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EIGHT-STATES FREE ROUTE AIRSPACE PROJECT
LARGE SCALE REAL-TIME SIMULATION
NORTH SCENARIO

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TITLE:

EIGHT-STATES FREE ROUTE AIRSPACE PROJECT
LARGE SCALE REAL TIME SIMULATION NORTH SCENARIO

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Abstract:

This report describes the Eight States Free Routes Project Large Scale Simulation, North. Parts of Berlin, København, Maastricht, Malmö, and Oslo FIR/UIR was simulated. The simulation was part of the Free Routes Airspace Concept Validation, and was the first of two planned large-scale simulations where the Free Routes concept was validated in an environment with several ACCs involved. The simulation was based on the draft Free Routes Operational Concept, using a sectorisation developed by the first Free Routes Fast Time Simulation, and was addressing airspace design criteria, system support to controllers, entry/exit procedures. Human Performance, Human Error and Safety issues were addressed in parallel studies conducted within the framework of the Free Routes Airspace Project, using the simulation as a vehicle to provide data.

SUMMARY

This is the report of the Eight-States Free Routes Airspace Project Large-scale Real-time Simulation, North. The simulation was the first of two large-scale real-time simulations following the small-scale simulations conducted within the project. These simulations provide, together with a number of other activities, the basis for the validation of the Free Routes Airspace Concept.

The simulation was conducted at the EUROCONTROL Experimental Centre, Bretigny and lasted for three weeks. 25 air traffic controllers from Berlin ACC København ACC, Lippe Radar (mil), Maastricht UAC, Malmö ACC, and Oslo ACC, together with an air defence specialist from the Swedish Armed Forces, participated in the simulation. Airspace covering parts of Denmark, Germany, Norway and Sweden was simulated. The emphasis in this simulation was on military operations.

Functionality and Human Machine Interface similar to the ones that are expected to be in operation in the ACCs within the simulated area before year 2005 formed the basis for the platform. This included OLDI/SYSCO, System Supported Civil-military Co-ordination, Medium Term Conflict Detection and Short Term Conflict Alert. The HMI used a stripless, object based, colour coded concept.

Free Routes was simulated in accordance with the draft Free Routes Operational Concept ver 0.3 [ref. 6]

The simulation showed that the Free Routes Concept can be implemented when the required supporting functionality is in place in the ACCs, and can lead to certain benefits. There are a number of very important implementation issues that will have to be analysed carefully together with more detailed system requirements before a possible implementation.

The question of reduction in controller workload was not addressed in this simulation, but will be covered in the FRA simulation which will take place during January-February 2001. EEC Note 22/99 [ref. 8] and EEC Note no. 14/2000 [ref. 10] have both already addressed this issue for parts of the simulated area.

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ABBREVIATIONS

Abbreviation	De-Code
APW	Area Proximity Warning
ATFM	Air Traffic Flow Management
AR	Air Routes
ARN	ATS Routes and associated Navigation means
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
BAF	Belgian Air Force
CFL	Cleared Flight Level
COP	Coordination Point
CWP	Controller Working Position
EEC	EUROCONTROL Experimental Centre
EXC	Executive Controller
FDP	Flight Data Processing
FIR	Flight Information Region
FR	Free Routes
FRA	Free Routes Airspace
FRAC	Free Routes Airspace Concept
FRAP	8-States Free Routes Airspace Project
GAT	General Air Traffic
HMI	Human Machine Interface
ISA	Instantaneous Self Assessment
MTCD	Medium Term Conflict Detection
OAT	Operational Air Traffic
OLDI	On-Line Data Interchange
ODS	Operator Display System
PLC	Planner Controller
R&D Areas	Restricted and Danger Areas
RFL	Requested Flight Level
RNLAF	Royal Netherlands Air Force
RVSM	Reduced Vertical Separation Minima
SSR	Secondary Surveillance Radar
STCA	Short Term Conflict Alert
TRA	Temporary Reserved Airspace
UIR	Upper Information Region
XFL	Exit Flight Level

REFERENCES

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2. Eight-States Free Routes Airspace Project EEC Activity Plan Plan ver. 2.0
3. Eight-States Free Routes Airspace Project LRT/North Facility Specification Part 1
4. Eight-States Free Routes Airspace Project MHI specification, LRT/North
5. Eight-States Free Routes Airspace Project LRT/North Controller Handbook
6. FRAP Operational Requirements Document, Part 1, Airspace Management, ver.0.3
7. FRAP Operational Requirements Document, Part 2, Systems, ver. 0.3
8. EEC Note no. 22/1999, FRAP Small-scale Real-time Simulation no. 1
9. EEC Note no. 6/2000, FRAP Small-scale Real-time Simulation no. 2
10. EEC Note no. 14/2000, FRAP Small-scale Real-time Simulation no. 3
11. EEC Note no. 17/2000, FRAP Small-scale Real-time Simulation no. 4

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1. INTRODUCTION

The first Large-scale Real-time Simulation of the Eight-States Free Routes Airspace Concept (FRAC) took place at the EUROCONTROL Experimental Centre between 27th November and 15th December 2000. The simulation was designed to meet the requirements of FRAP to validate the Free Routes Concept (FRAC).

The simulation was the first of two large scale simulations following four small-scale real-time simulations that, together with a number of other activities, are designed to validate FRAC within the airspace of the eight participating states (Belgium, Denmark, Finland, Germany, Luxembourg, The Netherlands, Norway, and Sweden).

Where the small-scale simulations can be regarded as study and development sessions, this simulation is seen as a validation of the Free Routes Airspace Operational Concept with more emphasis on validation than on development. The simulation was based on the upper airspace of parts of Berlin, København, Maastricht, Malmö FIRs/UIR. The airspace structure and sectorisation was based on the outcome of the FRAP Fast-time Simulations, and did not follow the existing FIR/UIR boundaries. It must be noted that this sectorisation is created for validation purposes only, and is not an implementation proposal.

25 civil and military controllers and air defence specialists took part in the simulation that covered the area around Oslo, Gothenburg, Copenhagen, Berlin and Hamburg. Only airspace from Fl285 and up was simulated.

The simulation was based on RVSM, as RVSM is expected to be in place before the implementation of Free Routes. Operational Air Traffic was not considered as RVSM capable.

The simulation used the standard EUROCONTROL Experimental Centre platform comprising OLDI Version 2, System Supported Civil-military Co-ordination and MTCD based on a strip less Human Machine Interface.

The FRAP Human Performance Study was involved in the simulation, and performed a number of measurements related to human performance, such as eye movement tracking and heart rate. The results of this study are published in a separate report. In addition, this simulation was also used to obtain information for the Free Routes Fast-time study and the Safety study.

2. OBJECTIVES AND MEASURES

2.1 OBJECTIVES

The general objective of the LRT-North real-time simulation was to validate the Free Routes Airspace Concept based on the draft FRA ORD during a real-time simulation with several ACCs involved.

More specifically the objectives were to:

1. Validate and optimise the sectorisation derived from the FRAP Fast-time simulation to support the validation of the FRAP concept.

2. Identify the impact on controller workload of the introduction of simple conflict detection.

3. Assess the proposed procedures for entry and exit to/from Free Routes airspace, identify possible problems related to this and propose procedures to overcome these problems.

4. Assess the effect on controller workload, situational awareness, and identify related system requirements, of tactical re-routing around segregated airspace.

5. Analyse the effect of tactical interventions on downstream sectors including the requirements on

   - OLDI/SYSCO
   - Trajectory prediction
   - Flight data distribution
   - Conflict detection

6. Validate the various procedures for handling OAT.

7. Provide support to the following work packages in FRAP, Fast time simulation, Safety Study and Human Resource Study.

2.2 MEASURES

In order to achieve the objectives, the following measures were taken:

Subjective data

- Questionnaires. The controllers were asked to fill in questionnaires before and after the simulation.
- Instantaneous Self Assessment (ISA)
- Debriefings. Controller opinions were collected during the daily debriefings

Objective data

The following data-sets were recorded:

- The number of pilot inputs/controller tactical instructions (level, heading, direct)
- Radio usage (number of calls per aircraft, average length of calls)
- Average flying time per sector
- The percentage of flights cleared to cruise at the level requested in the flight plan

2.2.1 Questionnaires

The participating controllers were asked to decide how much they agreed with a number of statements related to ATC and FRAC, as described in the example below

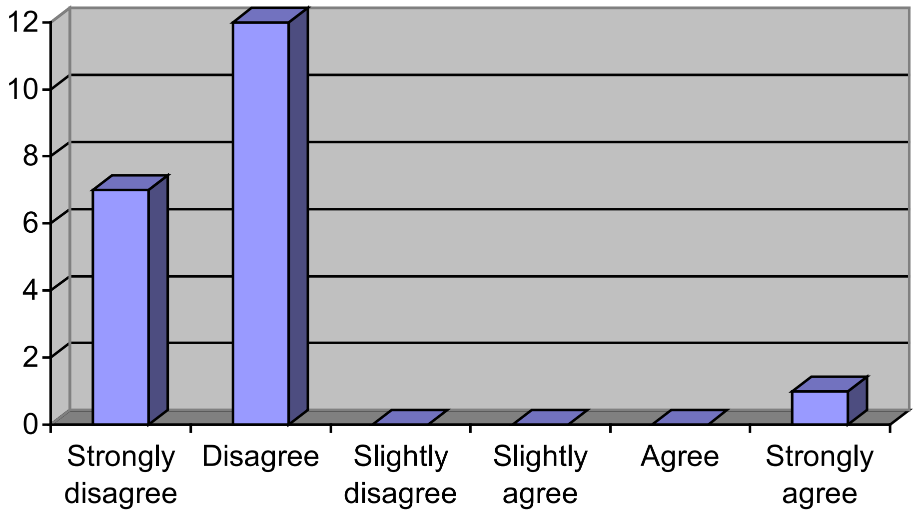


Figure 1: Example question: Control towers should be build higher to give controllers a better view of the surrounding landscape?

In the above example, 7 controllers strongly disagreed, 12 disagreed but 1 strongly agreed with the statement that control towers should be built higher.

Comments given by the controllers in the questionnaires are listed below the subject question.

2.2.2 ISA

ISA stands for Instantaneous Self-Assessment. It is a technique originally developed by DRA Portsmouth Maritime Command and Control and used at the EEC for several years.

Each control position is equipped with a small box containing 5 buttons labelled:

- Very High
- High
- Fair
- Low
- Very Low

At five-minute intervals the controller is prompted by a flashing red light to the button which corresponds to his perceived workload during the previous five minutes. The light flashes for 30 seconds during which time the controller must respond. At each interval a record is written of the button selected and the delay in responding so that by the end of the exercise there is a history of the variation of each controller’s perceived workload.

The main advantage of ISA is its simplicity. The procedure is very simple to explain and administer. The results are usually used to identify busy periods within a sector rather than as an absolute measure of workload.

The principle disadvantages are intrusiveness, especially in simulations involving new HMI, and also the ease with which the results can be 'corrupted' if the participants are not suitably motivated.

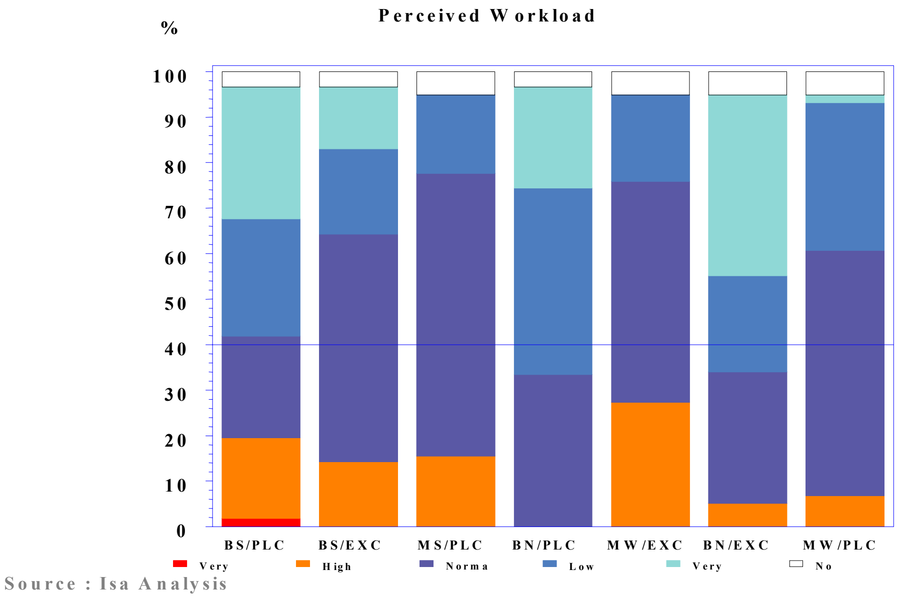


Figure 2: Example of ISA recording

2.2.3 Sample and data collected

24 controllers and one military air defence specialists were involved in this study. Only the 20 controllers working on measured positions used ISA and filled in questionnaires, but all 25 controllers took part in de-briefings. The main characteristics of this group are presented in Table 1 and Figure 3.

Total Sample	20
Male	18
Female	2

Table 1: Sample description

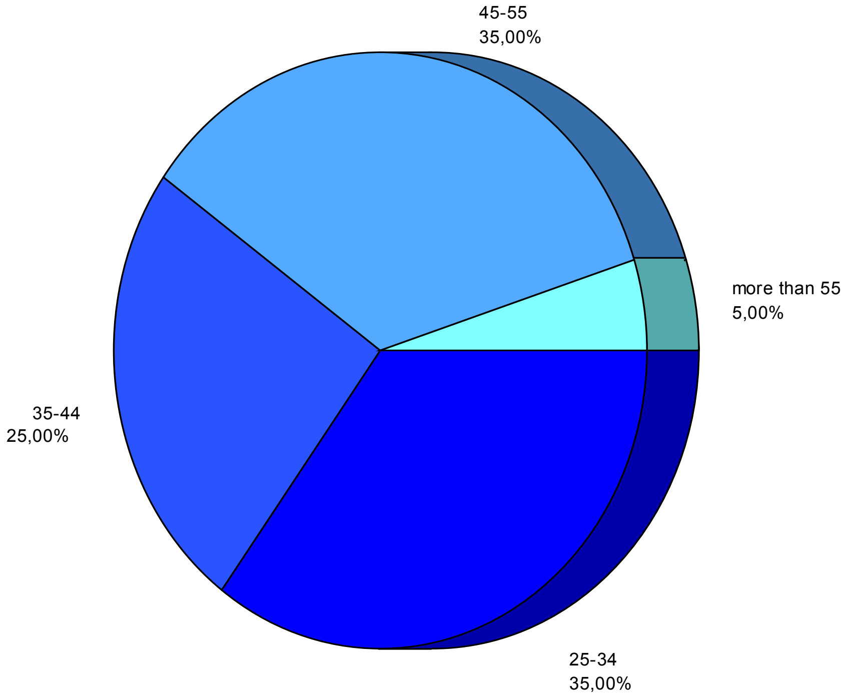


Figure 3: Age distribution, participating controllers

As can be seen, there was a wide and even distribution of ages amongst the participating controllers.

3. SIMULATION CONDUCT

3.1 AIRSPACE

3.1.1 The simulated area

The simulation airspace included of parts of Berlin, København, Maastricht, Malmö and Oslo FIRs/UIR.

In order to create a realistic traffic picture, parts of the surrounding airspace were included in the simulation as feed sectors.

3.1.2 Sector Design Principles

Nine sectors were simulated. The sector design was based on the results of the FRAP Fast-time Simulation.

In the FRAP Fast-time simulation a sector plan was developed for the FRAC validation study. The sector boundaries in this plan are not following UIR/FIR boundaries. All sectors were simulated from FL285 to unlimited

In two of the sectors (HAM and GES), Operational Air Traffic (OAT) was controlled by a dedicated military sector suite, in the remaining 7 sectors OAT was controlled by the civil sector suite. The LIPPE sector was handling OAT in the HAM and GES sectors.

Sector layout, names of the sectors and frequencies used should not be seen as an implementation proposal, but as support to the validation process only.

3.1.3 Operations Room Configuration

The operations room was configured with 25 Controller Working Positions (CWPs). 20 of these CWPs were used for measures.

Measured sectors were as shown in Table 2:

Sector Name	Sector Code	CWPs EXC	CWPs PLC
RAMME	RAM	1	1
VESTA	VES	1	1
ALSIE	ALS	1	1
GEDSER	GES	1	1
BAKKA	BAK	1	1
SVEDA	SVD	1	1
ROENNE	ROE	1	1
FRIEDLAND	FLD	1	1
HAMBURG	HAM	1	1
LIPPE	LIP	1	1

Table 2: Controller Working Position Configuration

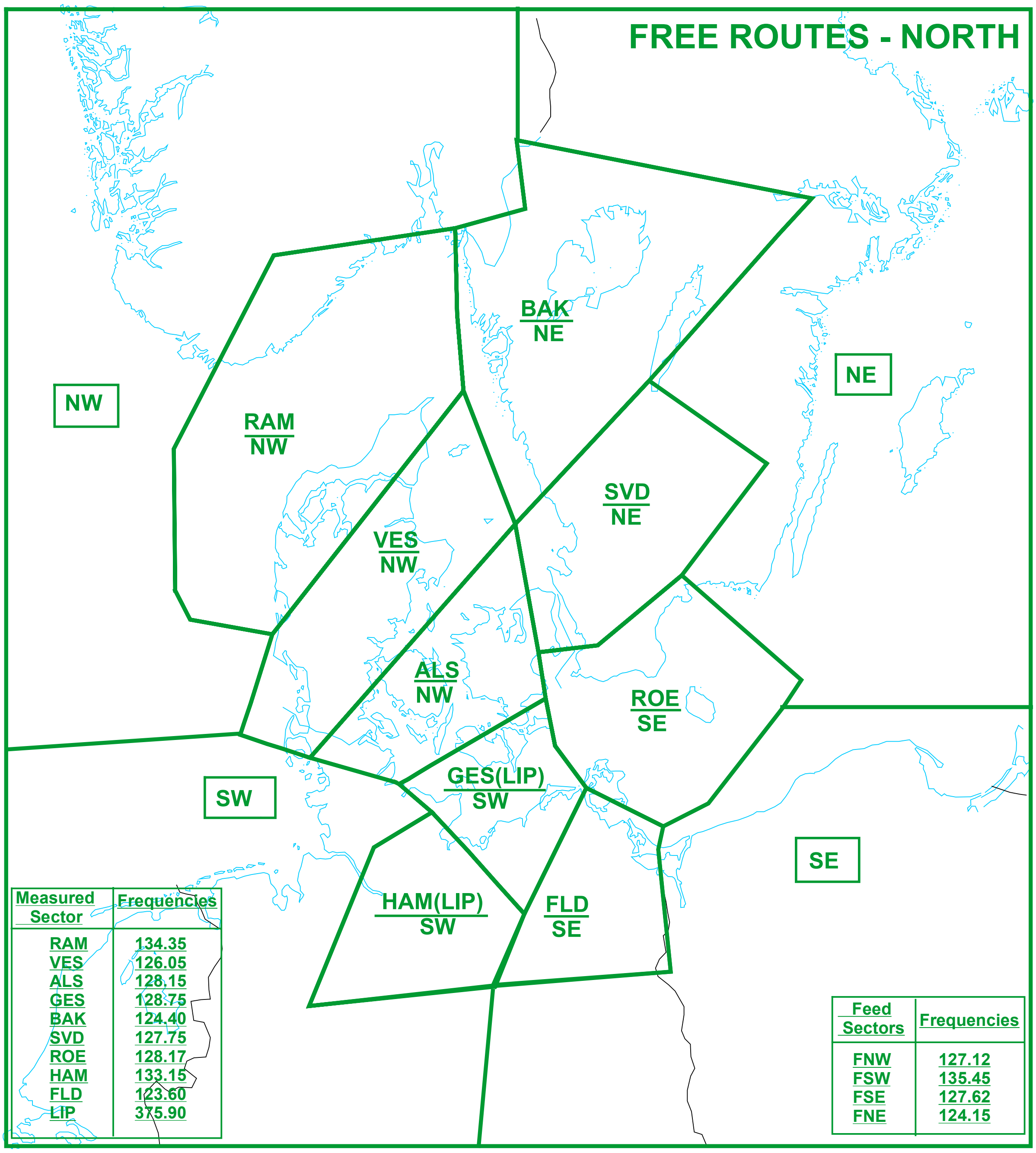


Figure 4: Simulated Airspace

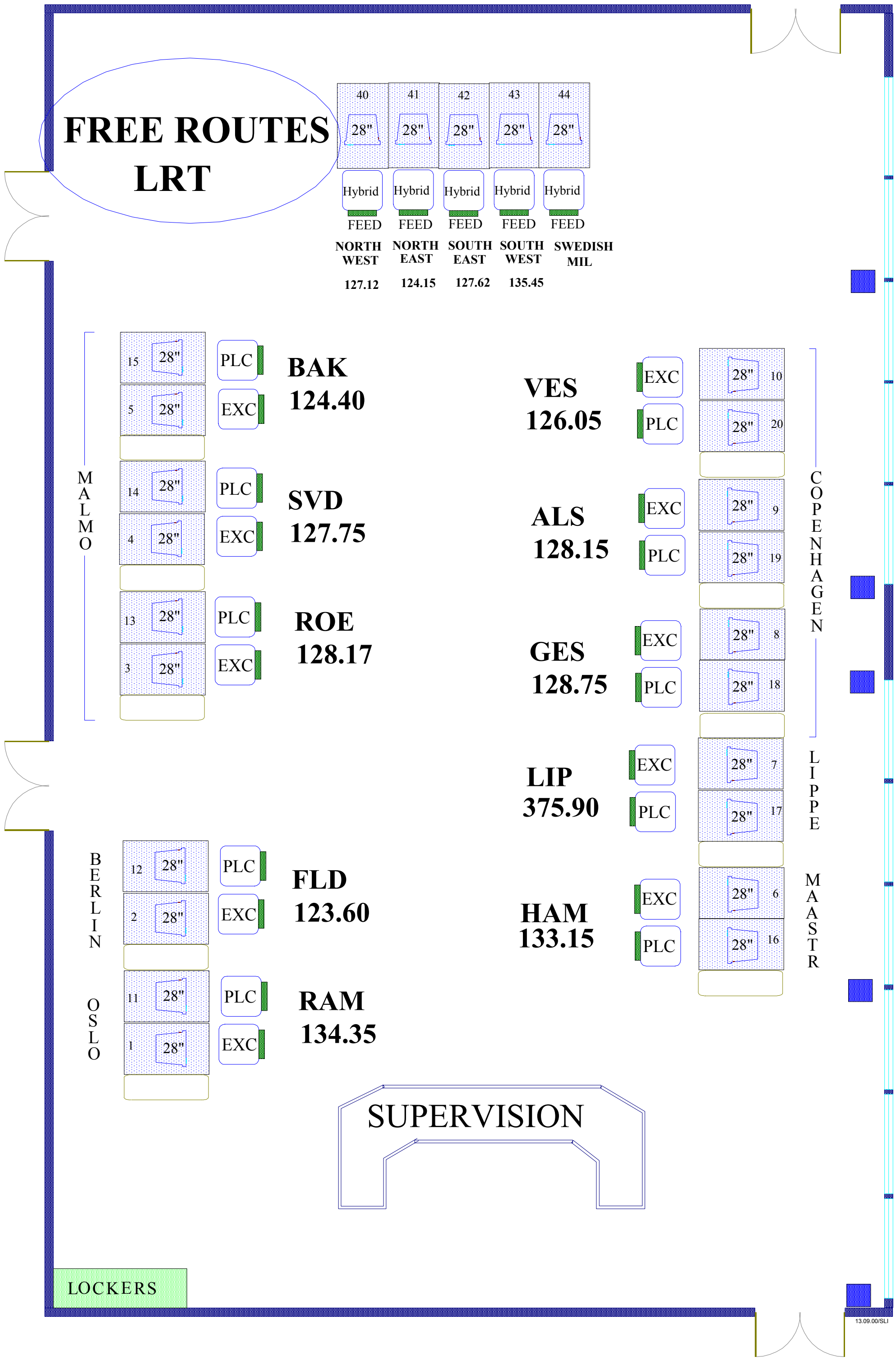


Figure 5: Operations Room Layout.

3.1.4 Route Structure

Military TACAN routes were simulated as they are today. No civil route structure was used during the simulation.

3.1.5 Restricted and Danger Areas and Temporary Segregated Airspace

The following Restricted and Danger Areas were included in the simulation:

Reference	Level
ED - D100	5.500' – 35.000'
ED - D101B	24.500' – 35.000'
ED - D19A	MSL – 40.000'
ED - D28	MSL – 30.000'
ED - D41A	MSL – 45.000'
ED - D41B	5.000' – 45.000'
ED - D44	MSL – 48.000'
ED - D46	MSL – 45.000'
ED - D47A	MSL – 50.000'
ED - D47B	MSL – 50.000'
ED - D47C	700' – 30.000'
ED - R10B	MSL – 40.000'
ED - R11A	MSL – 48.000'
ED - R11B	MSL – 30.000'
ED - TRA302	24.500' – 35.000'
ED - TRA306	24.500' – 35.000'/60.000'
ED - TRA308	24.500' – 35.000'
EK - BR1	MSL – 46.000'
EK - BR2	MSL – 46.000'
EK - D89	MSL – 60.000'
EK - R14	MSL – 45.000'
EN – DELTA	9.500' – 60.000'
EN – FOXTROT	9.500' – 60.000'
ES - S21	MSL – 34.000'
ES - S6	MSL – 46.000'
ES - S91	MSL – 46.000'
ES - S92	MSL – 46.000'

Table 3: Simulated R&D Areas

All areas were designed in accordance with the national AIP's or known plans for future development. Areas were activated and deactivated during simulation exercises in accordance with a schedule agreed with the participating military authorities.

3.2 TRAFFIC

3.2.1 Creation

Civil traffic samples were created from IFPS traffic recordings of 18th June 1999. After the data collection, the traffic samples were analysed and considered to be representative. No unusual ATFM or weather constraints were identified for that particular day. The levels of aircraft were then transformed into RVSM levels, using the guidelines developed by the RVSM project. Finally, the civil traffic was combined with the military traffic samples.

Four base samples were then created corresponding to different periods along the day, to get a realistic picture of the different traffic situations that occur during the day, with traffic levels corresponding to year 2003 forecasts.

Based on the 2003 traffic samples, four samples with an additional 25 % higher traffic level were created to represent a possible future traffic scenario.

Finally, a set of traffic samples with reduced traffic load was created for training purposes, here traffic was reduced to approximately 60% of the 2003 traffic levels.

The number of flights in each traffic sample can be seen in Table 6 below.

Each sample covered a time period of 1 hour 15 minutes, 60 minutes of which was measured for analysis purposes.

Civil traffic was routed directly from the entry point to FRA airspace to the exit point from FRA airspace, however, segregated airspace was circumnavigated by adding additional points to the route in order to simulate a scenario where operators were obliged to flight plan around segregated airspace.

Finally, military traffic was included in the traffic samples.

3.2.2 Traffic Sample Analysis

The analysis of the traffic samples below show the actual simulated load that each sample represented for the simulated measured sectors.

Traffic sample	Time slot
M1	08:10 - 09:10
M2	09:10 – 10:10
A1	13:50 – 14:50
A2	14:50 – 15:00

Table 4: Simulated time slots

	2003 Traffic			2003+ traffic		
Sector	Min. flow pr. hour	Max. flow pr. hour	Peak	Min. flow pr. hour	Max. flow pr. hour	Peak
ALS	36	50	21	49	58	22
BAK	30	36	18	39	56	23
FLD	32	42	18	41	50	19
GES	33	41	13	43	46	14
HAM	36	47	15	54	56	20
RAM	36	46	19	53	64	22
ROE	36	51	18	54	70	25
SVD	33	42	14	52	66	21
VES	40	46	17	52	56	22
LIP	12	16	7	12	16	7

Table 5: Average hourly throughput & instantaneous peaks

3.3 PROGRAM OF EXERCISES

In the Program of Exercises given below, exercises run in the Basic System Scenario are labelled _b, exercises run with MTCD are labelled _m. A description of the system scenarios is included in Para. 3.4.4.

Day/Date	Exercise 1	Exercise 2	Exercise 3
Day 1, 27 Nov.	TRNG	TRNG	TRNG
Day 2, 28 Nov.	TRNG	TRNG	TRNG
Day 3, 29 Nov.	TRNG	TRNG	TRNG
Day 4, 30 Nov.	A2T10	M1T10	M2T10
Day 5, 1 Dec.	A2T10	Lost due technical problem	
Day 6, 4 Dec.	A2T10	Lost due technical problem	
Day 7, 5 dec.	Lost due technical problem		
Day 8, 4 Dec.	A2T10	Lost due technical problem	
Day 9, 7 Dec.	Lost due technical problem		
Day 10, 8 Dec.	Lost due technical problem		
Day 11 11 Dec.	M2T12_b	A1T14_b	A2T14_b
Day 12 12 Dec.	M2T12_m	A1T14_m	A2T14_m
Day 13 13 Dec.	A1T14_m	M1T12_m	M2T12_m
Day 14 14 Dec.	A1T14_b	M1T12_b	M1T12_b
Day 15 15 Dec	M2T12_m	Final de-briefing	

Table 6: Programme of exercises

19 out of 32 planned measured exercises were executed.

3.4 SIMULATED ATC SYSTEM

3.4.1 Controller Working Positions

The Measured Sectors were all manned with two controllers, Executive Controller (EXC) and Planner Controller (PLC), each controller had a separate Controller Working Position (CWP). The CWP consisted of:

- Sony 29' square colour display, used to provide a multi-window working environment;
- Hewlett Packard processor (240/360/3000) and Metheus display driver;
- 3 Button Mouse;
- AUDIOLAN simulation telecommunication system with headset, foot switch and panel-mounted push-to-talk facility.

Each CWP included a subjective workload panel (Instantaneous Self-Assessment – ISA) used by the controller for periodic input (every 5 minutes) during measured exercises.

3.4.2 System Functionality

3.4.2.1 Surveillance

The entire simulated area was covered by radar. In general the vertical limits of radar coverage were from ground to unlimited.

3.4.2.2 Trajectory Prediction

Most of the simulated functionality was supported by Trajectory Prediction (TP). The TP predicts the future position of aircraft based on an aircraft model, constraints build into the simulator flight plan and a set of rules that interpret controller orders.

Longitudinal deviation was corrected automatically by the system.

Due to system problems, Longitudinal Deviation was not always correctly updated - this lead to errors in MTCD for about 10% of the flights.

3.4.2.3 Conformance Monitoring

Lateral deviation between the predicted and the actual position of the aircraft was not corrected automatically by the TP. A Conformance warning was presented for the controller, who then could choose if or when the TP should be updated taking the actual position of the aircraft into consideration.

3.4.2.4 OLDI/SYSCO

Estimates were sent by the preceding sector 9 minutes before the flight time for passing the sector boundary.

Time revisions were passed automatically by the system. Level revisions were passed as OLDI messages after input by the controller. Negotiations possibilities were available in the form of Counterproposal and Reject of level co-ordination messages.

3.4.2.5 Medium Term Conflict Detection

A relatively simple Medium Term Conflict Detection (MTCD) was provided to the controllers. In order to support distribution of task between the PLC and EXC, conflicts were divided into Planning Conflicts or Executive Conflicts

- Conflicts were classified as Planning Conflict if at least one of the flights involved in the conflict was still not under control of the sector.
- Conflicts were classified as Executive Conflict if at least one of the flights involved in the conflict was under control of the sector.
- Conflicts where one aircraft was controlled by the sector and the other aircraft was not under control by the sector was classified Planning Conflict and Executive Conflict.

The PLC received MTCD information about Planning Conflicts via a dedicated window, Conflict and Risk Display (CRD). In the CRD the PLC could select Planning Conflicts only, or all conflicts.

The EXC received MTCD information directly in the data label of the subject aircraft, in order to avoid the need for windows covering parts of the EXC radar picture. EXC could, however, select the CRD if required.

Both controllers could call down additional information about conflicts via:

- The Dynamic Flight Leg (DFL), where DFLs of conflicting aircraft would be shown with a colour coding of the portion of the trajectory where the aircraft were predicted to be in conflict.
- The Vertical Aid Window, that provided a vertical presentation of the conflicting flights and other flights along the trajectory of the subject aircraft.

In the CRD the controllers could choose to see Conflicts and Risks, or Conflicts only.

A Risk is defined as a situation where aircraft are within a defined lateral distance, and where there is an overlap of the level bands Actual Level/Exit Level/Cleared Level of the two aircraft. A Conflict is a Risk where the level bands Actual Level to Cleared Level of the two aircraft are overlapping.

MTCD look-ahead time was set to 15 minutes for Planning Conflicts and 5 Minutes for Executive Conflicts. Only conflicts where the predicted minimum distance between aircraft were 8 NM or less were presented to the controllers.

3.4.2.6 System Supported Civil-Military Coordination

Civil-Military co-ordination enabled civil controllers to request transit of TRA via the data label of the subject flight. After having received a crossing request, the military sector could either accept, reject or counter propose a different crossing level.

3.4.2.7 Safety Nets

Short Term Conflict Alert (STCA) was defined within the radar coverage area, taking into consideration Cleared Flight Level. The look-ahead time was 2 minutes.

3.4.3 Human Machine Interface (HMI)

3.4.3.1. General

Executive Controller (EXC) and Planner Controller (PLC) each had radar windows with colour coding of the data label to indicate the Flight Plan Life State. The data label contained callsign, Mode-C, Entry level (EFL), Cleared level (CFL), Exit level (XFL) and Route elements. Additional information such as heading and speed instructions could be added to the data label.

Flight plan data was presented on a call-down basis for one flight at a time in a dedicated window and in Sector Entry Lists for flights about to enter the sector.

A graphical presentation of the flights planned trajectory was available on a call-down basis.

Input of instructions was performed directly via the data label.

Short Term Conflict Alert (STCA) was activated if two flights were predicted to be within 3,7 NM and 700’ (1700’ for non-RVSM equipped aircraft and above Fl 400) within 1 minute.

3.4.4 Simulated System Scenarios

Two system scenarios were simulated, the **Advanced Scenario** where all the specified functionality was available to the controllers, and the **Basic Scenario** where MTCD was disabled.

3.5 ATC PROCEDURES

Revised Letters of Agreement between the involved ACCs were developed, in order to allow the use of Free Routes.

In general all traffic from airports below or close to the simulated airspace climbed to FL280. Traffic with destination at airports below or close to the simulated airspace was descended to FL290 by the measured sector and transferred to the Feed Sector below, released for further descend.

Levels were in accordance with the RVSM semi-circular rule.

Procedures for Operational Air Traffic were simulated as described below.

3.5.1 Operational Air Traffic

3.5.1.1 General

Apart from the sectors where Lippe Radar controlled OAT, the GAT sectors controlled OAT.

3.5.1.2 Lippe Radar

Lippe Radar is situated within Maastricht UAC, and uses the MADAP System together with Maastricht. All data is shared.

- Lippe Radar can operate OAT under radar control without informing Maastricht about the traffic. In this case Lippe Radar is responsible for maintaining separation to GAT.

- Lippe Radar can ask Maastricht to maintain separation to OAT, a single flight or a corridor.
- Lippe Radar can co-ordinate traffic with Maastricht, agreeing how separation will be maintained between flights, in which case the responsibility for maintaining separation is as agreed in the co-ordination

In this simulation Lippe Radar controlled OAT within the HAM and GES Sectors. Procedures similar to those for with Maastricht were established with the GES Sector.

3.5.1.3 Temporary Reserved Airspace

Depending on the activity within the TRA, civil flights were accepted through the TRA. This transit was done on a case-by-case basis using the System Supported Civil Military Co-ordination functionality or telephone.

Lippe Radar was the co-ordinating partner for areas in German airspace. A Swedish Air Force representative was the co-ordinating partner for TRAs with Danish, Norwegian and Swedish airspace.

The TRAs were simulated as they exist today.

3.6 SIMULATION LIMITATIONS

Due to network problems, only 19 of 30 planned simulations were executed. The simulation results are therefore based on less material than foreseen.

The TP problems described in Paragraph 3.4.2.2 lead to unreliable MTCD information for about 10% of the simulated flights.

High system load occasionally resulted in some delays in system response when inputting data.

4. CONTROLLER TRAINING

Sixteen of the participating controllers received five days training combined with the simulation test week. The program of the training week included theoretical lessons on HMI and system related matters as well as issues related to the Free Routes concept and the use of RVSM. After each theoretical lesson, the controllers trained on the simulation platform. The last two days of the week were used entirely to run simulated traffic at increasing traffic levels.

The remaining 9 controllers received an identical training program during the first 3 days of the simulation period. Only 3 of the 9 controllers had never worked on a similar simulated system.

The simulation of the feed sectors was considered by the controllers to be adequate .

Some of the controllers slightly disagree with the statement that the traffic was simulated in a realistic way. This was mainly due to problems simulating military traffic, especially the lack of capability to simulate changeover from OAT status to GAT status, a procedure that is used in the simulated area for particular routes.

5. RESULTS

As described in Paragraph 2.2, results are derived from three different sources

- System recordings, data recorded by the simulator system, e.g. radio usage
- Questionnaires, controllers working on measured sectors were asked to fill in a questionnaire at the end of the simulation
- De-briefings, verbal information derived during discussions with the participating controllers

For each objective, results are listed under these three headings, followed by a discussion to sum up the findings for the particular objective.

5.1 GENERAL FINDINGS

5.1.1 Questionnaires

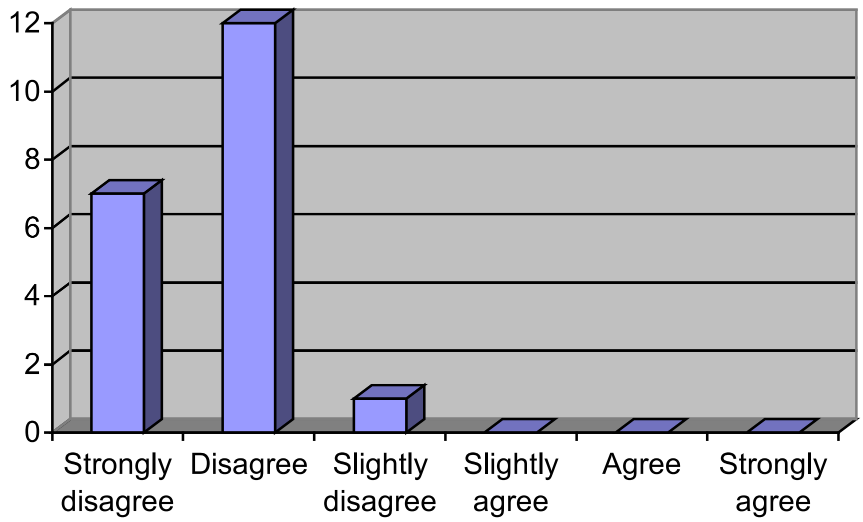


Figure 6: Question 1.1: The Concept of Operations for FRA is difficult to understand?

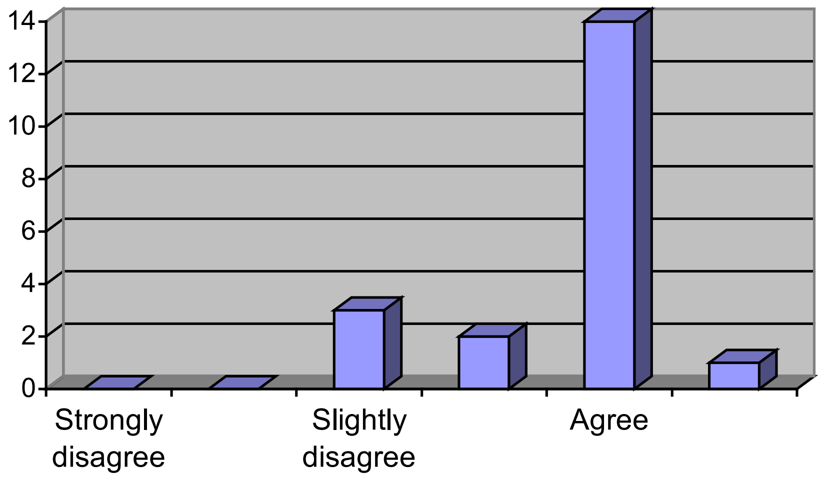


Figure 7: Question 1.2: The FRA procedures are easy to work with?

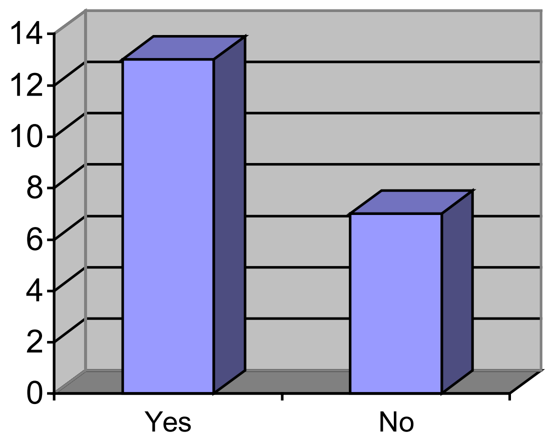


Figure 8: Question 1.3: Do you think that the way you work as a controller will change in FRA, will you get new or changed tasks?

Additional comments to Question 1.3:

- *There are no safe parallel routes , a level change requires a close look at the traffic situation where opposite traffic may be conflicting As planner it's more difficult to help when the traffic load is high*
- *Work for planner will change more to a second, you might even say primary, radar controller. You will need a planner controller more often than the situation today*
- *The work will be more tactical*
- *Monitoring and establishing flows for climb*
- *Descent on a tactical tasks, coordinating with mil*
- *From the OAT point of view FRA will increase the workload*

- *I will need a planner*
- *This is related with the new tools and the lack of strips and not so much with FRAP, the planner task will change.*
- *The strip system as we know it will have to be abolished, better tools for the planner are necessary*
- *EXC will be more tactical, you need a clear distribution of tasks between EXC and PLC*

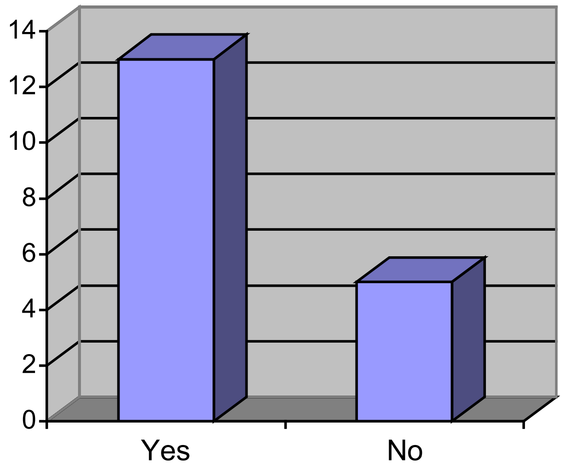


Figure 9: Question 1.4: Do you feel that the task distribution between PLC and EXC will change in FRA?

Additional comments to question 1.4:

- *Not in Maastricht, in general for most other centres I think there will be major changes.*
- *planner work will be more tactical as the workload increases*
- *not much, but the planner will probably working more tactically than today*
- *planner doing more monitoring of the radar screen*
- *the planner is acting as a second exe*
- *PLC will have to assist the EXE more and more while his former role has to be done by automatic systems which have to work very reliably*
- *the planner will need a radar picture*
- *the planner will be working on the radar scope instead of stripboard*

What is your overall impression of FRAC:

- *For the time I don't see an implementation due to loads of factors (political, different systems, etc.)*
- *It can work in real life but there is still a long way to go*
- *I'm totally in favor free route as from experience at MAAS UAC it will enable you to handle more traffic and it saves aircraft fuel and time*
- *In free route it's more difficult to foresee conflicts. An MTCD that is reliable and easy to understand is essential*
- *during military exercise time, I feel that gains from the concept to the airliners will generate a increase of workload and have effect on the safety, but during evenings and weekends it will be a good concept.*

- *I like it, I think it's feasible, I think everybody is able to work with this concept*
- *A lot of problems have to be fixed to be able to work in a safe way*
- *It will work, although it's a bit odd that when we get a lot of traffic in a TMA the normal solution is to have the traffic in fixed patterns*
- *I cannot imagine that it is implemented without a better preplanning of TSA etc.*
- *It will help to cope with the requirement in ATC over the next years provided that at least 5 states will be involved.*
- *A workable concept that should be implemented*
- *A good idea although it will increase workload on controllers unless serious attention is paid to airspace design*
- *no big chance from today*

5.1.2 Discussion

The general impression amongst the controllers participating in the simulation is that FRA could be implemented in the simulated airspace without major difficulties, provided that a number of added system requirements are put in place, procedures are adjusted to FRA, and the airspace is redesigned in accordance with Free Routes traffic flows. As can be seen from Question 1.1 and 1.2, controllers do not find it difficult to understand and work with the FRA concept.

It is clear from the simulation that FRA will change the controller's tasks. It is more difficult for the PLC to foresee and solve conflicts in the medium term, even with support from the system. This adds to the EXC workload.

The PLC often sees himself as a second EXC, it is difficult to work ahead, a keep in front of real-time, as it is normally required for a PLC. It is not clear whether this is a result of FRA only, or a combination of FRA, RVSM and the higher traffic load.

Conflicts are detected later than when operating in fixed routes, leaving less time to solve conflicts in an orderly way. It all became more tactical and strategic planning decisions were rare. This calls for a correctly functioning MTCD.

Similar results have been seen in other simulations using stripless HMI, but strip based systems are considered unsuitable for FRA (See EEC Note 21/99, 1st Small Scale Free Route Real-time Simulation) and for predicted future traffic levels.

Capacity and controller workload was not the objective for this simulation, however the perception amongst the participating was that workload would remain unchanged with no or low military activity, and increase with high military activity, compared to today's situation with widespread use of direct tracks.

Co-ordination with military requires more effort in FRA than in Fixed Routes. This is an inevitable result of the concept.

5.2 OBJECTIVE 1

Validate and optimise the sectorisation derived from the FRAP Fast-time simulation to support the validation of the FRAP concept

5.2.1 Questionnaires

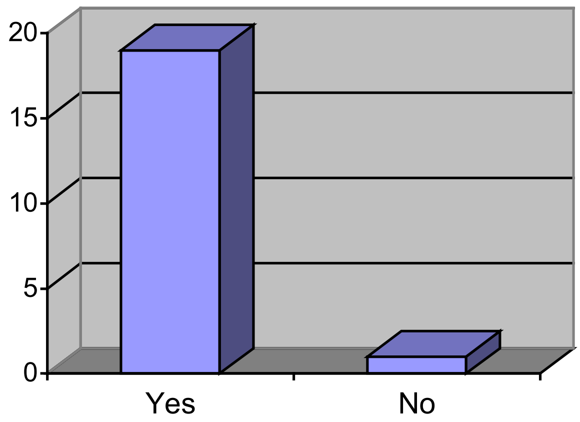


Figure 10: Question 2.1: Did you experience any problem with the simulated sectorisation?

Additional comments made in relation to this question:

- *Sector layout not coincident with traffic, too many boundary cases like crossings at the edge of the sector*
- *The HAM sector was too small compared to the reality*
- *Traffic just affecting a corner of sector and along borders*
- *Exit points was on the border of 2 sectors*
- *Flights flying very close to the border of the sector and crossing the sector for just a few miles*
- *Many aircraft are only scratching the sectors, we had too much corner cutting*
- *Sectors were not optimised for traffic with vertical movements*
- *BAK sector is too big*
- *VES sector to big*

What sort of modification would you like to see?

- *Create sectors which have their conflicts area more in the center when possible*
- *Cut the NE corner of BAK sector*
- *The main traffic flow has to be subject for intensive and more careful studies*
- *smaller sector*
- *FLD sector within the limits of Berlin sector today, less coordination; traffic flow not along boundaries, no short term transfer and no unnecessary frequency changes*
- *The problem with corner cutting will always be there but a good skip function and a presentation to the next sector would be a must*
- *VES sector needs to be separated in 2 sectors*

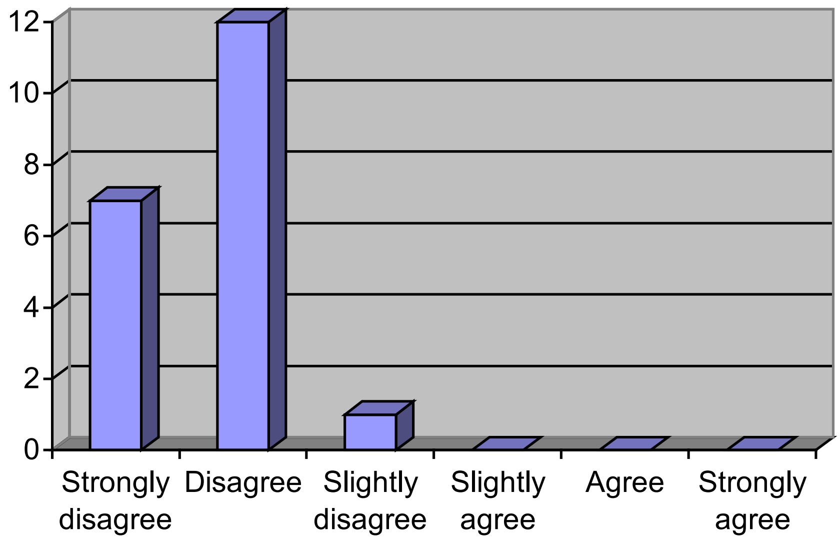


Figure 11: Question 2.2: Handling a mixture of FRA and non-FRA flights is confusing

5.2.2 De-briefings

The sector layout should to the extent possible reduce flights re-entering sectors in order to reduce workload.

Segregated airspace should be placed well within sector boundaries, so that they can be circumnavigated without entering neighbouring sectors, or shall be placed at sector boundaries, so that most circumnavigation will take place within a single sector

Sector layout should follow traffic stream not FIR boundaries.

Sectors should respect the practical limitations for presentations, e.g. not be to long.

5.2.3 Discussion

The sector layout should to the extent possible reduce flights re-entering sectors. Re-entering flights add to the EXC workload in terms of frequency changes and mental situational updates, it adds to the PLC workload in terms of added co-ordination.

In addition to workload issues, functionality used also has difficulties supporting flights with multiple entries and exits from a sector or ACC. This becomes clear when an aircraft has two different entries at different times and different levels co-ordinated with different co-ordination partners. This is a logical problem, that can be solved, but it is not clear how the information would be presented and accessed with the modern HMI. This caused problems during the simulation and the simulator was not able to cope. It is likely that real ATC systems will have the same or even more severe problems handling these situations.

Segregated airspace adds workload, either to co-ordinate through or to circumnavigate. It becomes really demanding if circumnavigation brings the aircraft into another sector, or worse still, another FIR, where flight plan data is not available.

Some areas extend from lower airspace to above Fl 285. It is expected that the military partner would insist on having the same design of the area in the entire level band. This means that areas that are kept clear of ATS-routes in lower airspace will often be situated in conflict with the FRA traffic flow.

Figures 12 and 13 show two possible layouts that would reduce this problem. Figure 14 shows the worst case, where workload is added not only to the subject sector, but also to neighbouring sectors.

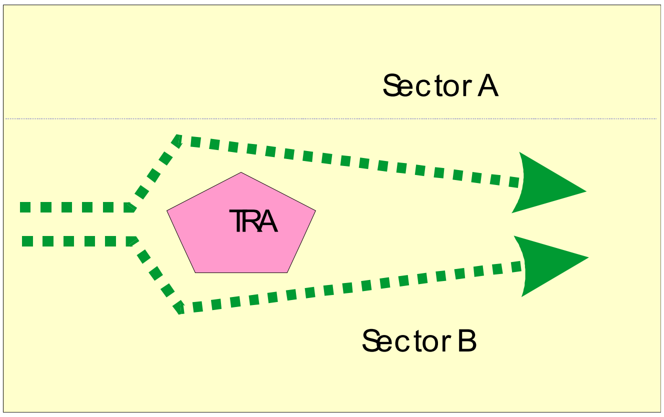


Figure 12: Sector Design, Military airspace/1

Traffic can be vectored around the TRA in Sector B without entering sector A.

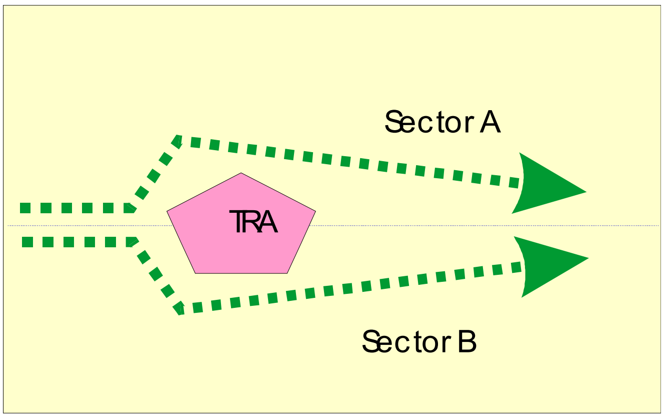


Figure 13: Sector Design, Military airspace/2

Traffic can be vectored around the TRA in Sector A and B without crossing the sector boundary.

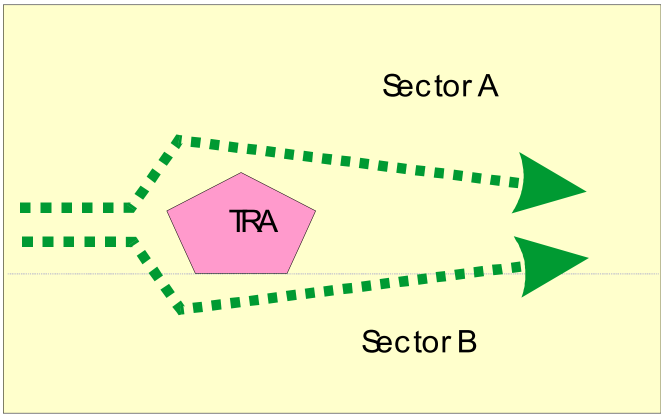


Figure 14: Sector Design, Military airspace/3

In order to fly the shortest way around the TRA, traffic in Sector A will have to enter Sector B, adding workload to the two sectors.

In today's airspace sectors and procedures are, amongst other things, designed in accordance with the route structure in order to:

- Distribute workload between sectors
- Reduce the number of sector crossing
- Avoid conflicts between aircraft at, or close to, sector boundaries

In FRA we have no means to control this. Operators are allowed to file preferred routes. As a consequence of this sectors will have to be designed in accordance with traffic flows in order to avoid added workload and to distribute workload evenly.

Not all sector shapes are optimal in FRA. Especially the problem with re-entering flights will have to be addressed carefully. Figures 15-18 show a number of possible designs, together with the problems related to each design. Main traffic flow is Northeast-Southwest in all examples.

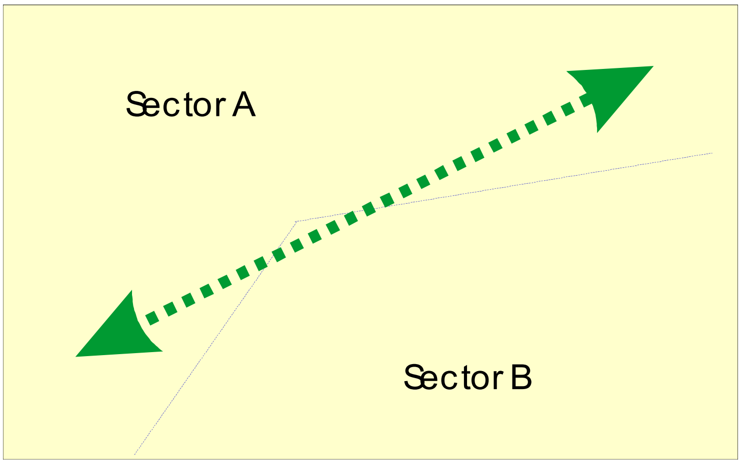


Figure 15: Sector design/1

The design of Sector B, as shown in Fig. 12 leads to re-entering of flights in Sector A, sometimes with only a seconds of flying time in Sector B. Small lateral deviations to the tracks will determine whether sector B is in the sector sequence or not. A layout like this was part of the simulated airspace, based on the Free Routes Fast-time Simulation, but had to be changed during the simulation Acceptance Test in order to reduce controller workload, and avoid system errors. This layout should be avoided.

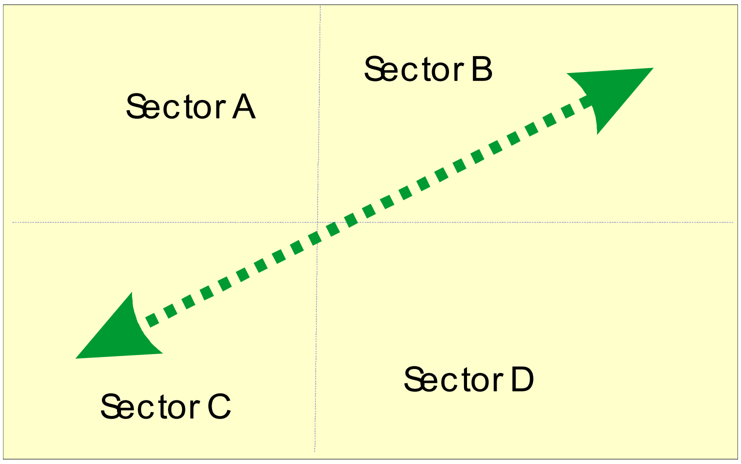


Figure 16: Sector design/2

Fig. 16 shows an example where 4 sectors can be involved in one co-ordination. This lay-out should be avoided.

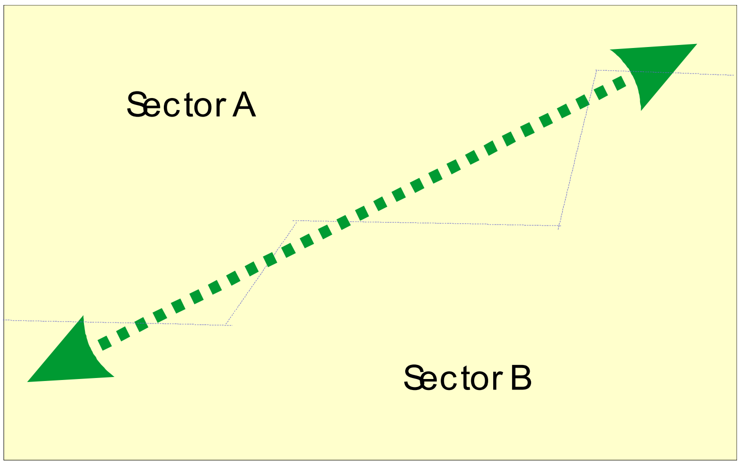


Figure 17: Sector design/3

FIR boundaries often follow the State boundaries. This leads to sector shapes as shown in Fig. 17. In a Fixed Routes environment this has little or no effect, but in FRA this will lead to situations that cannot be supported by the ATC system. It is important that sectors are designed based on traffic flows and not on FIR

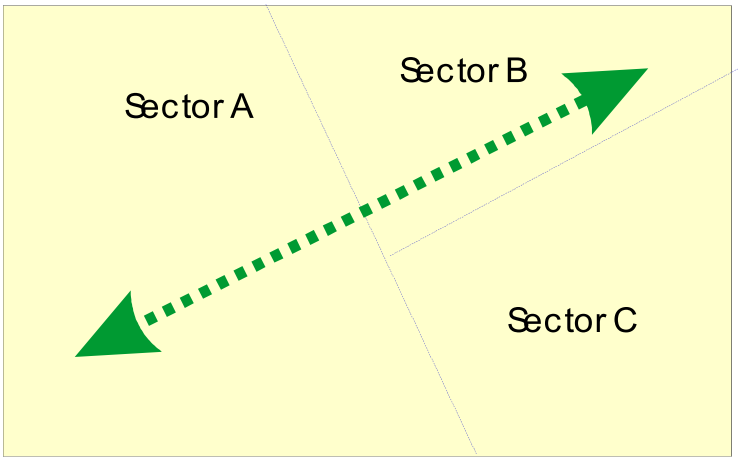


Figure 18: Sector design/4

Based on the experiences from the simulation, the three sectors shown in Fig. 18 have an optimum layout with regard to problem of re-entering flights. In addition to these basic considerations, it will be necessary to consider local constraints, military airspace etc.

The sectorisation used during the simulation was based on a Fast-time simulation, where only a brief discussion of sector design took place, and without any real-time simulation experience. This is clearly reflected in the questionnaire comments. It is recommended that a fast-time simulation be conducted focussed on implementation early in a possible FRAP Implementation Phase.

Another issues to be considered when designing sectors is that modern radar displays are square. Designing around traffic streams may suggest long narrow sectors. If they became too long, however, space would be wasted on the screen, and the required range setting to display the entire sector plus a buffer would become a problem for the controller.

5.3 OBJECTIVE 2

Identify the impact on controller workload of the introduction of simple conflict detection

5.3.1 Recordings

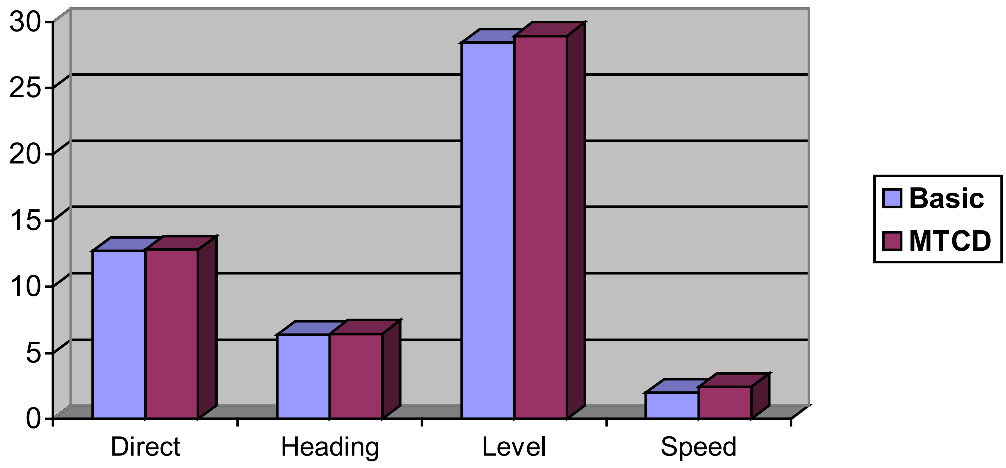


Figure 19: No. of pilot inputs, average for all measured sectors.

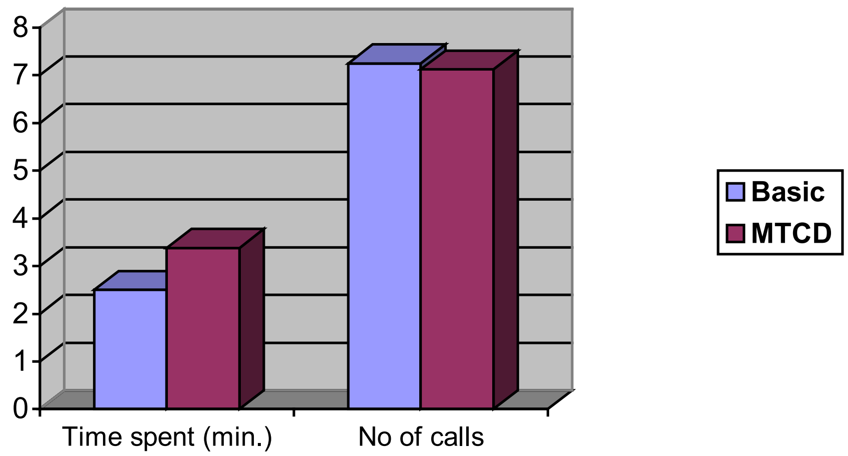


Figure 20: Frequency usage

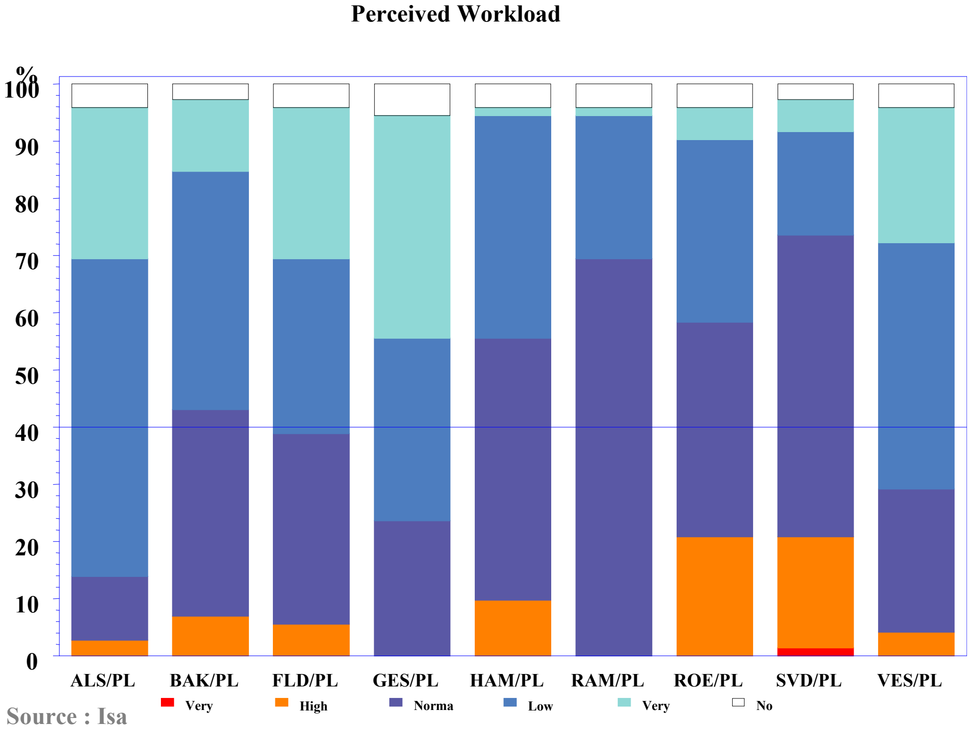


Figure 21: Perceived workload PLCs, Without MTCD

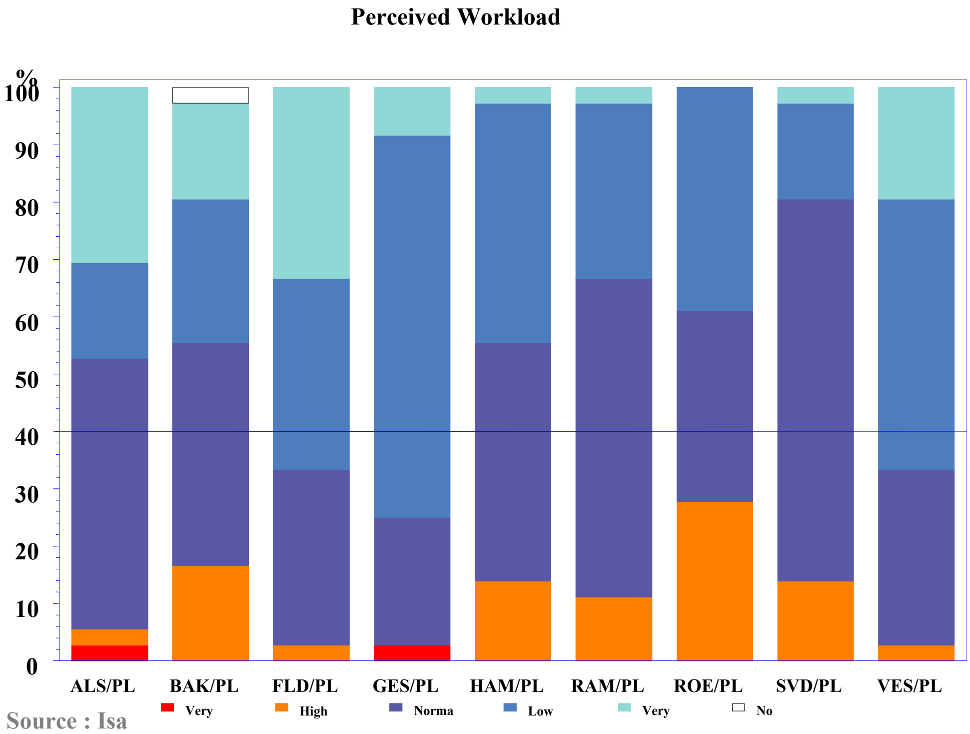


Figure 22: Perceived workload PLCs, With MTCD

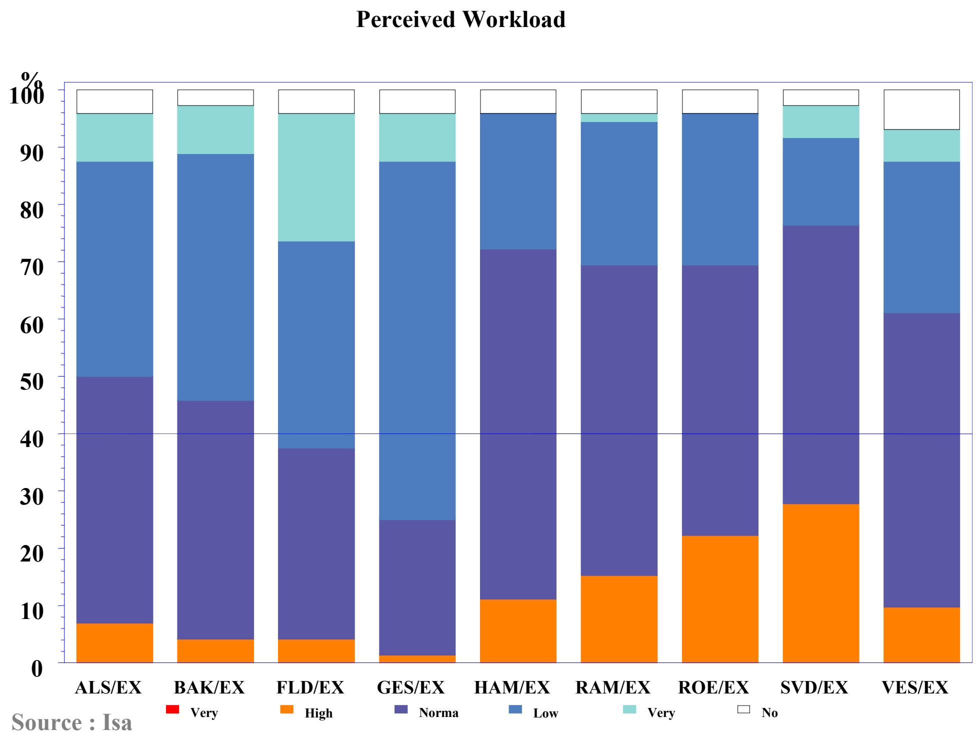


Figure 23, Perceived workload EXC, without MTCD

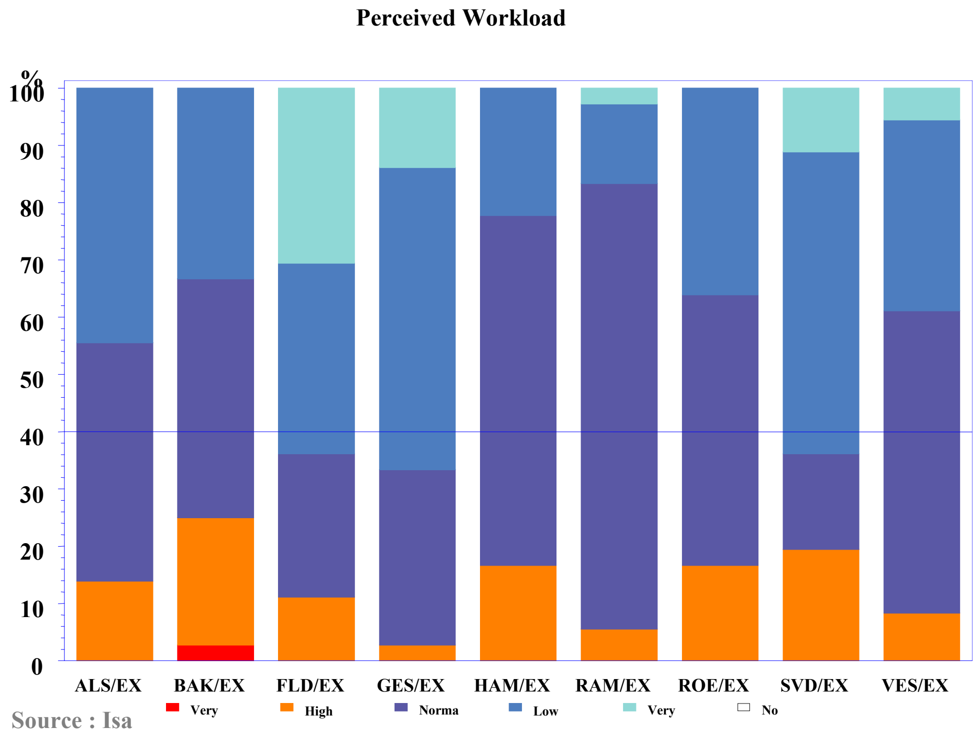


Figure 24: Perceived workload EXCs, with MTCD

5.3.2 Questionnaires

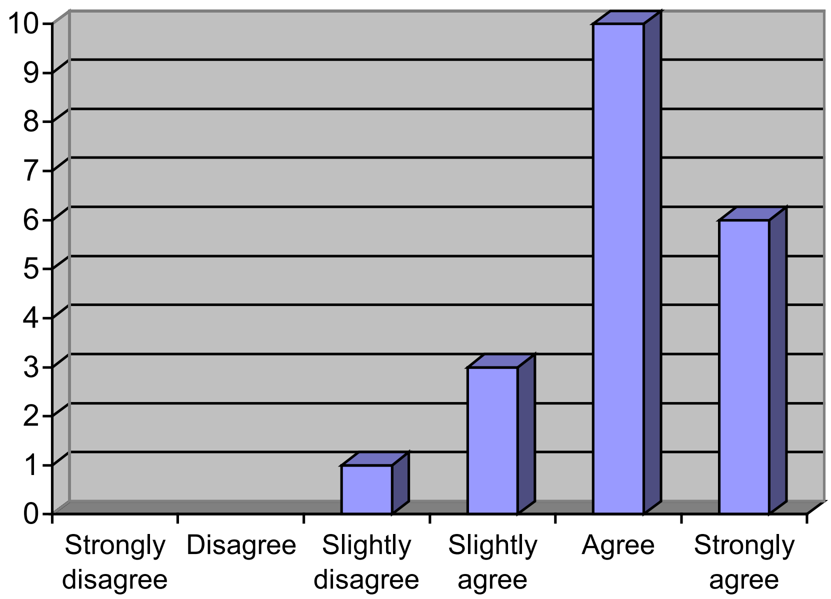


Figure 25: Question 3.1: It requires more attention to work traffic in FRA?

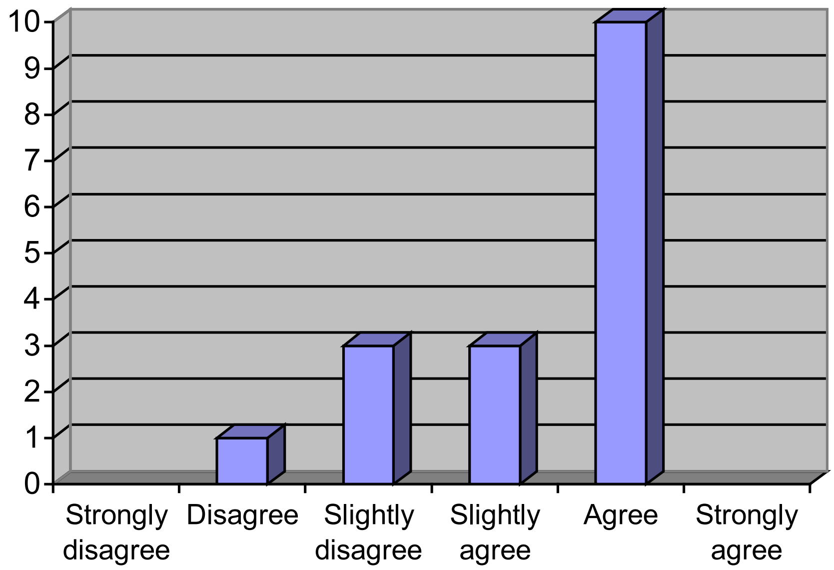


Figure 26: Question 3.2: FRA will require a re-distribution of tasks within the controller team?

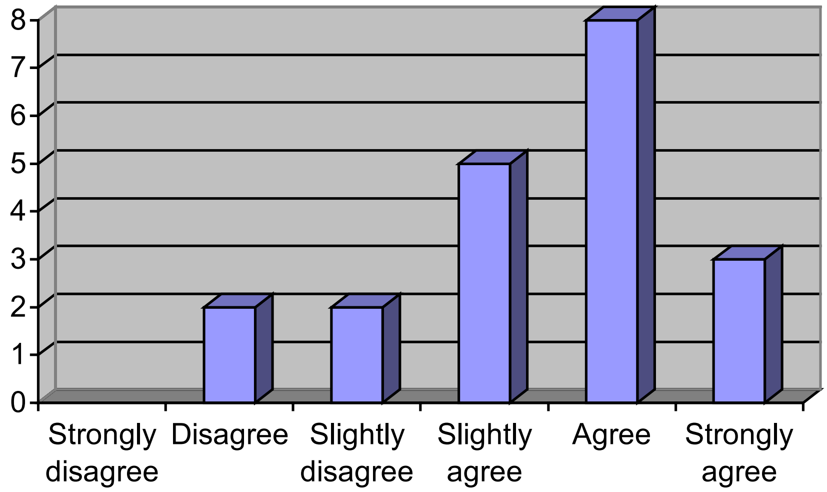


Figure 27: Question 3.3: Conflict solving becomes more tactical in FRA, it is difficult for the PLC to foresee conflicts?

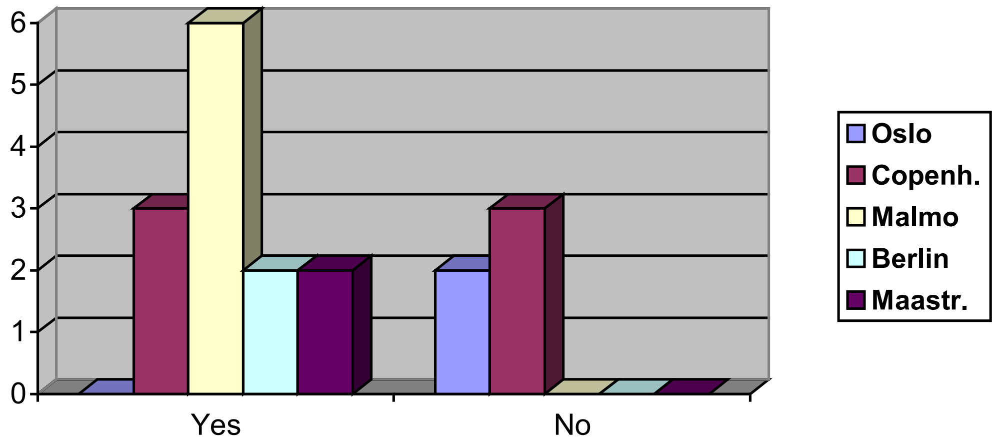


Figure 28: Question 3.4: Do you think a well functioning MTCD will be required in order to introduce FRA in the ACC where you normally work?

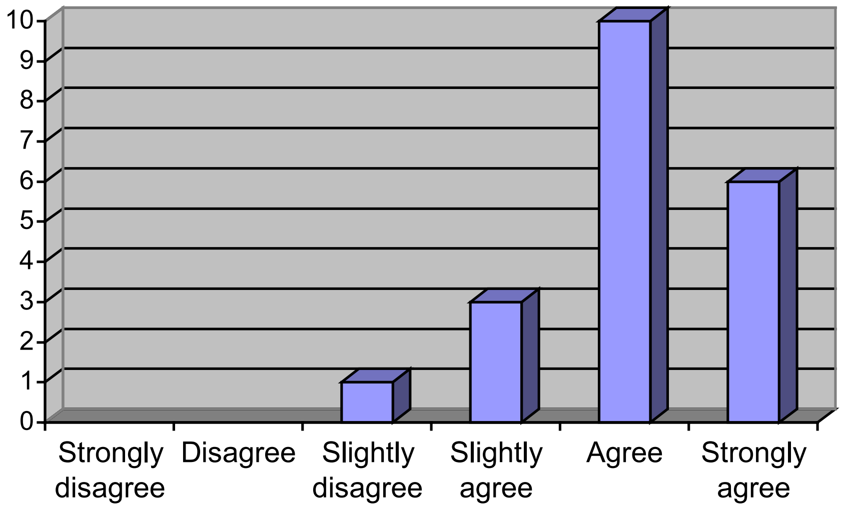


Figure 29: Question 3.5: It requires more attention to monitor traffic in FRA?

5.3.3 De-briefings

MTCD information required a buffer around the sector as well, as many conflicts occurred close to the sector boundary.

No MTCD information is better than wrong or missing information. The quality of the information presented during the simulation was not good - there were too many wrong or missing conflicts.

5.3.4 Discussion

The simulation was set up to answer the question whether MTCD is an enabler for FRA or not. It has to be said that the quality of the MTCD was less than 100%. It is estimated that about 90% of the conflicts were presented for the controllers in a correct way. The participating controllers considered that inadequate. This is worth bearing in mind when looking towards implementation of MTCD in real systems. In fact several controllers considered the MTCD a nuisance rather than help.

The logic behind the MTCD was rather simple, and did not take the rate of climb of aircraft into consideration like the MTCD developed by EATMP, however as the simulation was upper airspace only, this had a limited effect.

Question 3.1 indicates a clear controller perception that there is a need for system support to the controller to perform the monitoring tasks. This can be in the form of MTCD, Area Proximity Warning (APW) or Conformance Monitoring. In earlier simulations it was concluded that the need for system support to the monitoring task would arise at a lower traffic level in FRA than elsewhere.

The shift of workload towards the tactical side is a problem for FRAC, the tactical side is already the bottleneck in today's environment. This picture may change with the first implementation of Air ground data link, but that is not foreseen before the planned implementation of FRA.

Question 3.4 gives a clear picture of where MTCD is needed. In Oslo the traffic density is still fairly low, the monitoring task can be performed without system support. In the other simulated ACC's MTCD should be considered as an enabler for FRA.

The number of pilot orders can be used to express the EXC workload related to conflict resolution. As seen in Figure 19, no reduction in workload can be identified. The same applies for the PLC looking at the number and duration of radio transmissions (Figure 20). This is supported by Figures 21-24, ISA recordings, where no significant difference can be seen between the two scenarios Basic and MTCD. The conclusion is that no reduction of workload has been identified.

The tables showing perceived workload show now difference between the conditions with MTCD and without MTCD.

It must be remembered that this is based on an MTCD not working 100% correctly. The general feeling amongst most of the controllers was that MTCD would be required in order to identify all conflicts in due time. It is also clear that the EXC is becoming the bottleneck as the work is becoming more and more tactical. I way to offload the EXC by enabling the PLC to provide an efficient support is essential.

Further work aiming at developing the MTCD for FRA focusing on moving workload from the EXC to the PLC should be undertaken.

5.4 OBJECTIVE 3

Assess the proposed procedures for entry and exit to/from Free Routes airspace, identify possible problems related to this and propose procedures to overcome these problems.

5.4.1 Questionnaires

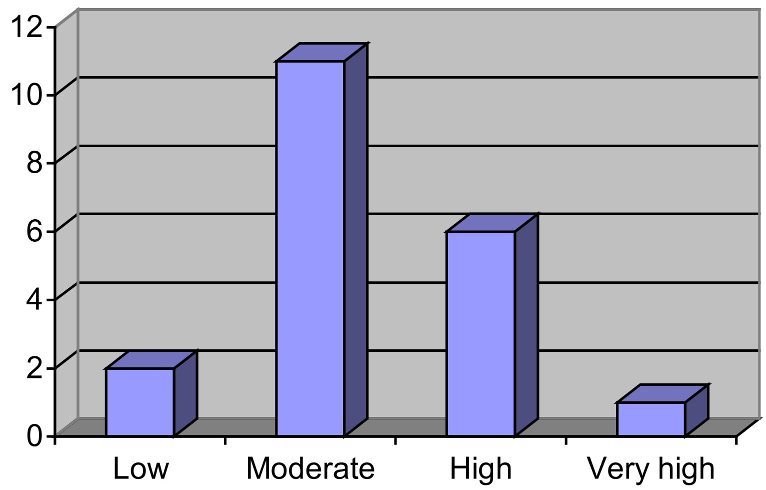


Figure 30: Question 4.1: Dealing with traffic at entry/exit points to/from FRA airspace, e.g. descending towards airports, how would you rate your work devoted to this?

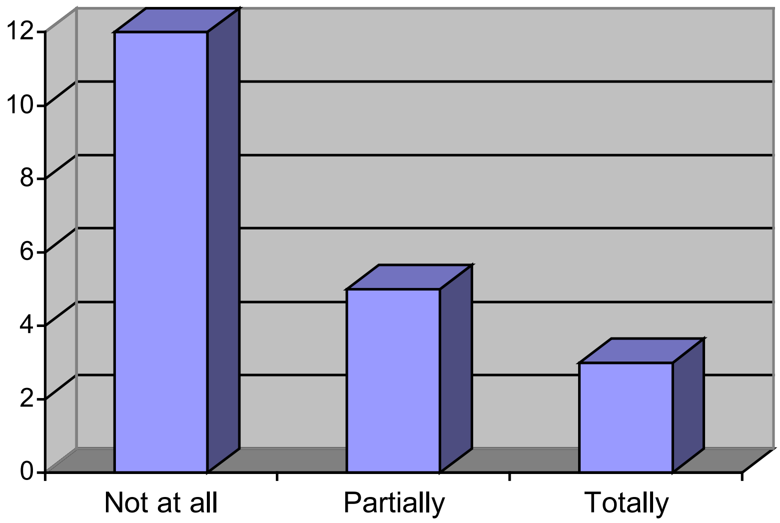


Figure 31: Question 4.2: Do you think it is more difficult to assure separation on entry/exit points in FRA compared to non-FRA?

The following comments were added to these questions:

- ♦ BAK sector, traffic inbound ESSA and departing ESSB southbound in conflict. Traffic in and out of Oslo via PENOR gave conflicts
- ♦ Inbound and outbound tracks should be separated using parallel routes or procedures for level separation should be established
- ♦ Place entry and exit points further from the airport

5.4.2 De-briefings

Entry and exit points are to close to the airports. This creates many conflicts between arriving and departing aircraft in the climb/descend phase.

Entry and exit points should be well separated, so that climb and descend sectors can be created.

Traffic from lower airspace shall only climb to the bottom of FRA without prior co-ordination

Sequencing is easier when aircraft are flying on the same track. Traffic should be in the route structure before the sequencing process starts.

5.4.3 Discussion

The Outcome of FRAP Rapid Prototyping suggested that Entry/Exit points should be 80NM to 100Nm from the subject airport. In this simulation the points were in general 60NM from the airports.

It was suggested during de-briefings that the optimum design would have Entry/Exit points very close the normal Top of Descend/Top of Climb points, in order to maintain traffic in the route structure during the climb and descend phases.

It is important that entry and exit points are well separated to avoid inbound and outbound traffic flying in the same direction during climb and descend. This corresponds to the findings from Rapid Prototyping.

At the same time this will bring traffic onto the same track during the sequencing, another issue raised during debriefings.

In line with the outcome of previous simulation, procedures used today around several airports i.e. that the lower sector climbs departing traffic to RFL was changed. Flights were climbed to Fl. 280 only. It was agreed that this was necessary, as climbing traffic is more frequently in conflict with overflying traffic in FRA.

Apart from this, the transition phase to/from lower airspace is not considered more difficult in FRA than in today's environment.

5.5 OBJECTIVE 4

Assess the effect on controller workload, situational awareness, and identify related system requirements, of tactical re-routing around segregated airspace.

5.5.1 Questionnaires

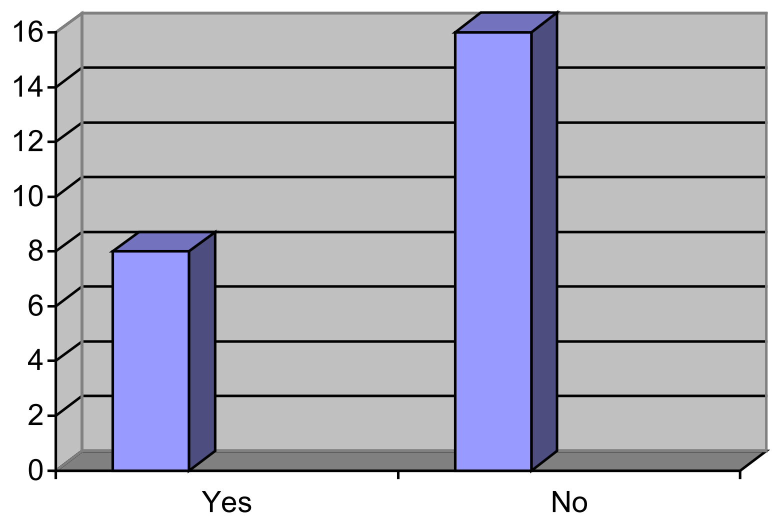


Figure 32: Question 5.1: Would you prefer that the flight plans were direct from FRA entry to exit, leaving conflicts with segregated airspace as a task to you?

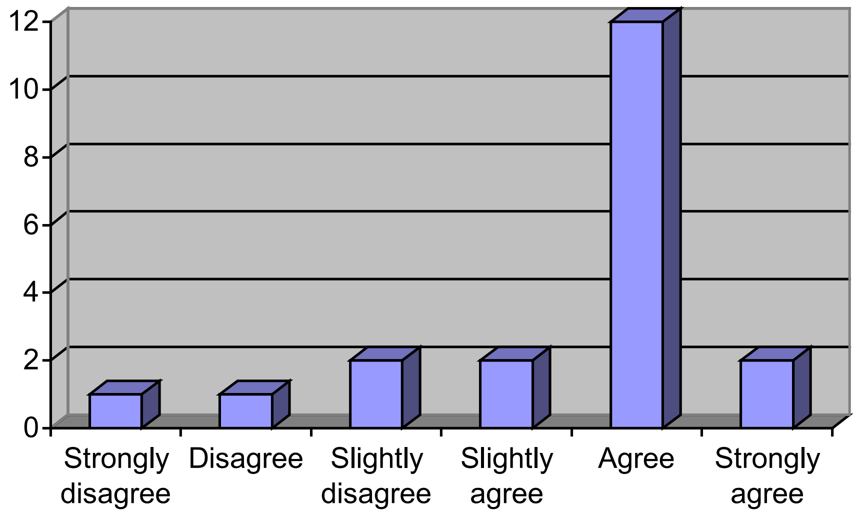


Figure 33: Question 4.2: Activation of segregated airspace has a bigger impact on capacity in FRA than in non-FRA?

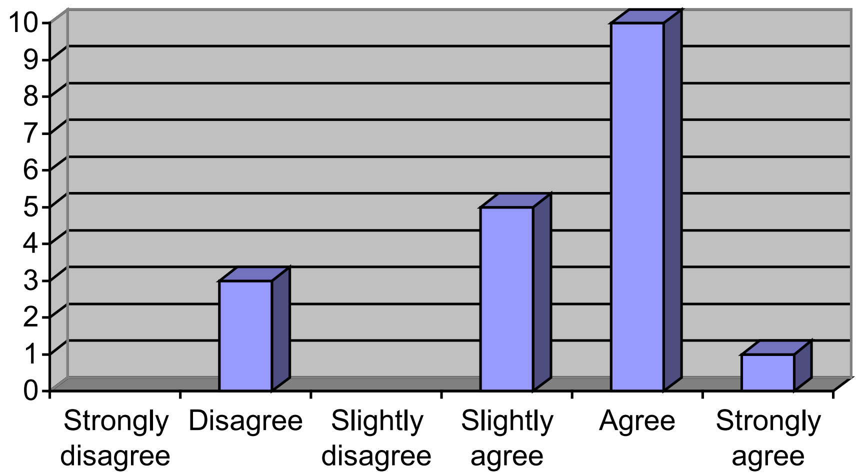


Figure 34: Question 4.3: In FRA it is not always clear why aircraft choose to fly their particular route?

5.5.2 De-briefings

- It is often difficult to find out why a particular point is on the flightplan.
- Points should be established around segregated airspace to ease the tactical task of re-routing aircraft. This would make it easier to explain the new route to the pilot, and enable the controller to issue a new route instead of having to keep the aircraft on headings.
- It is doubtful if sufficiently high quality of environmental date can be provided to operators enabling them to submit correct flightplans with regard to avoidance of active segregated airspace.

5.5.3 Discussion

It seems to be a requirement that operators plan flights around segregated airspace. The workload related to the re-routing around segregated airspace is considerable. This is in line with the requirement from operators to be able to estimate distance and time as accurately as possible to avoiding surprises en-route. There will still remain cases where a tactical re-routing is required. Two things can be done to reduce the workload related to this task:

- Reduce the number of tactical re-routings
- Reduce the work related to tactical re-routings

In order to reduce the number of tactical re-routings, information provided to aircraft operators must be as accurate as possible. This is clearly an area where things are not black and white, but a number of actions can be taken to improve the quality of environmental data, even if a 100% solution probably not will be achieved.

The following initiatives could be taken to improve the data quality:

- A Europe-wide, or at least covering the participating eight States, initiative to create a database covering planned and active airspace utilisation should be launched. This probably falls within initiatives already taken, the progress of these initiatives should then be followed, to ensure that the result will be available and implemented before the implementation of FRA.
- Military partners should respect planned activation of airspace, or as early as possible cancel airspace reservations, e.g. when it becomes clear that weather will not permit the planned mission.
- Routes should be updated as late as possible before take-off to allow the latest information to be taken into consideration.
- Initiatives should be taken to ensure that uplink of airspace status is considered as a possible candidate for early air ground data link application.

With regard to the workload related to tactical re-routing, it is clear that keeping aircraft on heading is more demanding than issuing a route change to the pilot, using points that are known to the ATC and airborne systems in advance. In order to do that, points should be established around segregated airspace.

These points should be the same as were used for flight planning.

To avoid confusion, a naming convention should be considered to enable the controller to understand why the points are in the flight plan thus easing the job of identifying aircraft that could be offered a more direct route when a segregated area is de-activated.

5.6 OBJECTIVE 5

Analyse the effect of tactical interventions on downstream sectors including the requirements on

- OLDI/SYSCO
- Trajectory prediction
- Flight data distribution
- Conflict detection

5.6.1 De-briefings

- It must be possible to identify to which sector in the next ACC the OLDI information has been sent.
- OLDI should be able to handle changes to the sector sequence, as they will occur often following tactical interventions.
- A function enabling the controller to inform the previous sector that the aircraft shall be transferred directly to the following sector, “skip a sector”, should be available, at least internally within an ACC.
- A minimum set of information about flights flying just outside a sector should be available to the sector.

5.6.2 Discussion

In the Fixed Route environment OLDI messages are always related to a Co-ordination Point (COP). The COP is not only a graphical point where the aircraft is leaving the area of responsibility of the ACC, it also identifies a set of procedures such as next sector, separation minima, agreed levels etc., possibly related to the further route of the aircraft, aerodrome of departure or destination.

In FRA, the notion of a COP does not exist in the way as in the fixed route environment. Aircraft are randomly leaving sectors without relation to a COP. This creates problems, not only because the OLDI Standard is based on the utilisation of COPs, but also because the liaison to a set of procedures has disappeared.

There may in FRA be a requirement to link to a COP, without requiring the aircraft to pass over the point, but maybe within a gate, enabling the controllers to identify next sector and possible procedural requirements.

Following tactical interventions, the system shall recalculate the trajectory of the aircraft, and if necessary change the sector sequence for the subject aircraft.

‘Assume’ and ‘transfer of control’ are the two tasks that require most of the EXCs attention, more than 50% of radio transmissions are related to these tasks. A SKIP function that would allow the EXC to propose to the preceding sector to change the flight directly to the frequency of the following sector would be very beneficial in order to reduce EXC workload and frequency load.

Simulation experience shows that such functionality is complicated to introduce. It is not only a matter of providing information on the next frequency to the upstream sector. All the conditions related to the transfer of control have to be transferred. It becomes even more complicated if the SKIP is succeeded by a request from the downstream sector to change the transfer conditions, e.g. change of exit level or request for release, or if the sector sequence changes. In these cases the sector which made the SKIP will have to be brought back in the loop.

It happens that flights leave the sector very close to a sector not in the sector sequence of the given flight. It these cases it is important that information is provided to this sector, and that the controller is aware that information has been passed, to avoid that unnecessary co-ordination is taking place.

In FRA there is a general requirement to have information flying close to the boundary of the sector without entering the sector. A minimum set of information, e.g. callsign, aerodrome of departure and destination, and possibly next route point, should be available for all flights inside a buffer around the sector, even if the flights are controlled by another ACC.

5.7 OBJECTIVE 6

Validate the various procedures for handling OAT.

5.7.1 De-briefings

- Adjustment of TRAs, considering FRA traffic flows as well as the lower level route structure is required.
- The co-ordination workload is increased
- OAT transit flights require more attention
- Some OAT operations conducted outside TRAs today may need a TRA in FRA

5.7.2 Discussion

It is still clear that the main problem for OAT during the simulation was RVSM.

For the Danish, Norwegian and Swedish airspace, where a Swedish Air Defence specialist managed the segregated airspace the general impression was, in line with the findings during SRT-2 (EEC Note No. 6/2000) that FRA not would create major difficulties for OAT. The workload will be increased, but adjustments of TRAs could reduce the number of flights requesting to penetrate the TRAs compared to the simulated environment. Depending on the type of operation conducted in the TRA, penetration by civil flights would be accepted, accepted through certain corridors, or not accepted.

In the three countries OAT transit flights are controlled by civil ATC. No changes were identified here.

For the Lippe Radar Controllers, who controlled OAT transit flights the main difference from today was that more attention was required to maintain the civil traffic picture. It was the impression that a closer co-operation than today with the civil controller would be beneficial.

5.8 OBJECTIVE 7

Provide support to the following work packages in FRAP: Fast time simulation, Safety Study and Human Resource Study.

5.8.1 Discussion

The results of these activities are available in separate reports issued within FRAP. The Reports are available through the EUROCONTROL Project Manager

6. CONCLUSIONS

Validate the Free Routes Airspace Concept (FRAC) based on the draft Free Routes Airspace Operational Requirements Document during a real-time simulation with several ACCs involved. General Findings:

- The Free Routes Airspace Concept is easy to understand and is accepted by the participating controllers. From a controller point of view the concept could be implemented when the required system support is in place.
- FRA shifts workload towards the executive controller.

Validate and optimise the sectorisation derived from the FRAP fast-time simulation to support validation of the FRAP concept.

- Redesign of today's sectors is required before implementation.
- New sector design principles considering traffic flows, minimising re-entrance and considering TRA's must be used.
- Adjustment of TRA's considering FRA traffic flows, military requirements and constraint from lower airspace is required to optimise airspace utilisation.
- More detailed studies using model-based simulations are required.

Identify the impact on controller workload of the introduction of simple conflict detection.

- The quality of the Medium Term Conflict Detection (MTCD) used during the simulation was inadequate.
- It seems that MTCD would be required in Maastricht, Berlin, Copenhagen and Malmö before implementation of FRA.
- No reduction in workload was recorded with MTCD.
- There is a need to further develop MTCD functionality and HMI to shift work back to the planning controller and reduce executive controller workload.

Assess the proposed procedures for entry and exit to/from Free Routes airspace, identify possible problems related to this and propose procedures to overcome these problems.

- Entry/Exit points to/from lower airspace should be 80-100NM from the airport.
- Entry/Exit points to/from lower airspace and should be well separated to avoid conflicts between climbing and descending aircraft.
- Flights should not climb from lower airspace directly to RFL without co-ordination with the FRA sector.
- Some controllers felt that the were a need to have traffic in a fixed routes structure before the sequencing starts in order to ease sequencing task

Assess the effect on controller workload, situational awareness, and identify related system requirements, of tactical re-routing around segregated airspace.

- Flight planning should be made around segregated airspace to reduce workload.
- Routes should be updated shortly before take-off to take latest information into consideration.
- A database with actual and planned status for segregated airspace should be established.
- A naming convention should allow for controllers to identify why particular points are in the flight plan.

Analyse the effect of tactical interventions on downstream sectors including the requirements on

OLDI/SYSCO
Trajectory prediction
Flight data distribution
Conflict detection

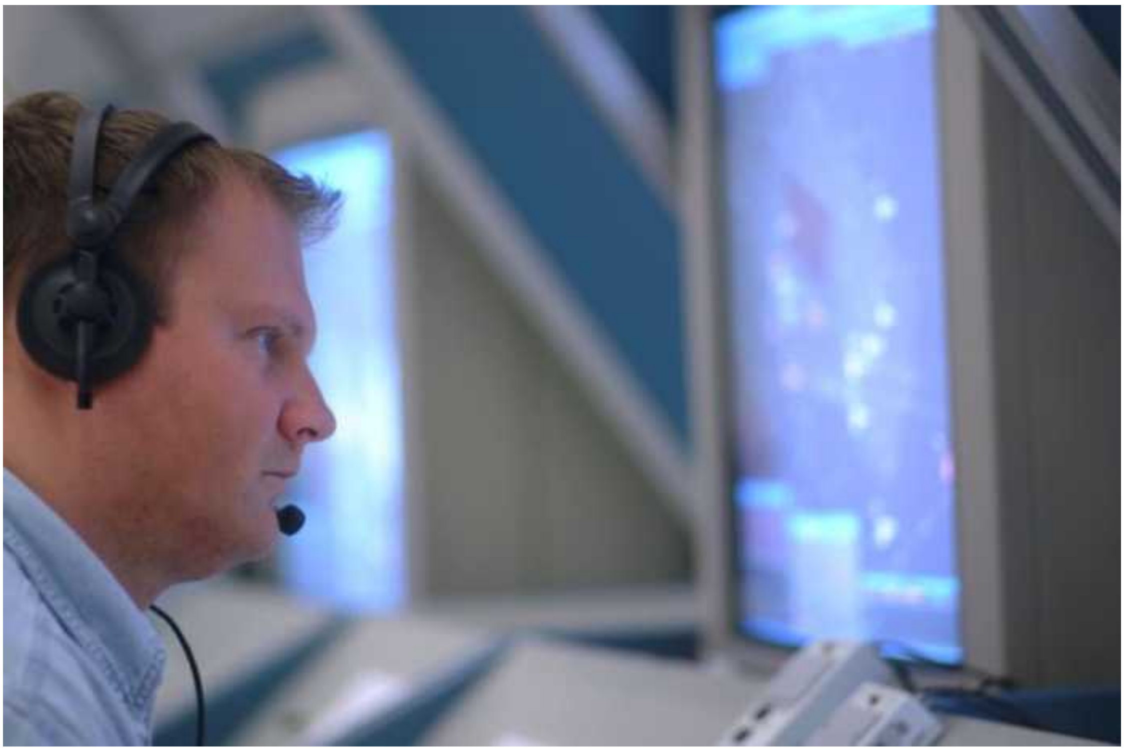
- OLDI should be able to handle changes to the sector sequence, as they will occur often following tactical interventions.
- OLDI must provide information about to which sector in the next ACC the OLDI information has been sent.
- Considerations should be made as to whether COPs should be extended to gates.
- Following tactical interventions, sector sequences must be re-calculated.
- A buffer zone around sectors must be established to allow the controller to call down information on these flights.

Validate the various procedures for handling OAT.

- FRA is not a hindrance to OAT.
- Workload on the OAT controller will increase.
- Some OAT operations taking place outside TRAs today may have to take place in a TRA in FRA.

Provide support to the following work packages in FRAP: Fast time simulation, Safety Study and Human Resource Study.

- This subject is covered in individual reports from the above studies.



7. RECOMMENDATIONS

The following additional studies should be carried out during the Validation Phase of the Eight-States Free Routes Project

1. Work should be undertaken to further develop tools that will enable the PLC to offload the EXC, reducing the risk of the EXC being overloaded.

2. Conduct Model based simulation to further optimise sectorisation, segregated airspace and entry/exit points, using the experiences gained during the FRAP validation process.

3. Perform additional studies and decide on procedures for flight planning around segregated airspace, and provide guidelines for tactical circumnavigation of airspace

4. The problem of COPs as points or gates should be studied to find solutions for the problems related to OLDI.

TRADUCTION EN LANGUE FRANÇAISE

RÉSUMÉ

On trouvera ci-dessous le rapport de la simulation en temps réel à grande échelle de la partie nord du Projet d'espace aérien à itinéraire libre dans huit États. Il s'agit de la première de deux simulations faisant suite aux simulations de moindre envergure déjà réalisées au titre de ce projet. Associées à une série d'autres activités, ces simulations doivent servir de fondement à la validation du Concept d'espace aérien à itinéraire libre.

La simulation s'est déroulée au Centre expérimental d'EUROCONTROL, à Brétigny, sur une période de trois semaines. Vingt-cinq contrôleurs de la circulation aérienne des CCR de Berlin, Copenhague, Malmö et Oslo, du centre radar militaire de Lippe et de l'UAC Maastricht, ainsi qu'un spécialiste de la défense aérienne des Forces armées suédoises, ont pris part à l'exercice, qui a porté sur l'espace aérien au-dessus de certaines parties du Danemark, de l'Allemagne, de la Norvège et de la Suède.

La plate-forme utilisée faisait intervenir des fonctions et une interface homme-machine identiques à celles qui seront mises en œuvre, avant 2005, dans les CCR de la zone simulée. Au nombre de ces fonctions figuraient l'échange de données en ligne et la coordination automatisée (OLDI/SYSCO), la coordination civile-militaire automatisée, la détection des conflits à moyen terme et l'avertissement de conflit à court terme. L'interface homme-machine (HMI) se présentait sous la forme d'un dispositif sans bande, à base objet et avec codage chromatique.

La simulation des itinéraires libres reposait sur l'application du projet de Concept opérationnel d'espace aérien à itinéraire libre.

La simulation a fait apparaître que le concept en question peut être mis en œuvre, pour autant que les CCR disposent des fonctions requises, et qu'il est porteur de certains avantages. Son adoption éventuelle nécessite toutefois que l'on étudie plus avant un certain nombre d'aspects capitaux de sa mise en œuvre et que l'on affine la définition des besoins du système.

La question de l'allégement de la charge de travail des contrôleurs n'a pas été abordée à cette occasion-ci mais le sera dans le contexte de la simulation FRA, prévue en janvier-février 2001. On notera cependant que les notes CEE 22/99 et 14/00 traitent, toutes deux, de cette question pour certaines parties de la zone simulée.

1. INTRODUCTION

La première simulation en temps réel à grande échelle du Projet d'espace aérien à itinéraire libre dans huit États (FRAP) s'est déroulée du 27 novembre au 15 décembre 2000 au Centre expérimental d'EUROCONTROL. Son objectif était de répondre aux spécifications du FRAP à l'appui de la validation du Concept d'espace aérien à itinéraire libre (FRAC).

Il s'agissait en l'occurrence de la première de deux simulations à grande échelle faisant suite à quatre simulations en temps réel de moindre envergure, l'objectif étant de permettre, en combinaison avec un certain nombre d'autres activités, la validation du FRAC dans l'espace aérien des huit États participants (Allemagne, Belgique, Danemark, Finlande, Luxembourg, Norvège, Pays-Bas et Suède).

Alors que les simulations à petite échelle peuvent être assimilées à des travaux d'étude et de mise au point, la simulation à grande échelle dont il est question ici a mis davantage l'accent sur la validation que sur l'affinement du Concept opérationnel d'espace aérien à itinéraire libre. Le cadre de la simulation était l'espace aérien supérieur de certaines parties des FIR/UIR de Berlin, Copenhague, Maastricht et Malmö. La structure et la sectorisation de l'espace aérien se fondaient sur les résultats des simulations en temps accéléré du FRAP et ne respectaient donc pas les limites de FIR/UIR actuelles. Il convient de noter que la sectorisation utilisée a été conçue pour les besoins de la validation et ne constitue pas une proposition de mise en œuvre.

Vingt-cinq contrôleurs civils et militaires ainsi que des spécialistes de la défense aérienne ont pris part à la simulation, qui couvrait la région englobant Oslo, Göteborg, Copenhague, Berlin et Hambourg. La limite inférieure de l'espace aérien simulé se situait au FL 285.

La simulation reposait sur l'application de minima réduits de séparation verticale (RVSM), l'instauration de ces derniers constituant un préalable à l'adoption éventuelle du concept d'itinéraires libres. Dans ce contexte, la circulation opérationnelle militaire était considérée comme ne disposant pas de moyens RVSM.

La simulation a été réalisée sur la plate-forme standard du Centre expérimental d'EUROCONTROL, laquelle intègre la version 2 d'OLDI, un système de coordination civile-militaire automatisée et un dispositif MTCD reposant sur une interface homme-machine sans bande.

L'équipe FRAP chargée de l'étude des performances humaines a pris part à la simulation et réalisé un certain nombre de mesures spécifiques ayant trait, notamment, aux mouvements oculaires et à la fréquence cardiaque. Les résultats de ces travaux font l'objet d'un rapport distinct. Par ailleurs, les résultats de la simulation ont été exploités pour obtenir des informations utiles pour la simulation en temps accéléré du concept d'itinéraires libres et l'étude des aspects liés à la sécurité.

2. OBJECTIFS

La simulation en temps réel à grande échelle de la partie nord du FRAP avait pour objectif global de valider le Concept d'espace aérien à itinéraire libre sur la base du projet d'ORD du FRA dans le cadre d'un exercice faisant intervenir plusieurs CCR.

Plus spécifiquement, les objectifs poursuivis étaient les suivants :

1. valider et optimiser la sectorisation découlant de la simulation en temps accéléré du FRAP, à l'appui de la validation du Concept d'espace aérien à itinéraire libre ;

2. évaluer les incidences, sur la charge de travail des contrôleurs, de l'introduction de la détection simple de conflits ;

3. évaluer les procédures proposées aux points d'entrée-sortie de l'espace aérien à itinéraire libre, cerner les problèmes éventuels et proposer des solutions ;

4. évaluer les incidences, sur la charge de travail des contrôleurs et leur perception de l'environnement opérationnel, des réacheminements tactiques autour de zones d'espace aérien réservé, et identifier les besoins connexes au niveau des systèmes;

5. analyser les incidences des interventions tactiques sur les secteurs en aval, notamment les exigences posées en termes :
   - d'échange de données en ligne et de coordination automatisée (OLDI/SYSCO) ;
   - de prévision de trajectoires ;
   - de diffusion des données de vol ;
   - de détection des conflits ;

6. valider les différentes procédures de prise en charge de la COM ;

7. appuyer les ensembles de travaux FRAP suivants : simulation en temps accéléré, étude des aspects liés à la sécurité et étude des facteurs humains.

3. CONCLUSIONS

Valider le concept d'espace aérien à itinéraire libre sur la base du projet d'ORD du FRA dans le cadre d'une simulation en temps réel faisant intervenir plusieurs CCR - conclusions générales :

- Le concept FRA est aisé à comprendre et est accepté par les contrôleurs participants. De l'avis de ces derniers, le concept pourra être mis en œuvre dès que les fonctions d'appui seront en place.
- Le concept FRA se traduit par un transfert de charge de travail vers le contrôleur exécutif.

Valider et optimiser la sectorisation découlant de la simulation en temps accéléré du FRAP à l'appui de la validation du Concept d'espace aérien à itinéraire libre.

- La mise en œuvre du concept suppose une réorganisation des secteurs actuels.
- Cette réorganisation doit s'effectuer sur la base de nouvelles règles (prise en considération des courants de trafic et des TRA, limitation au minimum des entrées-sorties répétitives).
- Un ajustement des TRA, qui tienne compte des courants de trafic FRA, des impératifs militaires et des contraintes liées à l'espace aérien inférieur, est nécessaire pour optimiser l'utilisation de l'espace aérien.
- Des études de modélisation approfondies sont également requises.

Évaluer les incidences, sur la charge de travail des contrôleurs, de l'introduction de la détection simple de conflits.

- La qualité de la MTCD utilisée dans le cadre de la simulation était médiocre.
- Maastricht, Berlin, Copenhague et Malmö devront être dotés de fonctions MTCD préalablement à la mise en œuvre du FRA.
- La fourniture de la MTCD ne s'est pas traduite par une diminution de la charge de travail.
- Il est nécessaire de développer plus avant les fonctions MTCD et la HMI pour rééquilibrer la charge de travail entre contrôleurs de planification et contrôleurs exécutifs.

Évaluer les procédures proposées aux points d'entrée/sortie de l'espace aérien à itinéraire libre, cerner les problèmes éventuels et proposer des solutions.

- Les points d'entrée-sortie de l'espace aérien inférieur devraient se situer à 80-100NM des aéroports.
- Les points d'entrée dans l'espace aérien inférieur devraient être clairement distincts des points de sortie afin de prévenir les conflits entre vols en montée et en descente.
- Les vols ne devraient pas être autorisés à passer directement de l'espace aérien inférieur au RFL sans coordination préalable avec le secteur FRA.
- Certains contrôleurs ont estimé qu'il convenait d'intégrer le trafic au réseau de routes fixes préalablement à la mise en séquence, de manière à rendre cette dernière tâche plus aisée.

Évaluer les incidences, sur la charge de travail des contrôleurs et leur perception de l'environnement opérationnel, des réacheminements tactiques autour de zones d'espace aérien réservé, et identifier les besoins connexes au niveau des systèmes.

- Il conviendrait, dans le but de réduire la charge de travail, de planifier les vols autour des zones d'espace aérien réservé.
- Les routes devraient être actualisées peu après le décollage afin de tenir compte des dernières informations disponibles.
- Il conviendrait de mettre en place une base de données concernant le statut effectif et programmé des zones d'espace aérien réservé.
- L'adoption d'une dénomination conventionnelle permettrait aux contrôleurs de comprendre pourquoi certains points particuliers figurent sur les plans de vol.

Analyser les incidences des interventions tactiques sur les secteurs en aval, notamment les exigences posées en termes :

d'échange de données en ligne et de coordination automatisée (OLDI/SYSCO)
de prévision de trajectoires
de diffusion des données de vol
de détection des conflits.

- Le dispositif OLDI devrait être en mesure de gérer les modifications de séquence des secteurs, étant donné que celles-ci feront généralement suite à des interventions tactiques.
- Le dispositif OLDI doit pouvoir fournir des informations quant au secteur emprunté par la trajectoire estimée pour entrer dans la zone du CCR suivant.
- Il convient de réfléchir sur l'opportunité d'étendre les COP aux portes.
- Les séquences de secteurs doivent être recalculées à la suite d'interventions tactiques.
- Il y a lieu d'établir une zone tampon autour des secteurs de façon à permettre au contrôleur d'appeler des informations sur les vols concernés.

Valider les différentes procédures de prise en charge de la COM.

- Le concept FRA ne constitue pas une entrave pour la COM.
- La charge de travail du contrôleur COM augmentera.
- Il se pourrait que certains vols COM actuellement effectués hors TRA doivent se faire en TRA en cas de mise en œuvre du concept FRA.

Appuyer les ensembles de travaux FRAP suivants : simulation en temps accéléré, étude des aspects liés à la sécurité et étude des facteurs humains.

- Cet aspect est abordé dans les différents rapports concernant les études précitées.

4. RECOMMANDATIONS

Les études complémentaires ci-après devraient être entreprises dans le cadre de la phase de validation du Projet d'espace aérien à itinéraire libre dans huit États :

1. Poursuite de la mise au point d'outils qui permettent au contrôleur de planification de décharger le contrôleur exécutif et, partant, de réduire les risques de surcharge de ce dernier.

2. Réalisation de simulations sur modèle à l'effet d'optimiser les secteurs, les zones d'espace aérien réservé et les points d'entrée-sortie, sur la base de l'expérience acquise au cours du processus de validation du FRAP.

3. Définition, sur la base d'études complémentaires, de procédures relatives à la planification des vols autour de zones d'espace aérien réservé, et formulation de lignes directrices pour le contournement tactique de zones d'espace aérien.

4. Analyse de la problématique des COP considérés en tant que points ou portes dans l'optique de résoudre les problèmes posés par l'échange de données de ligne (OLDI).