self Assessment) [7] at regular intervals of 5 minutes during each session. The ISA is applied by using a keyboard with five buttons and one indication light. When the indication light was switched on (every five minutes, for 60 seconds.), the controller had to press one of the five buttons representing his workload at that moment.

The description of the five ISA levels as explained to and to be used by the controllers is indicated in the table below.

ISA Level	**Workload Heading**	**Spare Capacity**
1	Under-utilised	Very Much
2	Relaxed	Ample
3	Comfortable	Some
4	High	Very Little
5	Excessive	None

Results

Questionnaire results.

The questions concentrated mainly on how transitions from FFAS to MAS and vice versa compared to current sector transitions. Comparison was mainly based on questions regarding workload, number of required instructions and the required strategy to be used by the controller. In addition, more general questions were asked about confidence in the proposed concept. These general questions were asked before the start of the trials and again at the end of the trials in order to see whether opinions had changed during the trials.

All questions were given in the form of a statement and the controller could indicate on a six-point scale whether he agreed or disagreed with the statement. The six-point scale is presented on the horizontal axis of the bar charts here. The vertical axis presents the number of controllers who gave the respective answer. In most charts four responses can be counted, but in some charts only three are available since some controllers did not answer all questions. Due to the small number of subjects no statistics have been applied to these results.

More general questions were asked before the trials were conducted and again afterwards. In the bar charts these are indicated as "pre trial" and "post trial" responses. The more detailed questions on the various transitions have been divided here on the basis of transition type (horizontal versus vertical).

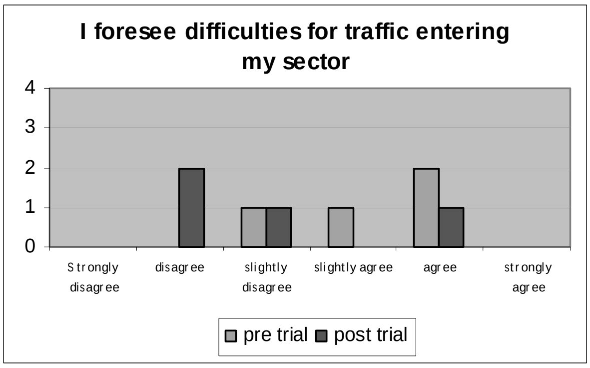

Figure 11: Questionnaire: foreseen MAS entry difficulties

Figure 11 shows whether controllers foresee difficulties when traffic enters their sector. It shows that after having participated in the trial, they become more confident about taking traffic under control coming from FFAS.

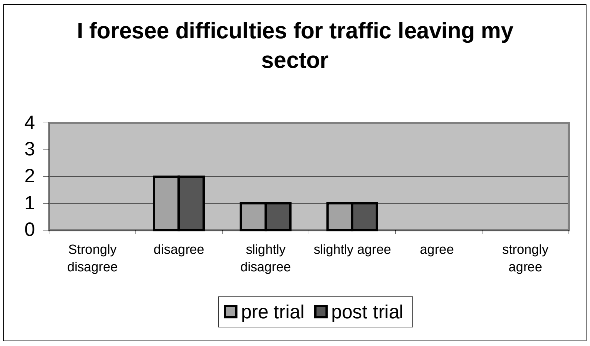

Figure 12: Questionnaire: foreseen MAS exit difficulties

Figure 12 shows that the trials did not influence controller's opinion regarding expected difficulties with traffic leaving the sector. Compared to the MAS entry situation less difficulties are expected here.

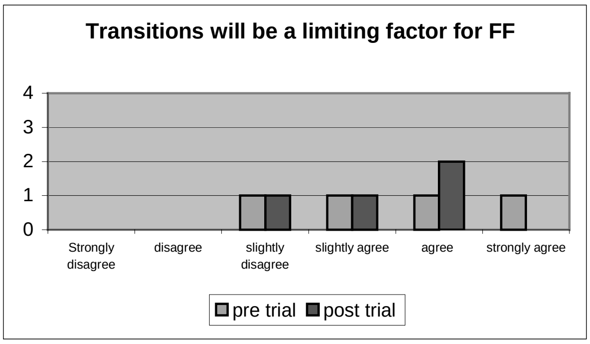

Figure 13: Questionnaire: limiting factor of the transition

Figure 13 shows that the majority of controllers feel that transitions will be a limiting factor. One suggestion for improving this situation was to provide a kind of corridor for MAS entry/exit transitions, rather than a single transition point.

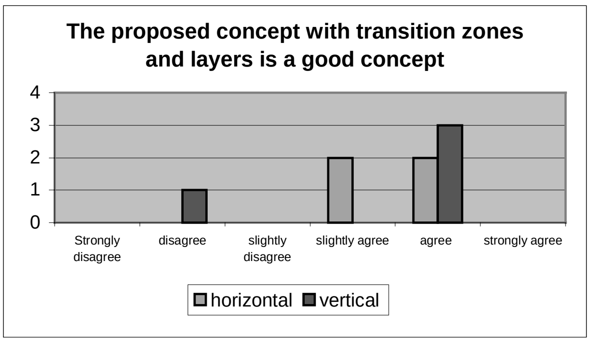

Figure 14: Questionnaire: acceptance of the concept using transition layers and zones

Figure 14 shows that the applied transition procedures in the trials were positively rated except for one controller having doubts about the vertical transition procedure. Main concern regarding this vertical transition was that it should be possible for aircraft to climb through the transition layer without needing to level off in transition layer. If aircraft would be required to level off in the transition layer this controller expected a capacity problem.

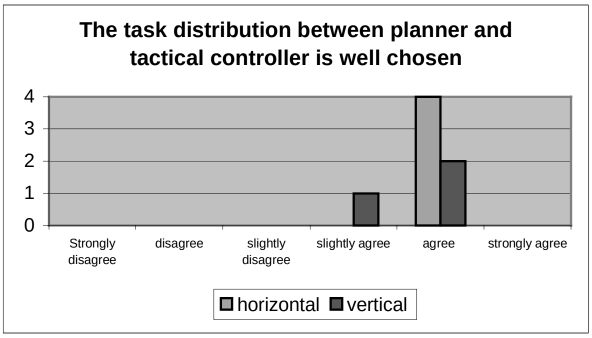

Figure 15: Questionnaire: task distribution between planner and tactical controller

Although the planner controller was not part of the trial and the work to be done by the planner was assumed to be performed as required for the situation, a question was posed regarding the task distribution (see figure 15). It indicates that this task distribution is well chosen although not based on hands-on experience in the trials. One controller did not answer the question for the vertical transition, indicating that it was difficult to answer without having an active planner controller involved in the trials.

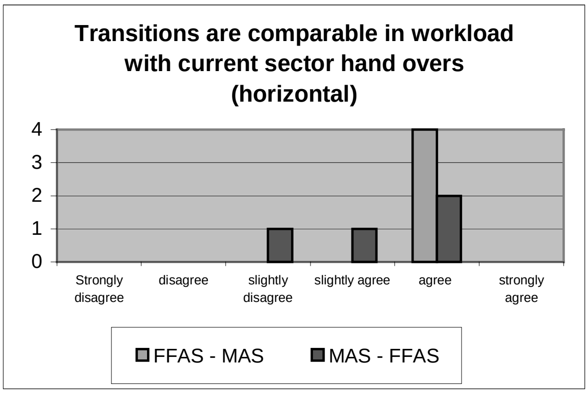

Figure 16: Questionnaire: workload compared to current operation for horizontal transitions

Figure 16 shows that controllers expect that their workload will not change compared to current operation in the horizontal transitions. It must be noted that no other objective workload measurements were taken during the trials and that no base line scenario was used against which to compare workload measures. So, this result must be seen as a first subjective indication from the controllers.

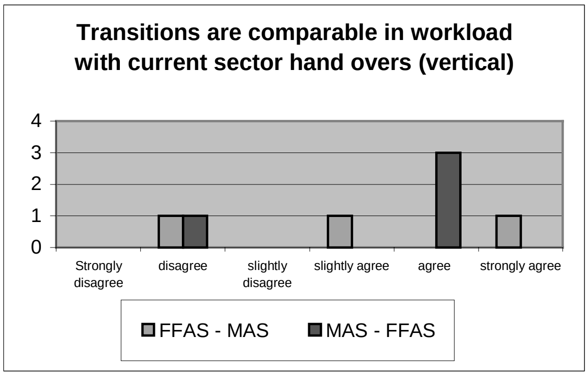

Figure 17: Questionnaire: workload compared to current operation for vertical transitions

Figure 17 shows that the situation for the vertical transitions differs from that of the horizontal transition as indicated in figure 15. One of the controllers doubted the value of vertical transition. The main reason for these doubts was the fact that aircraft climbing out of MAS into FFAS remaining in the transition layer would cause problems for aircraft willing to descend from FFAS into MAS. It was noted that more flexibility regarding the use of the transition layer was required.

<u>ISA results.</u>

The ISA score was obtained each 5 minutes during the trials. Since each scenario started with a small number of aircraft building up to a busier traffic situation, only ISA ratings between 15 and 30 minutes after the scenario start were used. The ratings were averaged over all controllers, split in the horizontal and vertical scenarios. Only the complex scenarios, comprising transitions in both ways, were taken into account.

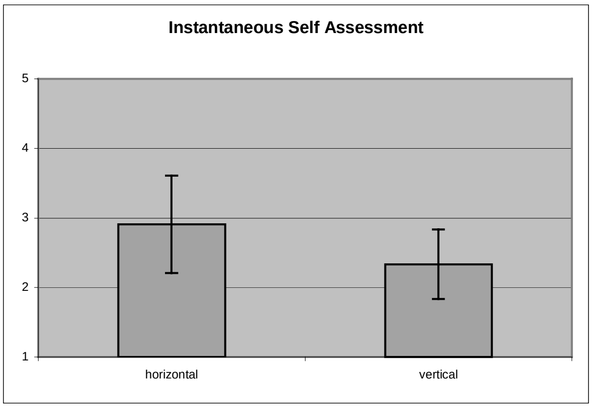

Figure 18: ISA ratings for horizontal and vertical transitions (scale runs from 1="under utilised" to 5="excessive").

Figure 18 shows the average ISA ratings and the standard deviation. The scale 1-5 represents the possible workload ratings: 1= "under utilised", 2= "relaxed", 3="comfortable", 4="high" and 5="excessive".

The ratings both for horizontal and vertical are in the range of “relaxed” to “comfortable”. It should be noted that the difference between the ratings for horizontal and vertical are not caused only by the applied procedure but also by the variation in traffic situation.

Controller comments and opinions.
Controllers indicated that the simulation reflected a realistic working position and a realistic traffic situation. In addition, controllers used the proposed R/T phraseology with some minor adjustments.

Regarding the transitions, the most important comment was that the entry and exit should be made more flexible, in terms of both entry and exit position, as well as the moment an aircraft could be cleared free flight or taken under control. This means that the MAS exit (and possibly the MAS entry as well) should consist of more than one single waypoint. Also, the moment of transitioning should be flexible. This extra flexibility would not only increase capacity but also have a positive effect on the controller’s workload.

Another important remark was that the task of the planner controller would change significantly and would require development of tools for supporting this new task.

Some of the controllers indicated that the transition into FFAS would be more flexible than current sector hand-over since no contract was required with the next sector. As long as an exit level was assigned and reached before MAS exit, this would be sufficient and was indicated as an improvement regarding flexibility. Interestingly, one controller indicated that, compared to current sector hand-over, he kept free flight traffic longer under control than he would when traffic would continue into an adjacent MAS sector.

Controllers are used to clearing aircraft to change frequency to another sector, when this aircraft is conflict free and will not receive any clearances from the specific controller before physically crossing the sector boundary. The flight crew will then contact the tactical controller of the adjacent sector. When this adjacent sector is FFAS, the controller has to give a conditional clearance to the aircraft, for example for the horizontal transition “After DEXIT cleared for Free Flight and monitor 136.465”. Until they’ve passed DEXIT, the flight crew will still have the frequency selected of the MAS tactical controller and will remain their route and altitude as instructed by the controller. After DEXIT they’re cleared to change frequency and fly in the free flight mode, without contacting anybody. Controllers want to assume aircraft coming from FFAS far before the sector boundary. Controllers want to give clearances to these aircraft, but these aircraft are still in FFAS and therefore responsible for separation assurance. To overcome this might use instructions like “can you accept a direct to (WAYPOINT)?”.

Conclusions

The aim of the NARSIM experiments was to get a first impression of the feasibility of the proposed future transition procedures between MAS and FFAS.

The feedback provided by the controllers showed that the proposed concept is promising and will, together with the recommendations, be used for future experiments.

No difficulties were expected for traffic entering the controller’s sector, although some controllers appeared to expect difficulties before having participated in the trial.

Controllers did not foresee difficulties for traffic leaving the sector. No change in opinion was observed in the course of the trial.

Controllers agreed on the necessity of a transition zone and layer. Especially the vertical layers used for the horizontal transition were considered helpful for conflict free transitions.

The transition layer in the vertical transition was appreciated, because of the procedural separation of aircraft entering and leaving MAS.

The introduction of the transition zones and layers as well as the single MAS exit and entry points also introduced a limiting factor for Free Flight and a decrease in the flexibility available in the task of air traffic controllers. Adjustments to the concept, mentioned in the following section, can re-introduce the flexibility and remove the limiting factor for Free Flight.

Task sharing between the tactical controller and planner controller was well chosen according to the participating controllers.

Workload was indicated to be comparable for current sector hand over for the horizontal transitions. For the vertical transitions the results show more variation.

Recommendations

Recommendations for future experiments are:

MAS to FFAS horizontal transition
Aircraft should, when they are not causing a conflict, be allowed to climb within the transition zone into FFAS.

The R/T message "expect Free Flight" would possibly be given by the controller via datalink. After this message is given, the aircraft label on the radar screen should change slightly, for example a new aircraft symbol should appear.

Depending on the airspace structure and traffic density, there will need to be one or more MAS exit points or even a MAS exit area. When using for example three MAS exit points, these points are stated in the flight plan and can be used for strategic conflict resolution.

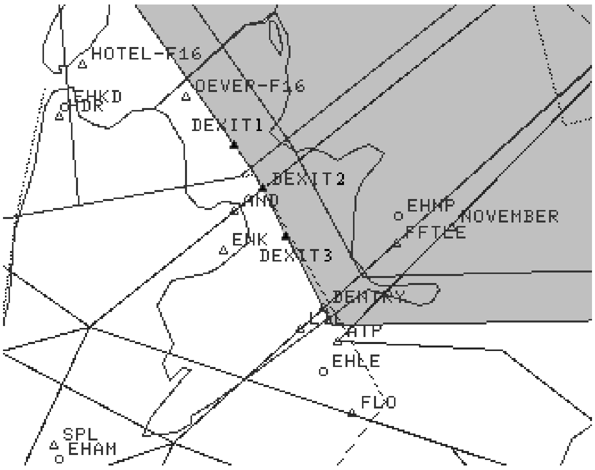

Figure 19: Multiple MAS exit points

Northbound traffic enters FFAS via DEXIT1.
North-eastbound traffic enters FFAS via DEXIT2.
Eastbound traffic enters FFAS via DEXIT3.

FFAS to MAS horizontal transition
Aircraft could, when allowed by the planner and/or tactical controller, descent within the transition zone into MAS. Depending on the airspace structure and traffic density, there may need to be more then one MAS entry point.

MAS to FFAS vertical transition
The same as for the horizontal transition; Aircraft should, when they are not causing a conflict, be allowed to climb within the transition zone into FFAS.

FFAS to MAS vertical transition
The next step will be simulations with both a tactical as well as a planner controller in the loop.

Related Current and Future activities

- Free Flight – Flight Management System (3FMS) project participation (project funded by EC DGXII).
- More Autonomous Aircraft in the Future ATM System (MA-AFAS) project participation (project funded by EC DGXII).
- Mediterranean Free Flight (MFF) project participation (project funded by EC TEN-T).
- NASA/NLR Free Flight project.
- Intent project participation (project funded by EC DGXII).
- Free Route Airspace Project (FRAP) – human factors assessments (funded by Eurocontrol)

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Abbreviations

3FMS	Free Flight FMS
AATMS	Airborne ATM System
ACOD	Area Conflict Detection
ACC	Area Control Centre
ADS-B	Automatic Dependent Surveillance – Broadcast
ASAS	Airborne Separation Assurance System
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATM	Air Traffic Management
CDTI	Cockpit Display of Traffic Information
CTR	Control Zone
DGXII	Directorate General XII
EC	European Commission
FF	Free Flight
FFAS	Free Flight Airspace
HMI	Human Machine Interface
IAF	Initial Approach Fix
MA-AFAS	More Autonomous Aircraft in the Future ATM System
MAS	Managed Airspace
MFF	Mediterranean Free Flight
MTCD	Medium Term Conflict Detection
NARSIM	NLR ATC Research Simulator
NLR	National Aerospace Laboratory (Nationaal Lucht- en Ruimtevaart Laboratorium)
PC	Planner Controller
PHARE	Programme for Harmonised ATM Research in Eurocontrol
R&D	Research and Development
RNAV	Area Navigation
RTA	Required Time of Arrival
RVSM	Reduced Vertical Separation Minima
TC	Tactical Controller
TEN-T	Trans-European Network for Transport
TMA	Terminal Area
TZ	Transition Zone
UAC	Upper Airspace Control
UAS	Upper Airspace
UMAS	Unmanaged Airspace

Definitions

Entry point
The entry point is positioned on the boundary between MAS and FFAS, in the transition zone. It is the waypoint at which aircraft can enter MAS and exit FFAS as part of horizontal transitions.

Exit point
The exit point is positioned on the boundary between MAS and FFAS, in the transition zone. It is the waypoint at which aircraft can exit MAS and enter FFAS as part of horizontal transitions.

Protected zone
A protected zone is a zone around each aircraft with a certain radius and height. The protected zone is the zone never to be penetrated by any other aircraft, in order to maintain separation.

Separation area
A separation area is an area between MAS and FFAS which is prohibited for all traffic. It ensures that no loss of separation can occur between FFAS and MAS traffic.

Transition
A transition is defined as a change from FFAS into MAS or vice versa. During this transition, separation responsibility is shifted from the flight crew to the ATCo or vice versa.

Transition zone
A transition zone (TZ) is a specific zone within FFAS, which is dedicated to aircraft in horizontal transition. The TZ is defined as an area around an exit and/or entry point.

Transition layer
A transition layer (TL) is a specific layer within FFAS, which is dedicated to aircraft in vertical transition. In this TL a transition leg is defined.

Transition leg
A transition leg is a part of the existing route structure, consisting of a transition leg start and end point for entry aircraft. This transition leg is used for vertical MAS entry transitions.