FRAMaK - Final Project Report (Demonstration Report)

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Abstract

This document provides the Demonstration report for the Live Trial and Demonstration activity 02.01 Free Route Airspace Maastricht and Karlsruhe (FRAMaK). It describes the results of demonstration exercises defined in the FRAMaK Demonstration Plan, edition 00.02.01, 13/09/2012, and how they have been conducted.

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In accordance with §18.1.2 (a) of the underlying Co-Financing Agreement this deliverable consists of SJU Foreground.

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Executive summary

Between June 2012 and May 2014 DFS Deutsche Flugsicherung, Deutsche Lufthansa and EUROCONTROL Maastricht UAC cooperated in the Free Route Airspace Maastricht and Karlsruhe (FRAMaK) project funded by the SESAR Joint Undertaking in the framework of SESAR Live Trial and Demonstration Activities.

The overall objective of the project was to demonstrate that cross-border Free Route capabilities extending over multiple ANSP AoRs with a very complex airspace structure comprising several major hubs and an extremely high traffic density can be realized and that these capabilities have positive impact on the KPAs Efficiency and Environmental Sustainability. The aforementioned Free Route capabilities have been determined in the FRAMaK Concept of Operations (ConOps) which describes FR-CAP-01 “Cross-Border Directs” and FR-CAP-02 “Cross-Border User Preferred Routes”.

<u>FR-CAP-01 “Cross-Border Directs”</u>

In preparation of the demonstration activities related to FR-CAP-01 the project team elaborated new Direct routing options or – to a minor extent – refined existing local DCTs. Finally in total 466 FRAMaK DCTs have been published in RAD Appendix 4 and have been made publically available even beyond project’s lifetime. These publications formed the basis for so-called Public Live Trials in which over four measurement periods of each one week duration all flights making use of these FRAMaK DCTs have been analysed referring to the baseline condition which was the previous year of each measurement period.

Based on the analysis of FPL and track data of 17,295 flights within four measurement periods of each one week duration the results of the FRAMaK Cross-Border DCT Public Live Trials (EXE-0201-D001) provide evidence for the benefits of Cross-Border Direct routing options. Reductions of FPL route length (-6.8 NM per flight or -0.6%) and actual flown track length (-3.7 NM per flight or -0.3%) provide important contributions for the enhancement of ATM performance in terms of efficiency and environmental sustainability.

These results were confirmed by EXE-0201-D002. The results of the SAAM Network Assessment show that – despite the high number of rather straight if not direct routing options already available prior to FRAMaK DCT demonstrations – the newly created FRAMaK Direct routing options provide a potential of more than 1.5 million NM route savings per year (4.2 NM per flight) corresponding to a potential reduction of fuel consumption of more than 9 million tons (25 kg per flight) and a reduction of CO_2 emission of more than 30 million tons (83 kg per flight). Thus, if airline operators make use of the new FRAMaK Direct routing options they might save up to 7.5 million Euro per year which are the estimated direct cost savings caused by fuel consumption, not taking into account potential but individual indirect cost benefits due to less flight time affecting maintenance, staffing etc.

As the initial aim of the project has been to demonstrate DCT routing options which “formalise day-to-day ATCO behaviour” in terms of the provision of tactical shortcuts an important finding is that within the FRAMaK area the FPL coherence, i.e. the accordance between FPL route and actual flown route, was improved by 4%, and 5% for weekend traffic. Reflecting well-known flows these DCTs were easily implemented without preceding real time simulations. Clearly, the implementation of DCTs creating new flows – as if developing new ATS routes – might require simulations preferably focussing on a limited number of additional route options.

In addition to this initial approach the project succeeded in developing new Cross-Border DCT routing options which offer completely new connections. Results show that actual route length savings are 3.7 NM per flight which show the additionally created potential. Route efficiency indicators REDES and RESTR calculated based on FPL and actual track data from Public Live Trials confirm these improvements indicating that the network available in the FRAMaK area now offers routing options more directed towards the destination and with more straightness than before.

The so-called Vertical Optimisation Directs, i.e. DCT routing options which were designed for improved vertical profiles by allowing for a late descent, have demonstrated an enormous potential for fuel burn savings. Especially if the new routing is not affected by flight level constraints potential savings reach up to 68 kg per flight. These promising results should lead to further investigations regarding connectivity between Upper Airspace (DCT or UPR) with aerodromes using optimised descent profiles which allow for a late descent.

An important finding is that there are certain lateral very small non-AMC manageable areas with high vertical extensions which – although regularly seldom used above FL245 – prevent the introduction of an unexpected high number of efficient direct routes.

While the project originally was aiming for the implementation of Cross-Border DCTs which do not rely on a Coordination Point on/at the AoR boundary between the UACs it became obvious that at this stage the exchange of flight information via the OLDI interface does not support such COP-less operations. As a recommendation for future DCT implementations (e.g. in the scope of FAB-wide or Cross-FAB activities) it can be concluded that there is a need for a harmonised implementation of this functionality.

As demonstrated in the successional simulation-based exercises EXE-0201-D003 and EXE-0201-004 a set of new weekend DCT routings for the KUAC core area can be made available for early implementation e.g. in DEC2014.

For the time being the development of individually designed (tailor made) new (cross-border) DCT route options in the core area represents a cost beneficial way to optimize horizontal flight efficiency while avoiding negative operational impacts and offering the safe opportunity for stepwise introduction.

As a first investigation about strategies to mitigate unwanted effects from sector clipping related to (cross-border) Direct Routing EXE-0201-D005 was conducted. It was shown that sector design and dynamic sectorisation concepts appear promising and feasible strategies, once fully validated and on-line implemented, allowing to focus Free Route design on maximum benefits for Airspace Users without high need to compromise for ATC performance. Sector Clipping should be duly investigated as they may cause operational issues and negatively affect controller workload and thus capacity. Sector Design and dynamic sectorisation concepts should be investigated as mitigation means.

<u>FR-CAP-02 “Cross-Border User Preferred Route”</u>

Focussing on FR-CAP-02 “Cross-Border User Preferred Route” demonstrations in EXE-0201-D006 were accomplished on six citypairs under study (3 of them inner-European, 3 transatlantic). In total 62 flights have been executed following a User Preferred Routing.

With the short-haul flights route lengths reductions between 1 NM and 16 NM were achieved, corresponding to fuel savings between 6 kg and 87 kg; on average the fuel reduction for short-haul flights is 5.5 kg per NM saved. Route lengths of transatlantic flights were reduced by 12-25 NM, accounting for fuel savings between 280 kg and 618 kg; average fuel reduction is 23.6 kg per NM saved.

From an Airspace User’s perspective the UPR demonstration showed with promising fuel and time savings that the further UPR development and implementation is desirable. As capacity constraints can already be found throughout Europe, technical improvements like a useable planning tool, FPL filing standards, i4D trajectories etc. have to be established beforehand.

On the other side ANSPs experienced throughout the FRAMaK UPR trials, that airspace capacity and efficiency might be reduced in particular in complex sectors of the Core Area if full Free Route with UPR (comprising entry, exit, and intermediate points) is implemented today.

Therefore, as an overall result ANSPs consider UPR operations possible in low to medium complexity areas or even in (usually) more dense areas at certain times, such as winter season or night. An implementation in more dense airspace will require further investigation and the availability of enhanced technical means, e.g. controller support tools, and enhanced working procedures / positions.

The initial FRAMaK UPR trials in the area of Karlsruhe UAC and Maastricht UAC have shown that the size of FRAMaK is near the minimum size to allow for UPR optimization within a single FRA. Through the support of Avinor, LFV, NATS, and Naviair it was possible to significantly enlarge the UPR Test Area in order to properly accomplish the UPR demonstrations. However, due to the restricted size of the demonstration area, the shortness of some routings within this area, the finite amount of waypoints and routings, the limitations of LIDO and the variability in airway charges, it was not possible to demonstrate significant savings due to wind effects and full free flight routings.

In the course of the demonstration deficiencies of today's flight planning tools were identified and possible solutions have been outlined.

Where mainly long directs have been planned vertical step climbs could be planned and filed only at waypoints. Due to lacking intermediate points the optimum vertical profile could not be followed as closely as on RAD conform routes comprising a higher number of waypoints.

The trial showed that for the majority of UPR flights DCT routing options were available or have been made available as new FRAMaK Cross-Border DCTs which in most cases properly matched the respective UPR routing for the specific citypair. Therefore, improvements in available DCT connections should be feasible as interim solution for the near future.

Special Use Airspace (SUA) may prevent the establishment of optimized routing options in various places. SUAs have been avoided within the FRAMaK trials by executing flights on weekend or in areas clear of those areas. For a widespread implementation of UPR operations more flexible handling options (A-FUA) regarding Special Use Airspace have to be in place. Operational needs of the stakeholders, for example preceding handling time of the flightplan and of fuel calculations have to be considered in order to implement operationally significant route changes.

UPR Live Trials have been useful in order to identify specific issues related to the compatibility of UPR routings with existing systems and structures. However, since UPR has been demonstrated on a case-by-case basis with a maximum of three flights per day this FRAMaK demonstration did only partly show operational issues and impacts not considering a large-scale application of this operational concept.

From the beginning of the project a conflict became visible between flight crews and ATCOs both aiming for shortest routes and shortcuts in order to straighten the routing on the one side and dispatch staff trying to find the best routing from an economical point of view which is not necessarily the shortest on the other side.

1 Introduction

1.1 Purpose of the document

This document provides the Demonstration report for the 02.01 Free Route Airspace Maastricht and Karlsruhe Live Trial and Demonstration activity. It describes the results of demonstration exercises defined in the FRAMaK Demonstration Plan, edition 00.02.01, 13/09/2012, and how they have been conducted.

1.2 Intended readership

This document is addressed to operational and technical experts dealing with the development and implementation of Free Route Airspace and intermediate capabilities, in particular RAD-published Cross-Border DCTs. With regard to the SESAR working programme in particular projects 07.05.04 "Flexible Airspace Management" (as far as related to Free Route operations) and the Operational Focus Area (OFA) 03.01.03 "Free Routing" are addressees of this Final Report.

1.3 Structure of the document

The document describes the framework of the demonstrations and provides an overview on Programme Management aspects. The preparation of demonstration exercises and the results are described in detailed in chapters 4-6 in which chapter 5 summarizes the results of the individual exercises. Conclusions and recommendations are to be found at the end of each results section. Chapter 7 describes the communication activities of the project and the project partners. Implications for future developments are outlined in chapter 8.

1.4 Glossary of terms

n/a

1.5 Acronyms and Terminology

Term	Definition
A/C	Aircraft
ACC	Area Control Center
ADEP	Aerodrome of Departure
ADES	Aerodrome of Destination
AFSBw	Amt für Flugsicherung der Bundeswehr; engl.: Bundeswehr Air Traffic Services Office
A-FUA	Advanced Flexible Use of Airspace
AIP	Aeronautical Information Publication
AIRAC	Aeronautical Information Regulation and Control
AirTOp	Air Traffic Optimizer
ANS CR	Air Navigation Services of the Czech Republic
ANSP	Air Navigation Service Provider
AO	Airline Operator
AOG	Airline Operations Group
AOM	Airspace Organisation and Management
AoR	Area of Responsibility
ARR	Arrival / arriving
ASM	Airspace Management

Term	Definition
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATC-TRC	Air Traffic Control – Route Control
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATS	Air Traffic Service
AUP	Airspace Use Plan
Austro Control	Austrian ANSP
BAC	Belgium Air Component
BADA	Base of Aircraft Data
Belgocontrol	Belgian ANSP
CAA	Civil Aviation Administration / Civil Aviation Authority
CDA	Continuous Descent Approach
CFMU	Central Flow Management Unit
CONOPS	Concept of Operations
COP	Coordination Point
CRAM	Conditional Route Availability Message
CWP	Controller Working Position
DCT	Direct routeing option
DEP	Departure / departing
DDR	EUROCONTROL Demand Data Repository
DFS	Deutsche Flugsicherung GmbH, German ANSP
DFS-PMH	Deutsche Flugsicherung GmbH – Project Management Handbook
DLH	Deutsche Lufthansa AG
DOD	Detailed Operational Description
DSNA	Direction des Services de la Navigation Aérienne, French ANSP
EBG	Einsatzberechtigungsgruppe, Engl.: sector group
ECAC	European Civil Aviation Conference
ECTL	Eurocontrol
E-OCVM	European Operational Concept Validation Methodology
ETFMS	Enhanced Tactical Flow Management System
EU ETS	European Union Emission Trading Scheme
FAB	Functional Airspace Block
FABEC	Functional Airspace Block Europe Central
FABEC CW	FABEC Central West Project
FABEC FRA	FABEC Free Route Airspace Programme
FDPS	Flight Data Processing System
FIR	Flight Information Region
FL	Flight Level
FMS	Flight Management System
FPL	Flight Plan
FRA	Free Route Airspace
FRAK	Free Route Airspace Karlsruhe, Project
FRAM	Free Route Airspace Maastricht, Project

Term	Definition
FRAN	Free Route Airspace North
FRAS	Free Route Airspace South
FR-CAP-01	Free Route Capability 1 “Cross-Border Directs”
FR-CAP-02	Free Route Capability 2 “Cross-Border User Preferred Routes”
FT	Flight Trial
FTE	Full-time Equivalent
FTS	Fast Time Simulation
FUA	Flexible Use of Airspace
GAT	General Air Traffic
GC	Great Circle
GND	Ground
HMI	Human Machine Interface
ICAO	International Civil Aviation Organization
ICAO	International Civil Aviation Organisation
ISA	International Standard Atmosphere
Isavia	ANSP of Iceland
ISO 9001	International Organisation for Standardisation, Standard, No. 9001, Quality management
KASIM	Karlsruhe Simulator, En route Radar Simulator
KPA	Key Performance Area
KPI	Key Performance Indicator
KUAC	Karlsruhe Upper Area Control Centre
LAT	Latitude
LFV	Luftfahrtsverket, Swedish ANSP
LIDO	Flight planning and dispatch solution by Deutsche Lufthansa AG
LON	Longitude
LVNL	Luchtverkeersleiding, Dutch ANSP
MAA	Military Aviation Authority
MIN FL	Minimum Flight Level
MPG	SESAR Master Planning Group
MTCD	Medium-Term Conflict Detection
MUAC	Maastricht Upper Area Control Centre
NAT	North Atlantic Track System
NATS	National Air Traffic Services of UK, British ANSP
NAV Portugal	Portuguese ANSP
Naviair	Danish ANSP
NCOP	Entry Coordination Point
NMD	EUROCONTROL Network Management Directorate
NORACON	North European and Austrian Consortium, consisting of Swedavia (Swedish airports) and eight European ANSPs: Austro Control (Austria) and the North European ANSPs (NEAP) including AVINOR (Norway), EANS (Estonia), Finavia (Finland), IAA (Ireland), ISAVIA (Iceland), LFV (Sweden) and Naviair (Denmark)
NOTAM	Notice to Airmen
NPt	Entry Point
OAT	Operational Air Traffic

Term	Definition
OFA	Operational Focus Area
OI	Operational Improvement
OJT	On the Job Training
OLDI	Online Data Interchange
P1/VAFORIT	ATM System of DFS - KUAC
PANSA	Polish Air Navigation Services Agency
R&D	Research & Development
RAD	Route Availability Document
REDES	Route Efficiency related to the effective approach (approximation) towards the destination
RESTR	Route Efficiency related to the lateral optimum within the concerned airspace
RFL	Requested Flight Level
RNAV	Area Navigation
RNDSG	Route Network Development Subgroup
RNLAF	Royal Netherlands Air Force
RTS	Real Time Simulation
SAAM	System for traffic assignment and analysis on a macroscopic scale
SC OPS	FABEC Standing Committee Operations
SDT	Scheduled Departure Time
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SID	Standard Instrument Departure Route
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
Skyguide	Swiss ANSP
STAR	Standard Arrival Route
SUA	Special Use Airspace
TMA	Terminal Control Area
TRA	Temporary Reserved Airspace
TWR	Tower
UAC	Upper Area Control Centre
UIR	Upper Flight Information Region
UPR	User Preferred Route / Routing
UTC	Coordinated Universal Time
WP	Work Package
XCOP	Exit Coordination Point
XPt	Exit Point

2 Context of the Demonstrations

2.1 Scope of the demonstration and complementarity with the SESAR Programme

2.1.1 Purpose of the Project

One of the SESAR CONOPS' key elements is the introduction of a Free Route system for particular areas of the airspace [22]. In view of the SESAR Deployment Free Route in connection with Flexible Management of Airspace forms the ATM Functionality #3 of the Pilot Common Project aiming for an initial implementation in the timeframe 2018-2022 [24]. In general, Free Route is seen as being part of a stepwise approach leading to trajectory based operations.

Free Route refers to a specified airspace within which users may freely plan a route between a defined entry point and a defined exit point, with the possibility to route via intermediate (published or unpublished) waypoints, with or without reference to the ATS route network, subject to airspace availability. Within this airspace, flights remain subject to air traffic control (by definition Route Network Development Sub Group - RNDSG) [18].

FRAM (Free Route Airspace Maastricht) and FRAK (Free Route Airspace Karlsruhe) are 2 Free Route Airspace projects, both initiated on an individual ANSP basis in 2009 and currently applied in the upper airspace of Germany and BENELUX. Both projects were developed separately and are restricted to the Area of Responsibility (AoR) of each respective control centre. Generally they are aiming for similar objectives, however with slightly different approaches.

Other Free Route projects (e.g. NAV Portugal and NORACON trials) have shown or plan to validate the feasibility and conditions of Free Routing as well. But none of the past or planned projects has validated Free Route under the specific conditions of Maastricht and Karlsruhe airspace located in the heart of Europe with a very complex airspace structure and a traffic density, which is under the highest of the world. Serving major traffic streams and major European hubs, it is a real challenge to introduce a cross border Free Route Airspace volume within this area. In order to give an impression of the traffic density: In 2011 more than 770.000 flight movements have been registered between the KUAC and MUAC airspace and vice versa.

The purpose of the FRAMaK project was to demonstrate Free Routing capabilities in the combined KUAC and MUAC AORs through live flight trials and live trial implementations. The FRAMaK project demonstrated the realisation of two types of Free Routing capabilities in a large-scale airspace volume across national and ANSP boundaries in a high density and complex area to the benefits of the Airspace User.

2.1.2 Scope of the project

The geographical scope of the project entailed the combined AoRs of Karlsruhe and Maastricht UAC located in the Brussels UIR, Amsterdam FIR, Hannover UIR, and Rhein UIR, excluding the ATS delegated areas unless otherwise agreed with the concerned state authorities (see Figure 1).

In view of the near-term targets, the project focussed on following Free Routing capabilities (referred to as [FR-CAP]):

- Cross-border DCTs from entry to exit lateral/vertical points of the combined airspaces of MUAC and KUAC Areas of Responsibility; further referred to as [FR-CAP-01].
- DCT segments from entry to exit lateral/vertical points of the combined airspaces of MUAC and KUAC Areas of Responsibility, allowing intermediate navigation points by free Airline Operator (AO) choice; further referred to as [FR-CAP-02].

In order to deliver complete solutions, the project also developed required Transition Routes to/from major airports connecting with the Free Route Airspace.

Military traffic (OAT) and the military training areas were out of the scope of this project and were not addressed, although the military partners were involved in the activities.

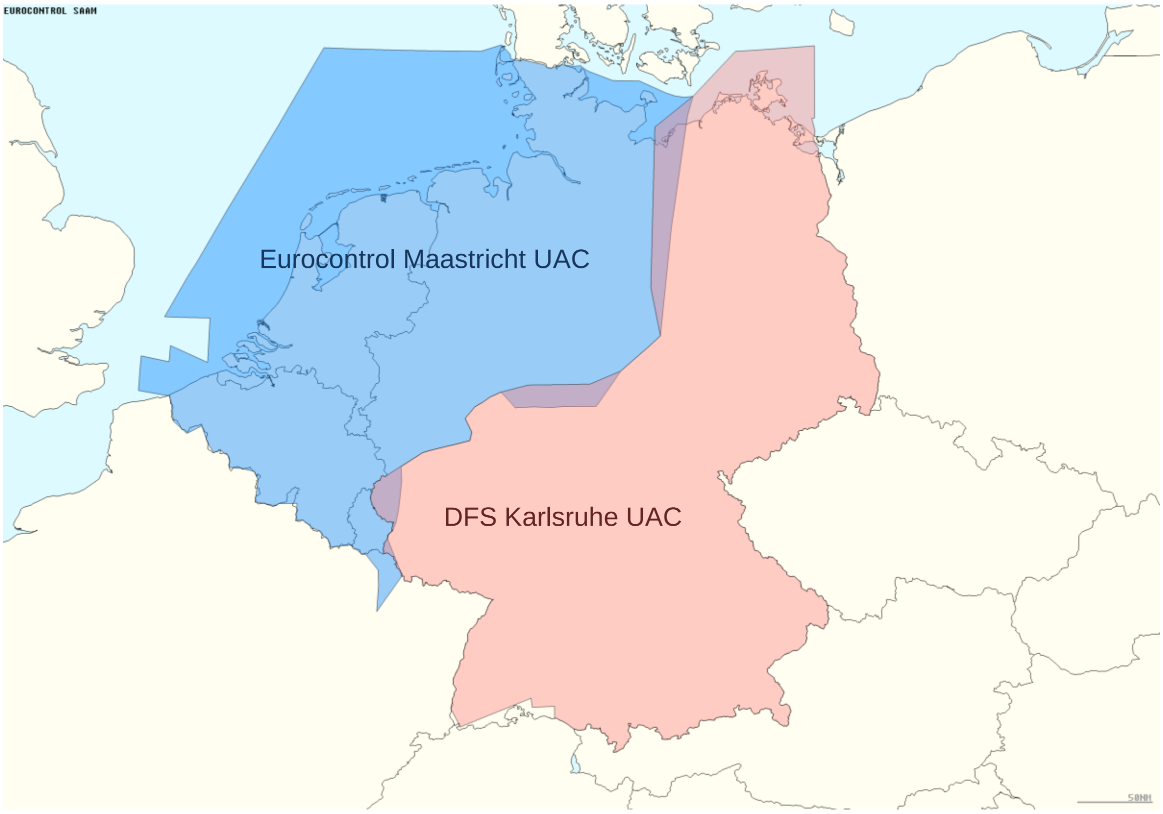

Figure 1: Geographical scope of the FRAMaK Project with Areas of Responsibility of DFS Karlsruhe UAC and Eurocontrol Maastricht UAC

2.1.3 Objectives of the project

The overall objective of the project was to demonstrate that cross-border Free Route capabilities extending over multiple ANSP AoRs with a very complex airspace structure comprising several major hubs and an extremely high traffic density can be realized and that these capabilities have positive impact on the KPAs Efficiency and Environmental Sustainability.

The project's aim was to develop and demonstrate solutions for Airline Operators' Flight Plan filing, airspace regulation publications, ANSP procedures, system adaptations, connection with sub- and adjacent fixed route systems etc. to achieve its goals in view of the short-tem capabilities of involved stakeholders in the timeframe of the project. Furthermore, the solutions were to be suitable for a common and generic application, available to all types of GAT flights, and ready for expansion over other areas

In an iterative approach comprising Fast Time Simulations (FTS), Real Time Simulations (RTS), Flight Trials (FT) and in-depth route analyses by an Airspace User (DLH) the project was going to achieve an acceptable balance between Flight Efficiency and Capacity requirements, while maintaining or improving the current safety standard and without hampering Military Mission Effectiveness.

For Aircraft Operators, the project should allow for an increase in Efficiency and Environmental Sustainability of airline operations. Thus, positive cost effects with regard to fuel consumption, aircraft flight hours and with regard to the regulations of the European Union Emissions Trading Scheme (EU ETS) were expected.

From the ANSPs' perspective the project should contribute to the Efficiency targets of the overall network as well as to the Environmental Sustainability of the European ATM system. Furthermore, the stability of the overall network was to be improved which would reduce downstream disruptions. The general effects of the Free Route Airspace concept on capacity in high density areas should form a key investigation area.

The project aimed for cross-border route designs which foster adequate and reliable capacity planning. Clearly and especially within the process of route design development and its demonstration by means of flight trials, capacity degradations violating capacity demands were precluded. From the very beginning this constraint was taken into account in the initial demonstration plan.

In particular, the SESAR FRAMaK Project had the following goals:

- demonstrate that Free Route is feasible across national and ANSP boundaries in a complex and high traffic density environment,
- demonstrate that a user preferred trajectory is feasible across national and ANSP boundaries in a complex and high traffic density environment,
- determine conditions for a realistic and stepwise transition towards a large cross border Free Route Airspace,
- validate the benefits and impacts of the Free Route Airspace solution with the customers,
- provide a Free Route Concept and Route design ready for implementation

As mentioned earlier the project aimed for gains in the Key Performance Areas

- Efficiency
- Environmental Sustainability

while the effects on Capacity had to be carefully evaluated.

The project should elaborate solutions related to operational requirements allowing for direct routing/free routing and user preferred profiles within the airspace of MUAC and KUAC. Initial steps should be accomplished for a Free Routing Airspace within which users can freely plan their routes between an entry point and an exit point with or without reference to the Air Traffic Services (ATS) route network.

Concerning the flight trials of FR-CAP-02, as a starting point defined waypoints within the Free Route Airspace were considered as still being used to enable flyable routings for the on-board Flight Management Systems (FMS). The Airspace User was supposed to freely choose either a direct routing between an entry and exit point of choice or to use existing waypoints in between which allow for a routing as close as possible to the most efficient one. No restrictions regarding ATS routes or specific sequences of these waypoints were assumed to be necessary.

The project aim was not only to deal with areas or times with less dense traffic, but to also include busy areas like KUAC Centre or MUAC within higher traffic time periods. Therefore, it had to consider both ATM restrictions on the one side and AO needs on the other.

2.1.4 Scope/perimeter of the demonstration

The demonstration should bring evidence that cross-border Free Route capabilities extending over multiple ANSP AoRs can be realised and that these capabilities lead to significant benefits for the Airspace Users, measurable in the Key Performance Areas Efficiency, and Environmental Sustainability.

The geographical scope of the project entailed the combined AoRs of Karlsruhe UAC and Maastricht UAC located in the Brussels UIR, Amsterdam FIR, Hannover UIR and Rhein UIR. Thus, the demonstration comprised a very complex airspace structure and a traffic density, which is under the highest of the world, serving major traffic streams and major European hubs.

In the course of this demonstration, solutions for AO Flight Plan filing, airspace regulation publications, ANSP procedures, system adaptations, connections with sub- and adjacent fixed route systems, etc. were to be developed. These items should be available for future operational usage also in terms of a common and generic application which is ready for expansion over other areas and applicable for all types of GAT flights.

Deviation 1: Modified structure of Demonstration Exercises

Deviating from the original project planning [5][16] in which three exercises have been outlined forming the demonstration programme:

- EXE-02.01-D001 Cross border DCT from entry to exit,
- EXE-02.01-D002 Cross border DCT connecting major hubs, and
- EXE-02.01-D003 Cross-border User Preferred Routes

in the course of project execution and the elaboration of experimental plans it became obvious that

- from a methodological perspective there is no benefit resulting from a distinction between EXE-02.01-D001 and EXE-02.01-D002
- in particular with regard to FR-CAP-01 a more detailed structuring of exercises would ease the preparation and accomplishment of work if reflecting – in principle – the outcomes of individual FRAMaK Work Packages supporting or complementing the Public Live Trials planned in EXE-0201-D001. Those additional exercises are formed by the outcome of
    - WP3 Network Assessment in which the potential savings related to new FRAMaK DCTs foreseen for publication in RAD App 4 were assessed by means of SAAM Fast Time Simulations (EXE-0201-D002);
    - WP4 KUAC Central Sectors Validation, comprising Fast Time Simulations assessing the potentials and the operational effects of different configurations of potential new FRAMaK DCTs related to the Karlsruhe UAC Core Area (EXE-0201-D003);
    - WP5 KUAC+MUAC Routes Validation (part A), a Real Time Simulation assessing the operational feasibility of different configurations of potential new FRAMaK DCTs related to the Karlsruhe UAC Core Area (EXE-0201-D004);
    - WP5 KUAC+MUAC Routes Validation (part B), a Real Time Simulation assessing the operational feasibility of different configurations of potential new FRAMaK DCTs related to the Maastricht UAC Core Area (EXE-0201-D005).

Therefore, the final planning [17] comprised six exercises:

- Exercises related to FR-CAP-01 "Cross-Border DCTs"
    - EXE-0201-D001 Public Live Trial of Cross-Border DCTs
    - EXE-0201-D002 Simulation-based assessment of Cross-Border DCTs - Network Assessment
    - EXE-0201-D003 Simulation-based assessment of Cross-Border DCTs - KUAC Core Area Fast Time Simulation
    - EXE-0201-D004 Simulation-based assessment of Cross-Border DCTs - KUAC Core Area Real Time Simulation
    - EXE-0201-D005 Simulation-based assessment of Cross-Border DCTs - MUAC Core Area Real Time Simulation
- Exercises related to FR-CAP-02 "Cross-Border User Preferred Routes"
    - EXE-0201-D006 Cross-Border User Preferred Routes Flight Trial

2.1.4.1 Demonstration Objectives

The following Table 1 describes the objectives and hypotheses of the demonstration programme and informs about KPAs which were addressed. Details on applied metrics (KPIs and other) for operational implementation of these KPAs are described in section 5.2.

Table 1: Demonstration Objectives

Objective ID	Description	KPAs
OBJ-0201-001	Horizontal Flight Efficiency of Cross-Border DCTs It is to be demonstrated that FPL routings and flight trajectories based on published DCT routings are closer to the optimum compared with FPL routings based on the existing ATS-route network[1]. Therefore, they are beneficial in terms of flight efficiency. The reduced deviation from the optimum positively affects flight duration and fuel burn. The reduced FPL route length results in weight reductions and again fuel burn due to lower amounts of contingency fuel.	Efficiency
OBJ-0201-002	Vertical Flight Efficiency of Cross-Border DCTs It is to be demonstrated that FPL routings and flight trajectories based on published DCT routings which offer optimized vertical profiles are closer to the optimum compared with FPL routings based on the existing ATS-route network. Therefore, they are beneficial in terms of flight efficiency. The reduced deviation from the optimum positively affects fuel burn.	Efficiency
OBJ-0201-003	Environmental Sustainability of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs due to improved flight efficiency positively affect CO_2 emission.	Environmental Sustainability
OBJ-0201-004	Safety of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs do not negatively affect Safety.	Safety
OBJ-0201-005	Capacity related to Cross-Border DCTs It is to be demonstrated that based on a suitable route design the usage of Cross-Border Directs will not negatively affect capacity of the FRAMaK airspace.	Capacity
OBJ-0201-006	Network effects related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect capacity demand in the adjacent centres/sectors serving the connecting ATS routes.	Capacity

[1] Whenever the traffic situation permits ATC usually provides tactical directs which deviate from the FPL (and the ATS route system) in order to improve flight efficiency. Therefore, the foreseen analyses of the current situation (baseline) will take into account both the FPL filed, ATS-based routeings and the actual flown tracks (eventually containing such tactical directs).

Objective ID	Description	KPAs
OBJ-0201-007	Predictability related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs improve the predictability of flights.	Predictability
OBJ-0201-008	Cost Effectiveness related to Cross-Border DCTs[2] It is to be demonstrated that the usage of Cross-Border Directs improve the cost effectiveness of flight handling through ANSPs.	Cost Effectiveness
OBJ-0201-009	Operator Workload related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect operator workload and situational awareness of both ATCOs and crews. Contrariwise, based on a suitable route design a reduction of workload and an increase of situational awareness might be achievable.	Other
OBJ-0201-010	Operational Feasibility of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs provide a sufficient feasibility for operational usage.	Other
OBJ-0201-011	Flight Efficiency of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes making best usage of e.g. wind effects positively affect flight duration and fuel burn	Efficiency
OBJ-0201-012	Environmental Sustainability of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes positively affect CO_2 emission.	Environmental Sustainability
OBJ-0201-013	Safety of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes do not negatively affect Safety.	Safety

[2] Cost Effectiveness is strongly related to the effectiveness of the airspace sectorization. In order to calculate the Controller Productivity in terms of G2G ANS Costs as foreseen in [21] details are to be known about the effective sector configuration during the measurement period and related staffing conditions. In EXE-0201-D001 “Cross-Border DCT Public Live Trials” regular flights were analysed over a total duration of 8 weeks (4 measurement periods with respective reference periods). In this period of time more than 200 different sector configurations were observed in the FRAMaK airspace. Clearly, it was not possible to analyse in detail the related sector configurations. Furthermore, due to shift of traffic flows (e.g. attraction of additional flights by improved routeing conditions) it is not possible to analyse the impact on cost effectiveness in terms of ATCO productivity. Therefore, the project decided to focus on an assessment of the sectorization, i.e. to analyse whether the (unmodified) sectorization is feasible for operations based on Cross-Border DCTs elaborated in FRAMaK.

Objective ID	Description	KPAs
OBJ-0201-014	Capacity related to Cross-Border User Preferred Routes It is to be demonstrated that the usage of Cross-Border User Preferred Routes will not negatively affect capacity of the FRAMaK airspace.	Capacity
OBJ-0201-015	Network effects related to Cross-Border User Preferred Routes It is to be demonstrated that the usage of Cross-Border User Preferred Routes will not negatively affect capacity demand in the adjacent centres/sectors serving the connecting ATS routes.	Capacity
OBJ-0201-016	Operator Workload related to Cross-Border User Preferred Routes It is to be demonstrated that the usage of Cross-Border User Preferred Routes will not negatively affect operator workload and situational awareness of both ATCOs and crews.	Other
OBJ-0201-017	Operational Feasibility of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes provide a sufficient feasibility for operational usage.	Other
OBJ-0201-018	Interference of simultaneous FRA operations It is to be demonstrated that simultaneous execution of FPLs comprising of Cross-Border DCTs and User Preferred Routes (dual mode operations) does not jeopardize positive effects demonstrated in single mode operation and has no negative impact on Capacity.	Efficiency Environmental Sustainability Capacity Other

2.1.4.2 Demonstration Scenarios

In order to demonstrate and to analyse the operational usage of the two operational capabilities:

1. Cross-Border DCTs from entry to exit lateral/vertical points of the combined airspaces of MUAC and KUAC Areas of Responsibility [FR-CAP-01],
2. DCT segments from entry to exit lateral/vertical points of the combined airspaces of MUAC and KUAC Areas of Responsibility, allowing intermediate navigation points for user preferred routes [FR-CAP-02]

three demonstration scenarios have been defined in order to facilitate the major operational use cases which arise from the FRAMaK project (Table 2).

Deviation 2: Direct Step into Mixed Mode Operation of DCT and UPR

During the preparation of User Preferred Route Flight Trials (EXE-0201-D006) it became obvious that from an operational perspective there was no need for any restrictions regarding the availability of FRAMaK Cross-Border DCTs (SCN-0201-001) during the execution of UPR Flight Trials. Thus, UPR Flight Trials (EXE-0201-D006) and the Public Live Trials of Cross-Border DCTs (EXE-0201-D001) have been accomplished at the same time. Therefore, there was no need for exclusive operations in the framework of SCN-0201-002; instead, all UPR Flight Trials have been accomplished according to scenario SCN-0201-003.

Table 2: Demonstration Scenarios

Scenario ID	Description
SCN-0201-001	**Cross-Border entry-exit DCTs** Scenario SCN-0201-001 refers to FR-CAP-01. The determination of Cross-Border entry-exit DCTs will be accomplished in WP 2 Route Design. DCTs will be published in the Route Availability Document (RAD), Appendix 4 "En-route DCT limits – DCT limits". FRAMaK entry and exit points will be defined as connecting points between the Cross-Border Direct routes to be developed in the project and the surrounding ATS Route System or Free Route airspaces both adjacent and subjacent to the FRAMaK airspace. SCN-0201-001 is related to ▪ MUAC/KUAC overflights, i.e. transfers through the combined Maastricht & Karlsruhe airspace, and ▪ flights to and from hubs and major airports affected by airspace design activities in the FRAMaK airspace, i.e. flights o arriving from a destination outside the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace, o departing from a hub within/below the FRAMaK airspace directed towards a destination outside the FRAMaK airspace, and o between hubs within/below the FRAMaK airspace, i.e. departing from a hub within/below the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace.
SCN-0201-002	***Cross-Border User Preferred Routes*** *Scenario SCN-0201-002 refers to flights according FR-CAP-02 allowing for user preferred Cross-Border routes abeam the geographically optimum Direct.* *This scenario will be demonstrated by means of approx. 50 specific trial flights of DLH.*
SCN-0201-003	**Mixed mode operation** Scenario SCN-0201-003 refers to the simultaneous application of both of the aforementioned scenarios, i.e. allowing concurrent filing of FPLs containing Cross-Border DCTs and User Preferred Routes.

2.1.4.3 Demonstration Exercises List

Table 3 summarizes key information regarding the individual demonstration exercises.

Table 3: Exercises overview

Demonstration Exercise ID and Title	EXE-0201-D-001 Public Live Trial of Cross-Border DCTs
Leading organization	DFS
Short Description	EXE-0201-D-001 is seen as the primary demonstration activity related to FRAMaK Cross-Border DCTs (FR-CAP-01). By means of publication of FRAMaK Cross-Border DCTs in the Route Availability Document (RAD) Appendix 4 these DCTs are publicly available for flight planning and persist after project's close-out. Therefore, this exercise is referred to as a Public Live Trial. The project started with the publication of new DCT routing options in SEP 2012. With the progress in FRAMaK WP2 Route Design several Implementation Packages have been published until the last one in MAR 2014. In total, 466 new DCT routing options have been published in RAD App 4. The connectivity between the FRAMaK airspace with the arrival/departure route system of these airports (STARs, SIDs, RNAV Transitions) may be facilitated by means of Compulsory Transition Routes. Such new routes outside the FRAMaK airspace are not subject to performance assessment. In order to demonstrate the effects and to investigate the validation objectives in the course of the FRAMaK project data from real world flights (both FPL and track data) were analysed in 4 measurement periods of one week duration each, thus reflecting the progress in DCT publication. For the statistical analyses data from 17,295 flights have been investigated.
Demonstration exercise objectives	OBJ-0201-001 Horizontal Flight Efficiency of Cross-Border DCTs It is to be demonstrated that FPL routings and flight trajectories based on published DCT routings are closer to the optimum compared with FPL routings based on the existing ATS-route network. Therefore, they are beneficial in terms of flight efficiency. The reduced deviation from the optimum positively affects flight duration and fuel burn. The reduced FPL route length results in weight reductions and again fuel burn due to lower amounts of contingency fuel. OBJ-0201-002 Vertical Flight Efficiency of Cross-Border DCTs It is to be demonstrated that FPL routings and flight trajectories based on published DCT routings which offer optimized vertical profiles are closer to the optimum compared with FPL routings based on the existing ATS-route network. Therefore, they are beneficial in terms of flight efficiency. The reduced deviation from the optimum positively affects fuel burn.

	OBJ-0201-003 Environmental Sustainability of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs due to improved flight efficiency positively affect CO_2 and NO_x emission. **OBJ-0201-007 Predictability related to Cross-Border DCTs** It is to be demonstrated that the usage of Cross-Border Directs improve the predictability of flights. **OBJ-0201-008 Cost Effectiveness related to Cross-Border DCTs** It is to be demonstrated that the usage of Cross-Border Directs improve the cost effectiveness of flight handling through ANSPs. **OBJ-0201-010 Operational Feasibility of Cross-Border DCTs** It is to be demonstrated that Cross-Border Directs provide a sufficient feasibility for operational usage. **Deviation 3: No assessment of Capacity effects (OBJ-0201-005 and OBJ-0201-006) in EXE-0201-D001** In general, the analysis of Capacity has to be accomplished by means of the KPI "ENR Throughput" which must refer to stable sectorizations in order to provide meaningful results. Though, based on the data collected in the course of the Public Live Trials more than 200 different sector configurations of the FRAMaK area were found within the 4 weeks of measurement periods and the corresponding 4 weeks of reference periods. It can be concluded that Capacity has not been hampered by FRAMaK DCTs because of an – overall – decreasing demand, and the fact that Public Live Trials have proven that no DCTs had to be withdrawn for Capacity issues neither local nor at the boundaries to adjacent ACCs.
Related Scenario	SCN-0201-001
OFA addressed	OFA 03.01.03 Free Routing
Applicable Operational Context	PAC 03 Moving from Airspace to 4D Trajectory Management SPC 03.01 4D Trajectory Management OI Steps: AOM-500 Direct Routing for flights both in cruise and vertically evolving for cross ACC borders and in high & very high complexity environments. AOM-504 Optimum Trajectories in Defined Airspaces at Particular Times. Accomplished according to operational concept description FR-CAP-01 [6].
Demonstration Technique	Live Trial (public)

Targeted E-OCVM Maturity Level	E-OCVM V4 – Industrialisation
Expected results per KPA	Efficiency: Increase Environmental Sustainability: Increase Safety: Neutral Capacity: Neutral Cost Effectiveness: Neutral
Number of trials	17,295 (number of real world flights analysed in the course of statistical analyses)

Demonstration Exercise ID and Title	**EXE-0201-D-002** **Simulation-based assessment of Cross-Border DCTs: Network Assessment**
Leading organization	ECTL NMD
Short Description	Complementing EXE-0201-D001 this exercise had a focus on the overall, especially network related, effects of Cross-Border DCTs in the Central European airspace. Furthermore, the results of this exercise inform about the potential savings of implemented FRAMaK DCT routing options for Airspace Users, based on the assumption that the Airspace User files the shortest route available.
Demonstration exercise objectives	OBJ-0201-001 Horizontal Flight Efficiency of Cross-Border DCTs It is to be demonstrated that FPL routings and flight trajectories based on published DCT routings are closer to the optimum compared with FPL routings based on the existing ATS-route network[3]. Therefore, they are beneficial in terms of flight efficiency. The reduced deviation from the optimum positively affects flight duration and fuel burn. The reduced FPL route length results in weight reductions and again fuel burn due to lower amounts of contingency fuel. OBJ-0201-003 Environmental Sustainability of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs due to improved flight efficiency positively affect CO_2 emission.

[3] Whenever the traffic situation permits ATC usually provides tactical directs which deviate from the FPL (and the ATS route system) in order to improve flight efficiency. Therefore, the foreseen analyses of the current situation (baseline) will take into account both the FPL filed, ATS-based routeings and the actual flown tracks (eventually containing such tactical directs).

	OBJ-0201-006 Network effects related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect capacity demand in the adjacent centres/sectors serving the connecting ATS routes. **Deviation 4: No assessment of Cost Effectiveness in the SAAM Network Assessment** During the definition phase of the FRAMaK project it has been assumed that the SAAM Network Assessment could inform about Cost Effectiveness. However, since we have to stress that the assessment only informs about potential route length savings and does not account for real-life flight planning it has been decided that effects of FRAMaK DCTs on Cost Effectiveness shall be assessed based on real-life data collected in the Public Live Trials.
Related Scenario	SCN-0201-001
OFA addressed	OFA 03.01.03 Free Routing
Applicable Operational Context	PAC 03 Moving from Airspace to 4D Trajectory Management SPC 03.01 4D Trajectory Management OI Steps: AOM-500 Direct Routing for flights both in cruise and vertically evolving for cross ACC borders and in high & very high complexity environments. AOM-504 Optimum Trajectories in Defined Airspaces at Particular Times. Accomplished according to operational concept description FR-CAP-01 [6].
Demonstration Technique	Fast Time Simulation
Targeted E-OCVM Maturity Level	E-OCVM V4 – Industrialisation
Expected results per KPA	Efficiency: Increase Environmental Sustainability: Increase
Number of trials	n/a

Demonstration Exercise ID and Title	**EXE-0201-D-003** **Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation**
Leading organization	DFS

Short Description	Complementing EXE-0201-D001 this exercise studied by means of Fast Time Simulation effects of different setups of FRAMaK Cross-Border DCTs in case of implementation in Karlsruhe Central Sectors with high traffic density. In this exercise available real-world FPLs were analysed for several DCT scenarios and the ATS route network as a reference. Potential flight efficiency benefits have been investigated by means of SAAM, while by means of AirTOp also workload effects have been evaluated.
Demonstration exercise objectives	OBJ-0201-001 Horizontal Flight Efficiency of Cross-Border DCTs It is to be demonstrated that FPL routings and flight trajectories based on published DCT routings are closer to the optimum compared with FPL routings based on the existing ATS-route network. Therefore, they are beneficial in terms of flight efficiency. The reduced deviation from the optimum positively affects flight duration and fuel burn. The reduced FPL route length results in weight reductions and again fuel burn due to lower amounts of contingency fuel. OBJ-0201-003 Environmental Sustainability of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs due to improved flight efficiency positively affect CO_2 emission. OBJ-0201-004 Safety of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs do not negatively affect Safety. OBJ-0201-005 Capacity related to Cross-Border DCTs It is to be demonstrated that based on a suitable route design the usage of Cross-Border Directs will not negatively affect capacity of the FRAMaK airspace. OBJ-0201-006 Network effects related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect capacity demand in the adjacent centres/sectors serving the connecting ATS routes. OBJ-0201-008 Cost Effectiveness related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs improve the cost effectiveness of flight handling through ANSPs. OBJ-0201-009 Operator Workload related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect operator workload and situational awareness of both ATCOs and crews. Contrariwise, based on a suitable route design a reduction of workload and an increase of situational awareness might be achievable.

Related Scenario	SCN-0201-001	
OFA addressed	OFA 03.01.03 Free Routing	
Applicable Operational Context	PAC 03	Moving from Airspace to 4D Trajectory Management
	SPC 03.01	4D Trajectory Management
	OI Steps:	
	AOM-500	Direct Routing for flights both in cruise and vertically evolving for cross ACC borders and in high & very high complexity environments.
	AOM-504	Optimum Trajectories in Defined Airspaces at Particular Times.
	Accomplished according to operational concept description FR-CAP-01 [6].	
Demonstration Technique	Fast Time Simulation	
Targeted E-OCVM Maturity Level	E-OCVM V3 – Pre-industrial development & integration	
Expected results per KPA	Efficiency: Increase Environmental Sustainability: Increase Safety: Neutral Capacity: Neutral	
Number of trials	504…1,345 (depending on scenario) (number of real world FPLs taken into account)	

Demonstration Exercise ID and Title	**EXE-0201-D-004** **Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Real Time Simulation**
Leading organization	DFS
Short Description	Complementing EXE-0201-D001 and in addition to EXE-0201-D-003 this exercise empirically evaluated effects of different setups of FRAMaK Cross-Border DCTs in Karlsruhe Central Sectors. By means of a Real Time Simulation especially operational feasibility has been investigated.
Demonstration exercise objectives	OBJ-0201-004 Safety of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs do not negatively affect Safety.

OBJ-0201-005	Capacity related to Cross-Border DCTs

It is to be demonstrated that based on a suitable route design the usage of Cross-Border Directs will not negatively affect capacity of the FRAMaK airspace.

OBJ-0201-009	Operator Workload related to Cross-Border DCTs

It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect operator workload and situational awareness of both ATCOs and crews. Contrariwise, based on a suitable route design a reduction of workload and an increase of situational awareness might be achievable.

OBJ-0201-010	Operational Feasibility of Cross-Border DCTs

It is to be demonstrated that Cross-Border Directs provide a sufficient feasibility for operational usage.

Deviation 5: Modification of objectives EXE-0201-D004

In the Demonstration Plan it has been foreseen that the Real Time Simulation concerning the high complexity airspace in the Karlsruhe UAC Core Area also benefits and impacts regarding Efficiency, Environmental Sustainability, Predictability and Cost Effectiveness would be in the scope of the demonstration activity.

However, during the preparation of the simulation it became clear that metrics related to these KPAs do refer to routing information comprising the complete flight path from ADES to ADEP and/or from the ECAC entry point to the ECAC exit point respectively, i.e. for computation of metrics the complete flight path must be available (for details please refer to section 4.1.5.2).

In order to ensure an efficient data preparation the scenario of a RTS is not covering such a big measurement area but is usually limited to the area in the scope of the simulation. As a consequence collecting data which would be necessary to compute the aforementioned metrics are not available in Real Time Simulations.

Thus, the objectives

- OBJ-0201-001
- OBJ-0201-003
- OBJ-0201-007
- OBJ-0201-008

are not covered by EXE-0201-D004.

However, this RTS complements the demonstration activity EXE-0202-D003 which already provides information on the aforementioned KPAs related to DCT routing options to be potentially implemented in the Karlsruhe Core Area. Furthermore, scenario FRA365 investigated the implementation of full Free Route in the KUAC Core Area. Thus, this deviation does not mean any loss of information.

Related Scenario	SCN-0201-001
OFA addressed	OFA 03.01.03 Free Routing
Applicable Operational Context	PAC 03 Moving from Airspace to 4D Trajectory Management SPC 03.01 4D Trajectory Management OI Steps: AOM-500 Direct Routing for flights both in cruise and vertically evolving for cross ACC borders and in high & very high complexity environments. AOM-504 Optimum Trajectories in Defined Airspaces at Particular Times. Accomplished according to operational concept description FR-CAP-01 [6].
Demonstration Technique	Real Time Simulation
Targeted E-OCVM Maturity Level	E-OCVM V3 – Pre-industrial development & integration
Expected results per KPA	Safety: Neutral Capacity: Neutral
Number of trials	504…1,345 (depending on scenario)

Demonstration Exercise ID and Title	**EXE-0201-D-005** **Simulation-based assessment of Cross-Border DCTs: MUAC Core Area Real Time Simulation**
Leading organization	Eurocontrol Maastricht UAC
Short Description	Complementing EXE-0201-D001 this exercise empirically evaluated effects of different setups of FRAMaK Cross-Border DCTs in the Maastricht UAC Core Area. By means of a Real Time Simulation especially operational feasibility has been investigated with a focus on sector clipping issues and methods to address negative effects.
Demonstration exercise objectives	OBJ-0201-004 Safety of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs do not negatively affect Safety. OBJ-0201-005 Capacity related to Cross-Border DCTs It is to be demonstrated that based on a suitable route design the usage of Cross-Border Directs will not negatively affect capacity of the FRAMaK airspace.

	OBJ-0201-009 Operator Workload related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect operator workload and situational awareness of both ATCOs and crews. Contrariwise, based on a suitable route design a reduction of workload and an increase of situational awareness might be achievable. **OBJ-0201-010 Operational Feasibility of Cross-Border DCTs** It is to be demonstrated that Cross-Border Directs provide a sufficient feasibility for operational usage.
Related Scenario	SCN-0201-001
OFA addressed	OFA 03.01.03 Free Routing
Applicable Operational Context	PAC 03 Moving from Airspace to 4D Trajectory Management SPC 03.01 4D Trajectory Management OI Steps: AOM-500 Direct Routing for flights both in cruise and vertically evolving for cross ACC borders and in high & very high complexity environments. AOM-504 Optimum Trajectories in Defined Airspaces at Particular Times. Accomplished according to operational concept description FR-CAP-01 [6].
Demonstration Technique	Real Time Simulation
Targeted E-OCVM Maturity Level	E-OCVM V3 – Pre-industrial development & integration
Expected results per KPA	Safety: Neutral Capacity: Neutral
Number of trials	n/a (Being a Real Time Simulation the number of flights is higher than in real life traffic in order to compensate for simulation effects.)
Remarks	**Deviation 6: Re-Focus of the MUAC Real-Time Simulation** In the Demonstration Plan it has been foreseen that the Real Time Simulation concerning the high complexity airspace in the Maastricht UAC Core Area would study additional "ambitious" DCT routing options, e.g. supporting high density traffic flows. However, since such kind of DCT routing options were already implemented in the course of the FRAMaK project it was decided to re-focus the RTS in order to evaluate mitigation of negative

	effects from sector clipping caused by direct routings. Thus, this deviation does not mean any loss of information.

Demonstration Exercise ID and Title	**EXE-0201-D-006** **Cross-Border User Preferred Routes Flight Trial**
Leading organization	DLH
Short description	EXE-0201-D-006 had a focus on the Airline Operator's option of filing User Preferred Routes within the FRAMaK airspace (FR-CAP-02). In accordance with the FRAMaK Operational Procedure for Cross-Border User Preferred Routes Demonstrations [4] and the FRAMaK - Cross-Border User Preferred Routes Demonstrations Test Plan [2] Deutsche Lufthansa accomplished 62 UPR Test Flights on six citypairs Frankfurt – Stockholm, Frankfurt – Los Angeles, Frankfurt – Vancouver, and Munich – Manchester, Munich – Oslo, Munich – San Francisco. The flight trials started in September 2013 and were completed in March 2014. From Dec 2013 an extended UPR Test Area, comprising parts of UK airspace as well as Danish, Norwegian and Swedish airspace could be used for the planning of User Preferred Routes.
Demonstration exercise objectives	OBJ-0201-011 Flight Efficiency of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes making best usage of e.g. wind effects positively affect flight duration and fuel burn. OBJ-0201-012 Environmental Sustainability of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes positively affect CO_2 emission. OBJ-0201-013 Safety of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes do not negatively affect Safety. OBJ-0201-014 Capacity related to Cross-Border User Preferred Routes It is to be demonstrated that the usage of Cross-Border User Preferred Routes will not negatively affect capacity of the FRAMaK airspace. OBJ-0201-015 Network effects related to Cross-Border User Preferred Routes It is to be demonstrated that the usage of Cross-Border User Preferred Routes will not negatively affect capacity demand in the adjacent centres/sectors serving the connecting ATS routes.

	OBJ-0201-016 Operator Workload related to Cross-Border User Preferred Routes It is to be demonstrated that the usage of Cross-Border User Preferred Routes will not negatively affect operator workload and situational awareness of both ATCOs and crews. **OBJ-0201-017** Operational Feasibility of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes provide a sufficient feasibility for operational usage. **OBJ-0201-018** Interference of simultaneous FRA operations It is to be demonstrated that simultaneous execution of FPLs comprising of Cross-Border DCTs and User Preferred Routes (dual mode operations) does not jeopardize positive effects demonstrated in single mode operation and has no negative impact on Capacity.
Related Scenario	SCN-0201-003
OFA addressed	OFA 03.01.03 Free Routing
Applicable Operational Context	PAC 03 Moving from Airspace to 4D Trajectory Management SPC 03.01 4D Trajectory Management OI Steps: AOM 501 Free Routing for Flights both in cruise and vertically evolving within low to medium complexity environments. AOM-502 Free Routing for Flights both in cruise and vertically evolving within high & very high-complexity environments. Accomplished according to operational concept description FR-CAP-02 [6].
Demonstration Technique	Live Trial (designated flights)
Targeted E-OCVM Maturity Level	E-OCVM V3 – Pre-industrial development & integration
Expected results per KPA	Efficiency: Increase Environmental Sustainability: Increase Safety: Neutral Capacity: Neutral
Number of trials	62 flights

2.1.4.4 Coverage of Demonstration Objectives by Demonstration Exercises Matrix

		Objectives related to FR-CAP-01 Cross-Border DCTs										Objectives related to FR-CAP-02 Cross-Border UPRs							
		OBJ-0201-001 Efficiency (hor.)	OBJ-0201-002 Efficiency (vert.)	OBJ-0201-003 Environment	OBJ-0201-004 Safety	OBJ-0201-005 Capacity (local)	OBJ-0201-006 Capacity (Network)	OBJ-0201-007 Predictability	OBJ-0201-008 Cost Effectiveness	OBJ-0201-009 Workload	OBJ-0201-010 Operational Feasibility	OBJ-0201-011 Efficiency (hor.)	OBJ-0201-012 Environment	OBJ-0201-013 Safety	OBJ-0201-014 Capacity (local)	OBJ-0201-015 Capacity (Network)	OBJ-0201-016 Workload	OBJ-0201-017 Operational Feasibility	OBJ-0201-018 Interference of FRA OPS
Exercises related to Cross-Border DCTs	**EXE-0201-D001** Public Live Trial	X	X	X				X	X		X								
	EXE-0201-D002 SAAM Network Assessment	X		X			X												
	EXE-0201-D003 KUAC Central FTS	X		X	X	X	X		X	X									
	EXE-0201-D004 KUAC Central RTS				X	X				X	X								
	EXE-0201-D005 MUAC Central RTS				X	X				X	X								
UPR	**EXE-0201-D006** UPR Flight Trial											X	X	X	X	X	X	X	X

2.1.4.5 Demonstration Exercises Schedule

The FRAMaK Demonstration Exercises have been accomplished as depicted in Figure 2

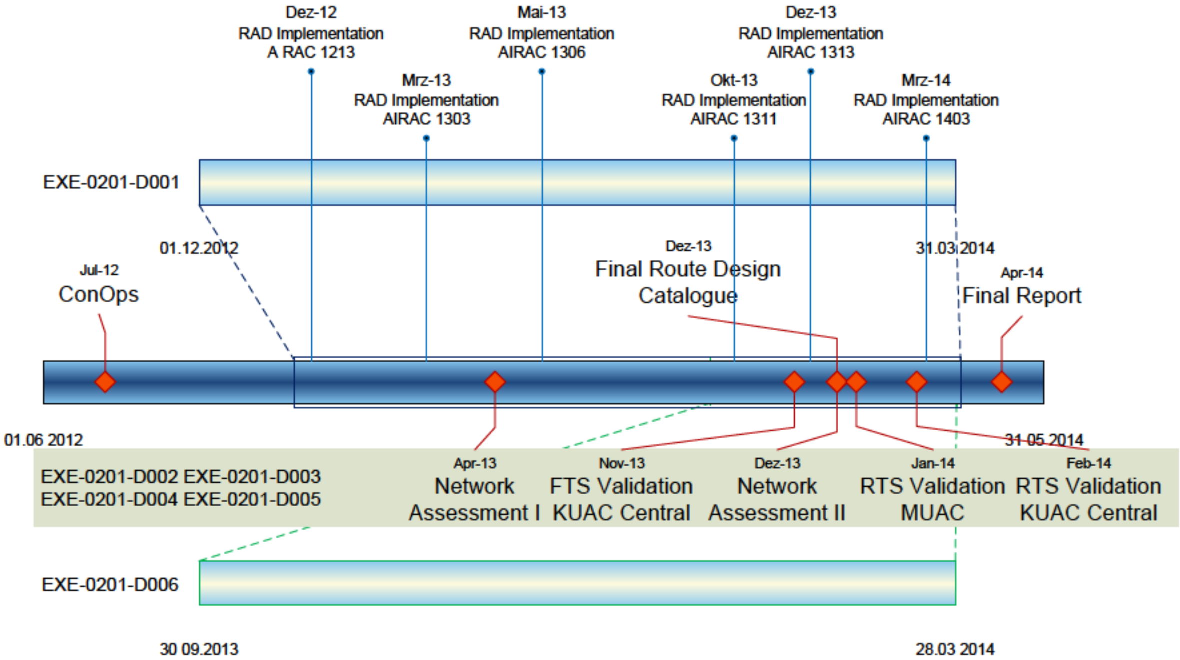

Figure 2: FRAMaK Demonstration Exercises schedule

2.1.5 Link with the SESAR Programme

The FRAMaK project was mainly linked to SESAR Work Packages B, 4, and 7. In the SESAR Concept of Operation Step 1, Free Route is mentioned as one important concept element.

WP 4 (Enroute Operation; Project 04.02 which is steering e.g. 04.07.01, 04.07.02, 04.07.03) and WP 7 (Project 7.5.3 / Free route trials in North European airspace) will pick this up as a more detailed description in the respective DODs. The FRAMaK project worked towards a stepwise implementation of this concept element.

Certainly the FRAMaK project was linked to the goals of the European ATM Master Plan. In its 7th meeting the Master Planning Group (MPG) has identified 12 so-called “Essentials” applicable to SESAR Step 1. These are operational changes which are essential to be deployed in order to reach the SESAR targets. One of the essentials is “Free Routing”.

Free Routing is one of the operational focus areas (OFA 03.01.03), containing Operational Improvements (OIs AOM 501 - 504) for all SESAR Story Board Steps. This shows a clear stepwise approach to introduce Free Routing as a contribution to the Key Feature “Moving from Airspace to 4D Trajectory Management”.

In order to ensure coherence and complementarity of the FRAMaK project with ongoing work in the SESAR working programme (WP7, WP11, respective OFAs) FRAMaK trracked the progress and took into account documents with regard to potential input for the FRAMaK work.

2.2 Stakeholder identification, needs and involvement

Free Route initiatives started individually at MUAC and KUAC in the FRAM respectively FRAK projects since 2009, both having achieved already several Free Route options in their respective airspaces in 2011.

The FRAMaK consortium fostered a common project for cross-border applications which would allow for better efficiency in the development of a common, i.e. consistent, concept and which would allow for benefits especially with regard to KPA Efficiency.

The application for the SESAR CFP facilitated exposure and acted as catalyst for further Free Route initiatives beyond the targeted area, and helped the consortium members to speed up planned implementations.

Participants of the FRAMaK project were DFS Deutsche Flugsicherung GmbH, EUROCONTROL and Deutsche Lufthansa AG (DLH):

DFS acted as the consortium leader. The Karlsruhe UAC of DFS was one of the operational ANSP target entities for the envisaged demonstration. DFS Research & Development provided Fast Time Simulation support.

EUROCONTROL was a consortium member. It participated with Maastricht UAC as one of the operational ANSP target entities for the envisaged demonstration. NMD provided Fast Time Simulation support and NMOC operations has been involved for flight planning validation.

Deutsche Lufthansa AG was a consortium member. It provided customer expectations with regard to route design. DLH conducted flights in the framework of the envisaged demonstration of both Cross Border Directs and Cross Border User Preferred Routes. For both configurations DLH provided analyses of airborne flight data from an Airline Operations point of view.

Internal stakeholders – i.e. the Upper Area Control Centres of DFS Karlsruhe and EUROCONTROL Maastricht, DFS R&D, EUROCONTROL NMD, and DLH – were involved directly in the project.

A close coordination / cooperation took place with adjacent UACs, ACCs as well as with EUROCONTROL NMOC.

External stakeholders as Airspace Users being customers of the Free Route Airspace were airlines, business, general and military aviation.

In detail the following interfaces have been identified:

- EUROCONTROL NMD (Network Management Directorate)
- EUROCONTROL NMOC (Network Management Operations Centre)
- FABEC Free Route Airspace Programme
- Military authorities:
  - Air Defence and Military ATC of Germany and the BENELUX states
  - Air Force Headquarters: BMVg StabInspL / AFsBw, BAC, RNLAF, MAA
  - Military Airspace Users: German, Belgian and Netherlands Air Force
- Surrounding ANSPs:
  - ANS CR (Czech Republic)
  - Austro Control (Austria)
  - Belgocontrol (Belgium)
  - DFS (Germany): ACCs Bremen, Langen, Munich
  - DSNA (France)
  - Isavia (Iceland)
  - LFV (Sweden)
  - LVNL (The Netherlands)
  - NATS (UK)
  - Naviair (Denmark
  - PANSA (Poland)
  - Skyguide (Switzerland)
- SESAR WP B, WP 4, WP 7

3 Programme Management

3.1 Organisation

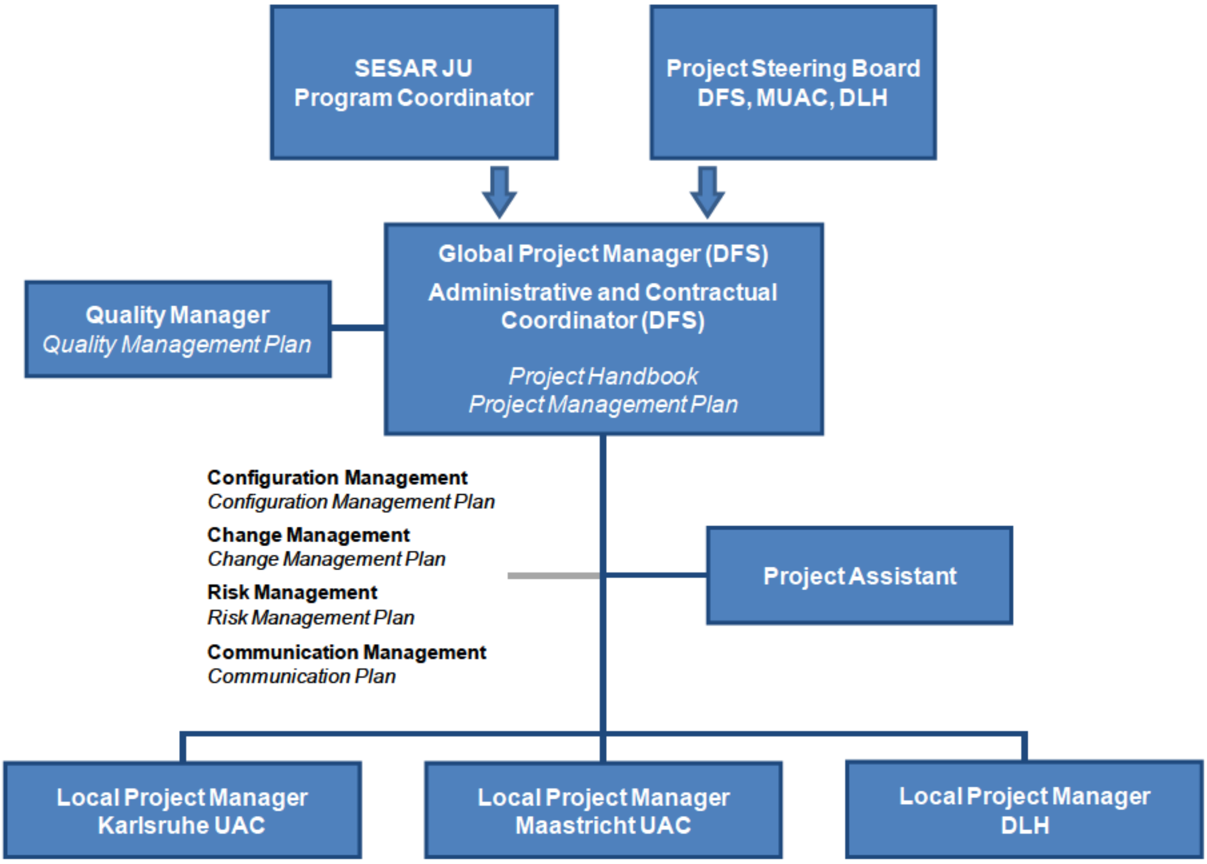

Figure 3: Structure of the FRAMaK Project

DFS as the consortium leader provided an overall project coordinator (Global Project Manager), whose task was to ensure – together with the Local Project Managers of the individual organisation – the planning, execution, reporting and communication of the FRAMaK project. The Global Project Manager acted as the direct interface to the SJU.

Each of the 3 consortium members of FRAMaK were represented by a Local Project Manager with responsibility for the contribution of his organisation and the internal organisation, coordination, communication and reporting of the project.

A Project Steering Board (PSB) has been installed to advise and supervise the project from the perspective of the participating organisations. The steering board has been staffed with executive managers.

The work done by the project itself has been mainly performed by experts committed by the line organisations from project partners, i.e. dispatchers and flight-planners from Lufthansa, airspace experts, ATCOs and project experts from the ANSPs. The SESAR Contribution Management rsp. Coordination Offices of the partners were involved.

The following table informs about the assignments of persons to roles.

Table 4: Roles and assignments

Role	Designated Person	Company
Global Project Manager		DFS
Administrative and Contractual Coordinator		DFS
Local Project Manager Karlsruhe UAC		DFS
Local Project Manager Maastricht UAC		EUROCONTROL
Local Project Manager DLH	(until OCT 2013) (since NOV 2013)	DLH
Steering Board Member:	(until JUN 2013) (since JUN 2013)	EUROCONTROL
Steering Board Member		DLH
Steering Board Member		DFS
Quality Manager		DFS

3.2 Work Breakdown Structure

The project activities were packaged as follows:

Table 5: FRAMaK Work Breakdown Structure

Project Management	
WP 0	**Project Management** WP 0.1 Project Kick-Off WP 0.2 Project Initiation WP 0.3 Project Reporting WP 0.4 Project Close-out
Phase 1 – Preparatory Work	
WP 1	**Preparation of CONOPS (DOD level)** WP 1.1 Draft development WP 1.2 Collection user/customer needs/expectations WP 1.3 Final CONOPS

WP 2	**Route Design**		
	WP 2.1	ANSP route design activities (incl. route design workshops and SAAM route verification)	
	WP 2.2	Airline analysis	
Phase 2 – Simulation Phase			
WP 3	**Network Assessment (SAAM)**		
	WP 3.1	SAAM I	
	WP 3.2	SAAM II	
	WP 3.3	SAAM Network Assessment Report	
WP 4	**KUAC Central Sectors Validation (AirTOp Simulation)**		
	WP 4.1	Preparation FTS	
	WP 4.2	Conduction FTS	
	WP 4.3	Validation Report	
WP 5	**KUAC + MUAC Routes Validation (2 Real Time Simulations)**		
	WP 5.1	MUAC RTS	
	WP 5.2	KUAC RTS	
	WP 5.3	Validation Report	
Phase 3 – Flight Trials			
WP 6	**Operational Validation (Flight Trials)**		
	WP 6.1	Preparation of Operational Validation	
	WP 6.2	Conduct Flight Trials	
		WP 6.2.1	FR-CAP-01 Cross-border DCT Live Trials
		WP 6.2.2	FR-CAP-02 Cross-border User Preferred Trajectories Flight Trials
	WP 6.3	Analysis of Flight Trials / Operational Validation Report	
Transversal Activities			
WP 7	**Safety Assessment**		
WP 8	**Communications and Dissemination**		
WP 9	**Technical Supporting Activities**		

The working programme comprised the following activities:

Table 6: Project working programme

CONOPS
While focusing on general applicable concept elements, framing potential solutions to feasible implementation candidates within the scope of the FRAMaK project.
DESIGN
▪ Collection of user preferences and capabilities, ▪ Design of [FR-CAP-01] and [FR-CAP-02] candidate solutions, ▪ Definition of required transition routes for connection to concerned airports.
VALIDATION
▪ Fast-time simulation of candidate solutions for initial verification of user benefits as well as potential impact on ANSP capabilities, ▪ Real-time simulations for high-fidelity confirmation of ANSP capabilities; e.g. to confirm the feasibility of free routing in busy/complex control sectors such as the KUAC Central-West area.
TRIALS
▪ Planning and introduction of candidate solutions for trial applications, involving safety assessment, publications, installing procedures, adapting systems, training staff etc. as required, ▪ Testing and if necessary adaption of NMOC and ANSP system capabilities required for selected solutions, ▪ Organisation, execution and analysis of Flight Trials for the 2 Free Route applications: - [FR-CAP-01] candidates will be validated and tested through live trials where opportunity traffic (as well as specifically designated flights, if so considered necessary) will deliver ample results and data to verify successful achievements, - [FR-CAP-02] candidates will be validated and tested by dedicated live flight trials conducted by DLH, enabled through temporary network provisions. Through data collection and user feedback, sufficient evidence will be gathered to govern future implementations available to all applicable GAT flight operations.

DFS, EUROCONTROL and DLH, as members of the consortium, planned and executed all required work to achieve the project goals, whereas the control centres of Maastricht (EUROCONTROL MUAC) and Karlsruhe (DFS KUAC) were the designated organisations for operational ANSP participation.

In all phases of the project, DLH supported in design, estimation of benefits, and proof of concept.

The project involved EUROCONTROL Network Management Directorate (NMD) for fast-time simulation support and NMOC operations for flight planning validation. If and where necessary, the project interfaced with military and TMA authorities and/or neighbouring ANSP organisations to realise its objectives.

3.3 Formal Deliverables

Table 7: Formal deliverables schedule

Deliverable name	Planned Date	Actual Date
Demonstration Plan (A1)	16.07.2012	16.07.2012
Demonstration Report (B1)	30.04.2014	19.05.2014

3.3.1 Other deliverables and key project milestones

Table 8: Other deliverables schedule

Deliverable/Milestone name			Planned Date	Actual Date
D04	FRAMaK Validation / Demonstration Plan	WP4+5+6	16.07.2012	16.07.2012
D02	CONOPS Document (part of DEL 01.II)	WP1	16.07.2012	16.07.2012
M01	Project Review Gate	NA	30.05.2013	23.05.2013
D06	KUAC Central Sectors Validation Report (FTS)	WP4	30.11.2013	15.01.2014 (Interim) 27.06.2014
D11	Technical test reports	WP9	30.11.2013	15.01.2014 03.04.2014 (update)
D03	FRAMaK Route Design Catalogue	WP2	31.12.2013	15.01.2014 03.04.2014 (update)
D05	SAAM Network Assessment Report	WP3	31.12.2013	15.01.2014 15.04.2014 (update)
D09	Safety Assessment Summary Report	WP7	31.03.2014	15.04.2014
M02	Project Review Gate	NA	28.03.2014	28.03.2014
D08	FRAMaK Operational Validation Report (Flight Trials)	WP6	15.04.2014	30.05.2014**Fehler Textmarke nicht definiert.**
D07	FRAMaK Routes Validation Report (MUAC + KUAC) (RTS)	WP5	30.04.2014	04.05.2014 (Part I: MUAC)

				27.06.2014Fehler Textmarke nicht definiert. (Part II: KUAC)
D10	Copy of communication material	WP8	30.04.2014	02.07.2014

3.4 Risk Management

For details regarding risk management processes and mechanisms applied in the framework of the FRAMaK project please refer to the project's documentation associated with the FRAMaK Project Handbook [2].

4 Execution of Demonstration Exercises

4.1 Exercises Preparation

4.1.1 Demonstration Concept Overview

4.1.1.1 Concept for the Demonstration of Cross-Border Directs [FR-CAP-01]

In the course of the FRAMaK project a route design for the provision of Cross-Border Directs within the common Maastricht and Karlsruhe airspace has been elaborated, determining entry and exit points as well as transitions from/to the (conventional) ATS Route System. The Cross-Border Direct routing options were published in the Route Availability Document (RAD); for details see 4.1.3. Through this publication the Cross-Border Direct routing options were provided for operational usage to all Airspace Users and will persist beyond the FRAMaK flight trial period ending March 2014. Specific communication informed Airspace Users about the possibility to file these Cross-Border Direct routes in flight plans.

It was assumed that Airspace Users would significantly utilize the newly available Cross-Border Directs which would ensure the large scale demonstration providing a good basis for further analyses of recorded traffic data in order to assess the demonstration objectives. DLH as a consortium member ensured maximum use of those new Directs and also provided special feedback of unexpected technical flight planning difficulties and expected positive impact on flight efficiency.

One of the key investigation areas from an ANSP perspective is to analyse if and how Cross-Border DCTs affect capacity in high traffic areas. For areas of low to medium traffic density in which no capacity degradations were to be expected, i.e. especially in the northern parts of Karlsruhe UAC AoR and Maastricht UAC AoR, Cross-Border DCT routing options were published – in accordance with official procedures – in RAD App 4 based on expert judgements and Fast Time Simulations checking for potential Network-related effects (especially shifting of traffic flows) and the potential savings related to envisaged DCT routing options. DCT routing options published in this way have been publicly available for flight planning and were therefore considered being subject to Public Live Trials (EXE-0201-D001) which were analysed based on FPL and track data collected during 4 measurement periods of one week each.

For areas of high traffic density, primarily formed by the southern parts of Karlsruhe UAC AoR and Maastricht UAC AoR serving the major traffic flow along the axis Amsterdam – Frankfurt – Munich, due to the risk of significant capacity degradations for those high density conditions capacity limits were determined and the operational concept was validated by means of Fast Time Simulations (EXE-0201-D003) and Real Time Simulations (EXE-01-01-D004, EXE-0201-D005).

Deviation 7: Modified Scope of Analyses: Transition Routes

The FRAMaK working program focussed on the experimental implementation and validation of the two capabilities FR-CAP-01 (Cross-Border DCTs), comprising overflights through the FRAMaK airspace as well as inbound/outbound traffic to/from major airports / hubs below this volume, and FR-CAP-02 (User Preferred Routes). Notwithstanding the FRAMaK Demonstration Plan and the FRAMaK Concept of Operations the performance effects resulting from (Compulsory) Transition Routes implemented to improve the connectivity between the Free Route Airspace and major airports has not been assessed in the course of the FRAMaK performance assessment due to a.) the late implementation of these routings and b.) the high number of additional factors influencing the performance of these routings.

4.1.1.2 Concept for the Demonstration of Cross-Border User Preferred Routes [FR-CAP-02]

Since the provision and usage of User Preferred Routes has impact on the flight planning process of the airlines a corresponding demonstration cannot be realized in a large scale trial as applied for the Direct route concept. Therefore, in the FRAMaK context this operational concept was evaluated by means of distinct flights of the project partner DLH.

The FRAMaK project defined, enabled and assessed User Preferred Routes, approximated by DCT segments, such that flights could e.g. follow great circle direction, optimise wind effects or avoid severe weather conditions. These routes were not published but were available for 62 specific scheduled DLH flights serving the citypairs Frankfurt – Stockholm, Frankfurt – Los Angeles, Frankfurt – Vancouver, and Munich – Manchester, Munich – Oslo, Munich – San Francisco in the period from September 2013 until March 2014; these flights formed the EXE-0201-D006.

In addition to FPL and track data also aircrafts' system data and feedback collected through questionnaires to ATCOs, crews and airline dispatchers were measured / collected for analyses.

4.1.2 Operational concept

Being part of the A1 Deliverable as a basis for all demonstration activities the FRAMaK project elaborated a FRAMaK Concept of Operations describing the operational elements for both operations in the framework of FRAMaK Cross-Border DCTs (FR-CAP-01) and FRAMaK Cross-Border User Preferred Routes (FR-CAP-02). A summary is provided below, for details please refer to the "FRAMaK - Concept of Operations" ([6])

The FRAMaK airspace seamlessly interfaced both vertical and lateral via Entry (NPt) and Exit (XPt) points with adjoining non-FRAMaK fixed route airspace or other Free Route Airspaces.

Free Route flights entering and exiting the FRAMaK airspace across its lateral or vertical boundaries had to file at least one NPt and one XPt. (Figure 4, Figure 5).

The possibility to file FRAMaK Cross-Border DCT segments (capability referred to as FR-CAP-01) were available to all airspace users via a GAT FPL, containing a FRAMaK DCT from NPt to XPt, as published in the RAD. Note: This possibility persists after project close-out.

The possibility to file a Cross-Border User Preferred Routing consisting of one or more DCT segments within the FRAMaK airspace (FR-CAP-02) was only available for trial flights operated by DLH and have been exclusively organised for the purpose of the FRAMaK project. DLH had the option to file multiple segments via intermediate points or parts of ATS routes subject to compulsory ATM conditions.

Note:

For the purpose of this project, Cross-Border free routings were restricted to the confines of the FRAMaK area. Further Cross-Border free routing options into/from adjacent/subjacent FRA may be enabled through other initiatives.

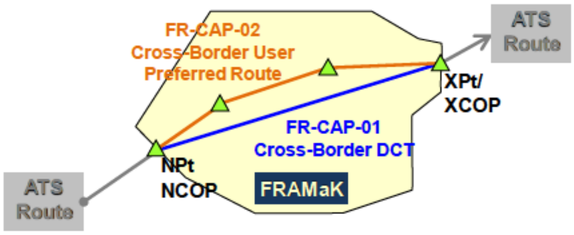

Figure 4: Schematic structure of FRAMaK Cross-Border DCTs and Cross-Border User-Preferred Routes (horizontal cut)

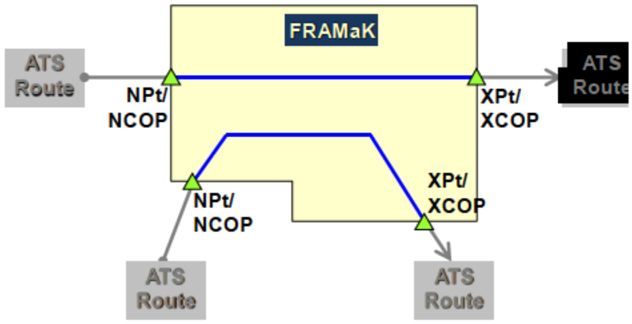

Figure 5: Schematic structure of FRAMaK Cross-Border DCTs and Cross-Border User-Preferred Routes (vertical cut)

If for technical and/or operational reasons entry or exit points could not be used as coordination points at adjacent/subjacent centres, transparency buffers were defined at the boundary within the FRAMaK area. In this case the entry/exit moved along the ATS route inside the FRAMaK area to ensure transparency with the adjacent/subjacent centre (Figure 6, Figure 7).

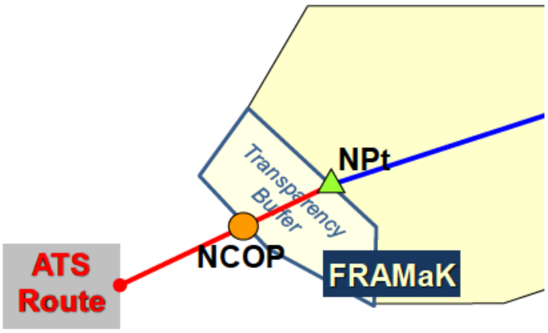

Figure 6: Transparency Buffer (horizontal cut)

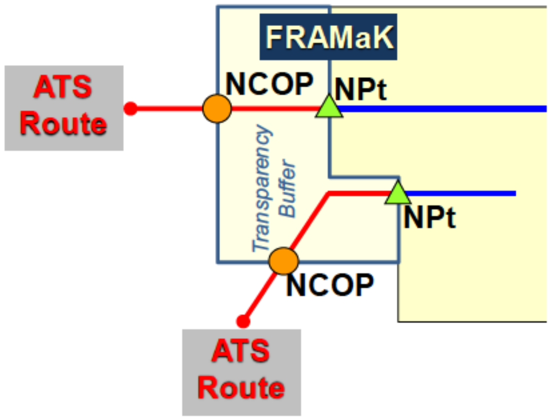

Figure 7: Transparency Buffer (vertical cut)

4.1.3 Preparation of FR-CAP-01 Public Live Trials

4.1.3.1 Route Design (WP2)

A major objective of the Free Route Airspace Maastricht and Karlsruhe (FRAMaK) project is to demonstrate the benefits of "Cross-Border Directs", i.e. DCT routing options which are crossing the boundary between Karlsruhe AoR and Maastricht AoR. Therefore, experts from Eurocontrol Maastricht UAC and DFS Karlsruhe UAC elaborated DCT routing options aiming for an improved horizontal flight efficiency, especially for – though not limited to – those FPL routings crossing the AoR boundary between Maastricht UAC and Karlsruhe UAC. The operational capability arising from those Cross-Border DCTs is referred to as FR-CAP-01.

In the course of the WP2 Route Design activities the project partners organised 11 "Route Design Workshops" of 2 days duration each:

- Route Design Workshop No. 1, 23-24/07/2012, Maastricht
- Route Design Workshop No. 2, 04-05/09/2012, Karlsruhe

- Route Design Workshop No. 3, 24-25/10/2012, Frankfurt
- Route Design Workshop No. 4, 05-06/12/2012, Maastricht
- Route Design Workshop No. 5, 17-18/01/2013, Karlsruhe
- Route Design Workshop No. 6, 06-07/03/2013, Langen
- Route Design Workshop No. 7, 18-19/04/2013, Maastricht
- Route Design Workshop No. 8, 13-14/06/2013, Frankfurt
- Route Design Workshop No. 9, 19-20/09/2013, Brussels
- Route Design Workshop No. 10, 12-13/10/2013, Langen
- Route Design Workshop No. 11, 11-12/12/2013, Bretigny

At these workshops the project partners identified and coordinated

- potential improvements of existing Direct routing options - e.g. those being developed in the framework of the local projects Free Route Airspace Karlsruhe (FRAK) or Free Route Airspace Maastricht (FRAM) - supporting the seamless crossing of the AoR boundary, e.g. with regard to operational availability;
- potentials for enhancing the availability of cross-border routing options by complementing DCTs locally available (stemming e.g. from FRAM and FRAK respectively) with new DCT routing options if no feasible ATS route was available;
- new Cross-Border DCT routing options with or without intermediate points (or Coordination Points) in support of major traffic flows - especially those from/to London, Paris - overflying the combined AoR or Karlsruhe UAC and Maastricht UAC;
- new Cross-Border DCT routing options with or without intermediate points (or Coordination Points) in support of traffic flows from / to major airports in the area of Karlsruhe and Maastricht, i.e. Belgian, Dutch, German airports and ELLX, and in the vicinity, e.g. EKCH, EPWA, LKPR, LOWI, LOWS, LSZH;
- new Cross-Border DCT routing options affecting high-density airspace in the MUAC and/or KUAC Cores Areas which were not foreseen to be published for the Public Live Trials (EXE-0201-D001) but were designated to be further investigated in Fast Time Simulations (EXE-0201-D003) and/or Real Time Simulations (EXE-0201-D004, EXE-0201-D005).

The Route Design Workshops formed the basis for further UAC-internal coordination and discussion and – for those DCTs foreseen for Public Live Trials (see above) – the subsequent publication of DCT routing options in the Route Availability Document (RAD), Appendix 4, under responsibility of the Eurocontrol Network Management Directorate (NMD).

From the date of publication the DCT routing options have been available for the Public Live Trial in the course of FR-CAP-01 Demonstrations.

The complete list of DCT routing options available for Public Live Trials has been published in an internal deliverable [7].

4.1.3.2 Safety Assessments (WP7)

Procedures related to Safety have been accomplished in line with the regular safety procedures and processes in place for the publication of RAD Appendix 4 DCT routing options at Karlsruhe UAC, Maastricht UAC and Eurocontrol NMD.

Deutsche Lufthansa accomplished a Risk Assessment focussing on operational implications related to Cross-Border DCTs, in particular in view of the execution of long-range flight legs.

For details please refer to the FRAMaK D09 Safety Assessment Summary Report [14].

4.1.3.3 Communication Activities

The Airspace Users were invited to state their requirements and were informed about the proposed solutions in the course of customer workshops (c.f. chapter 7 "Summary of the Communication Activities") and conferences (e.g. the AOG Meeting) as well as based on feedback on customer reports (in the framework of "Live Trial Data Analysis & Ad-hoc reporting", WP6.3.1).

Main internal stakeholders on DLH side are the dispatch / flight planning department, the pilots and their fleet management as well as the fuel efficiency department which all were informed by means of internal communication channels.

4.1.3.4 Technical Support Activities (WP9)

Since both ATC systems, MADAP at ECTL Maastricht UAC and P1/VAFORIT at DFS Karlsruhe UAC – being in the same system family – are stemming from the same system manufacturer and are in principle able to handle LAT/LON information the FRAMaK project assumed that this would allow for an automatic OLDI ACT message exchange based on LAT/LON coordinates in connection with Cross-Border DCTs and Cross-Border User Preferred Routes. An early realisation of capabilities for an automatic OLDI LAT/LON data exchange on ACT messages would have been related to significant benefits to the FRAMaK project both with regard to Cross-Border DCTs and Cross-Border User Preferred Routes.

In order to demonstrate the functional capabilities of a LAT/LON-based handover of flights between MUAC and KUAC technical test have been accomplished at Karlsruhe AUC and Maastricht UAC.

As is has been shown in the technical tests, although both systems should be in principle compliant to the usage of LAT/LON information and although both systems are characterised as "OLDI compliant" both the usage of LAT/LON-determined points and the usage of the "nearby COP solution" could not demonstrate the functional capabilities regarding the interaction between MADAP and P1/VAFORIT which are needed for the implementation of Cross-Border DCTs.

Depending on the specific configuration the tests have shown symptoms like

- System rejections of OLDI ACT messages and related error messages, and
- Erroneous trajectory updates,

both requiring manual handling of Flight Plans.

In cases when data have been accepted by the FDPS other system components were not able to cope with e.g. LAT/LON-based information which led to situation pictures not understandable for the controllers.

In expert discussions it was stated that obviously the implementation of the OLDI standard into ATC systems is lacking a sufficient level of standardisation: Although relying on the same standard for data structures and data exchange in different systems the OLDI interface has been implemented in different ways. Furthermore, concepts of subsystems, especially the HMI, obviously did not consider the wide range of applicable mechanisms for data exchange foreseen in the OLDI standard.

From a technical perspective the desired system behaviour should consider:

- In general the cleared WPT should be displayed to the accepting controller, if a DCT is inserted in the system by the transferring sector.
- No manual route update by the controller would be required upon sector entry.
- In addition, the route update should be accomplished by the SDM Message to get a precise trajectory prediction.

In general, the technical tests brought evidence regarding the need for more guidance for the implementation of the OLDI standard into ATC systems or a more stringent determination of the OLDI standard itself. With regard to the implementation of Cross-Border DCTs in the course of the FRAMaK project due to the need for manual FPL handling these will be limited to those DCTs covering low to medium density traffic flows. For major traffic flows an automatic system processing is crucial.

For details regarding the technical tests performed please refer to the FRAMaK D11 Technical Test Report [16].

Deviation 8: Technical Limitations for Implementation of COP-less DCTs

As a consequence for the FRAMaK project, in particular the implementation of COP-less Cross-Border DCTs, the project had to consider that flights using COP-less Cross-Border DCTs require manual coordination which clearly was not possible for DCTs serving major traffic flows. Therefore the implementation of COP-less Cross-Border DCTs had to remain limited to low and medium density flows.

As a workaround DCTs supporting major traffic flows were published as segmented DCTs comprising a COP in the vicinity of the AoR boundary between Karlsruhe UAC and Maastricht UAC.

4.1.4 Preparation of FR-CAP-02 User Preferred Route Flight Trials (WP6)

4.1.4.1 Operational Procedure and Test Plan

Regulations for the design of FRAMaK User Preferred Routes and for the creation of Flight Plans for have been elaborated in the framework of Rote Design Workshops (see 4.1.3.1) and published as a project-internal document ("FRAMaK - Cross-Border User Preferred Routes Demonstrations - Test Plan", [3]).

Since the UPR Flight Trials were accomplished by regular (scheduled) flights a special procedure was developed in cooperation with Eurocontrol NMOC for the Flight Trial notification and the FPL submission and validation ("FRAMaK - Operational Procedure for Cross-Border User Preferred Routes Demonstration", [4]).

Deviation 9: User Preferred Route Test Area Expansion

Following communication with adjacent ANSPs Avinor, LFV, NATS, and Naviair expressed their interest in supporting the FRAMaK User Preferred Route Demonstrations by offering the complete airspace or parts of it for the UPR Flight Trials of Lufthansa.

Effective from 12/12/2013 the UPR Test Area was expanded and comprised the area of BODO OCEANIC FIR, KOBENHAVN FIR, LONDON UIR (NE of GODOS – NATEB – GOMUP), NORWAY FIR, SCOTTISH UIR and SWEDEN FIR (Figure 8).

The Operational Procedure has been revised in the course of the UPR Test Area expansion in cooperation with supporting ANSPs Avinor, LFV, NATS, and Naviair.

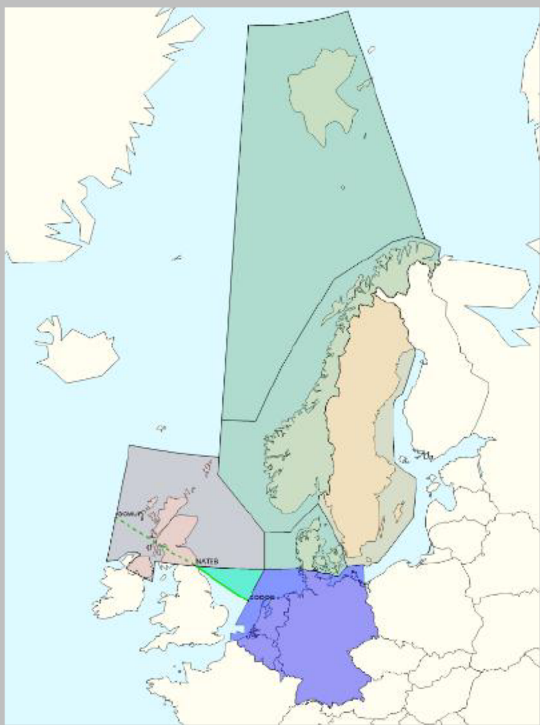

Figure 8: Expanded FRAMaK User Preferred Route Test Area

4.1.4.2 Safety Assessments (WP7)

User Preferred Route Flight Trials have been subject to regular safety procedures and processes in place at Karlsruhe UAC, Maastricht UAC and Eurocontrol NMD.

Deutsche Lufthansa accomplished a Risk Assessment focussing on operational implications related to User Preferred Route Flight Trials.

For details please refer to the FRAMaK D09 Safety Assessment Summary Report [14].

4.1.4.3 Communication Activities (WP8)

General information was provided to adjacent ANSPs in the course of regular work meetings (c.f. chapter 7 "Summary of the Communication Activities") and conferences (e.g. AOG Meeting).

ATCOs at Karlsruhe UAC and Maastricht UAC were briefed by means of internal communication.

Adjacent ACCs (adjacent ANSPs and ACCs of DFS serving Lower Airspace) were informed about the envisaged FRAMaK User Preferred Route Demonstrations and were briefed not to provide any tactical changes of the routing affecting route segments in the FRAMaK airspace for reasons other than safety.

Main internal stakeholders on DLH side are the dispatch / flight planning department, the pilots and their fleet management as well as the fuel efficiency department which all were informed by means of internal communication channels.

4.1.4.4 Technical Support Activities (WP9)

Based on the FRAMaK WP6 FR-CAP-02 Test Plan [2], Appendices A-C, the Deutsche Lufthansa dispatch support created User Preferred Routes and stored them as Lufthansa Company Routes in Lido/Flight to facilitate the calculation of the UPRs for the test flights. Most of the NAT entry/exit points have been connected to EDDF and EDDM via UPRs, some of them with 2 or 3 UPR. The intention was to offer a broad optimization area for the test flights to/from KLAX, KSFO and CYVR. For the flights to/from ENGM, ESSA and EGCC have been created between 1 and 4 UPRs for each city pair. In total Lufthansa created 103 UPRs. NOTAMs and Restricted Airspaces have been considered. Reason why Company Routes were developed was that the LIDO Free Flight module could not optimize the routes just using waypoints (cost optimization). LIDO Free Flight module was also unable to handle the restrictions which apply to the FRAMaK FR-CAP-02 demonstrations (flight planning in accordance with compulsory transition routes etc.).

For the planning of UPR trajectories, Lufthansa uses the flight planning system Lido/Flight provided by Lufthansa Systems. Lido/Flight already supports Lufthansa in all aspects of operational flight planning. The system therefore integrates all relevant flight planning data and constraints in Europe such as AIP, RAD, AUP, NOTAM, etc.

The system has the capability to generate UPR trajectories outside a defined ATS-route network. This system capability is referred to as FreeFlight module which generates a network of segments, in addition to published ATS-route structures, which is required by the discrete optimization algorithms integrated in Lido/Flight. The main application of the FreeFlight module are Oceanic areas (where no ATS-routes exists and flight planning is based on latitude / longitude grid points instead of published waypoints) and it can also be used for the European Free Route concept.

The FRAMaK FR-CAP-02 study, with its particular implementation of Free Route, imposes some requirements towards the flight planning process which shall be further assessed if it is transferred to an operational implementation. In particular, the following requirements of FRAMaK shall be further studied by flight planning system providers:

1. Intermediate Waypoints: The FRAMaK concept specifies an explicit set of intermediate waypoints which are located inside the test area. This shall avoid that the flight plan includes an intermediate waypoint which is only available in the lower airspace beneath the test area. The described FRAMaK requirements towards the "Intermediate Points" specified in Appendix C of "FRAMaK - Cross-Border User Preferred Routes Demonstrations - Test Plan" is new compared to other Free Route airspaces in Europe.

2. Transition Routes: The FRAMaK concept includes mandatory transition routes to / from major airports. A similar concept is already used in Free Route Airspace Denmark & Sweden but FRAMaK imposes a new requirement that links vertical profile requirements to mandatory routes.
3. Vertical Route Efficiency: according to ICAO DOC 4444, the change of cruise flight level can be initiated and indicated at published waypoints or by stating the Latitude / Longitude position in field 15 of the ICAO flight plan. As flight level changes at coordinates cannot be processed by all ATM systems, flight planning systems are currently designed to initiate a change of cruise flight level at a published waypoint only. If segments within a Free Route environment are very long, it can occur that the descent due to flight profile restrictions has to be initiated way too early in the flight plan compared to the actual ATC clearance (e.g. the distance between two waypoints is 500 nm and a profile restriction is applicable at the end of this segment, the descent is initiated about 500nm too early). This has negative implications on the planned fuel consumption and requires general solution for long segments (published or within Free Route areas) which has to be coordinated on Eurocontrol / ICAO level. This limitation of ATC systems can be solved by allowing intermediate waypoints with less distance to a waypoint with profile constraints so that an appropriate Top of Descent point can be determined.

Dispatcher started to create the flightplans of FRAMaK flights as usual. Fuel- and time optimization of a certain routing taking Notams and restrictions into account was the base to create a legal flightplan. The entry waypoints into upper airspace of participating FIRs would lead to a first try to adjoin one of the UPR-Routings. For some entry points there were sometimes more than one UPR-Predictions offered in the flightplanning tool. A flight plan was created accordingly with UPRs. If it turned out that a routing with UPRs was best – means the fastest and the lowest costs, following the FRAMaK Operational Procedure for Cross-Border UPR Demonstrations [4] the dispatcher sent the ATC flight plan to all concerned ANSPs. Afterwards dispatcher calls all supervisors of the ANSPs in charge and asks for acknowledgement of the flight plan. After a while it wouldn't be necessary to call anymore, all involved supervisors would send an acknowledgement via email right away – of course only if they accepted the flight plan. In case a routing would not go through any participating airspaces an email to all ANSP would be send to de-register the flight(s).

On ANSP side no specific technical support activities were accomplished related to User Preferred Route Flight Trials. The results of technical tests performed with regard to COP-less Cross-Border DCTs (4.1.3.4) did not negatively affect the UPR Demonstrations due to the small number of flights which could be handled manually.

4.1.5 Performance Assessment Methodology

4.1.5.1 General Approach

The general approach of the FRAMaK demonstrations is to study effects of FR-CAP-01 and FR-CAP-02 respectively on the Key Performance Areas addressed in the FRAMaK working programme, i.e.

- Efficiency and
- Environmental Sustainability

while the effects on Capacity have to be carefully evaluated. Safety will be carefully monitored since a reduction of safety is unacceptable. Predictability and Cost Effectiveness will be analysed in order to identify potential side effects. Key performance indicators regarding KPA environment are in line with the proposed GHG indicators from SESAR WP 16.03.02 (e.g. delta fuel burn / delta CO_2, deviation to great circle distance according to PRU) [26].

The acceptability of new FRAMaK DCTs and UPRs will be assessed quantitatively in terms of level of utilization and qualitatively by collecting feedback from ATCOs, dispatchers and flight crews by means of questionnaires.

Operator workload will be assessed by means of state-of-the-art workload assessment techniques.

In a nutshell, the assessment shall analyse the benefits of FRAMaK DCTs and UPRs in the aforementioned performance areas in reference to current ATS-route based operations (reference) and shall compare both conditions (FRAMaK DCT Ops and ATS-based Ops) with theoretical horizontal optimums formed by Great Circle routings (outside 40 NM TMA areas)[4].

4.1.5.2 Effects to be analysed / Experimental Design

In order to identify and quantify effects of new operational concepts several comparisons between (Key Performance) indicators were foreseen in the context of the following analyses:

- Analyses related to the current situation (reference),
- Analyses related to FR-CAP-01,
- Analyses related to FR-CAP-02,
- Analysis of contrasts between FR-CAP-01 and FR-CAP-02.

For both of the mentioned primary KPAs route length (or route extension) forms one of the primary drivers for optimization and the basis for data analysis, especially with regard to FR-CAP-01. We assume that the introduction of new FRAMaK DCTs or the usage of UPRs will have effects within the FRAMaK area (local effects leading to enhanced directness and enhanced flight efficiency inside the FRAMaK airspace) and beyond (global effects e.g. due to shifting of traffic flows between the FRAMaK airspace and adjacent AoRs and therefore route extension variations also outside the FRAMaK airspace). Some examples can illustrate this differentiation:

Assuming there is an ATS route within the FRAMaK airspace currently available which is frequently used for flights connecting ADEP and ADES (Figure 9, green line). If a new FRAMaK DCT is introduced (blue line) it is possible to calculate the enhanced directness and straightness of the DCT routing. This can be done by exclusively referring to the FRAMaK airspace which would express, to which extent the route extension of relations between ADEP and ADES has been reduced within the FRAMaK airspace.

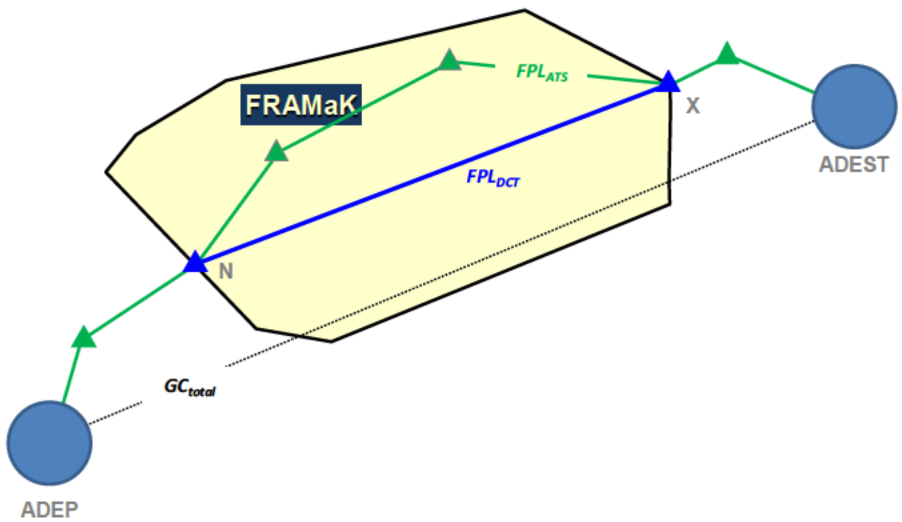

Figure 9: FRAMaK DCT and current ATS route both within FRAMaK airspace

Figure 10 reflects situations which show the limitations of an only local assessment:

- For the FRAMaK DCT ($\overrightarrow{N_2X_2}$) not connecting the entry (N_1) and exit (X_1) waypoint of an existing ATS route, the route efficiency benefit is not directly related to the route lengths within the FRAMaK area because FRAMaK parts of total routings are differing. It might even happen

[4] Due to constraints regarding availability of data for the analysis of FPLs and track information only portions of the flight covered by the ECAC area will be considered.

that a FRAMaK DCT is longer than the FRAMaK part of the current ATS route for the citypair ADEP-ADES but the total route length is shortened by the new (long) DCT.

- If the new FRAMaK DCT has a higher efficiency than the violet ATS-based routing available in an adjacent airspace, this will probably attract additional traffic from the adjacent airspace to the FRAMaK area. Clearly, a local assessment could be accomplished comparing the green ATS route with the DCT – however, the value of this assessment would be limited if the green ATS routing is usually not used for flights connecting ADEP and ADES. Thus, also in this case the effect of the FRAMaK DCT can only be assessed when referring also to non-FRAMaK route segments.

  It has to be noted that in the course of such total assessment non-FRAMaK effects will influence the results: If adjacent ANSPs modify routings to or from the FRAMaK airspace, e.g. introducing DCTs from ADEP to the entry point or from the exit point to ADES (Figure 10, dashed blue lines), the resulting total route efficiency will be affected by any of these modifications.

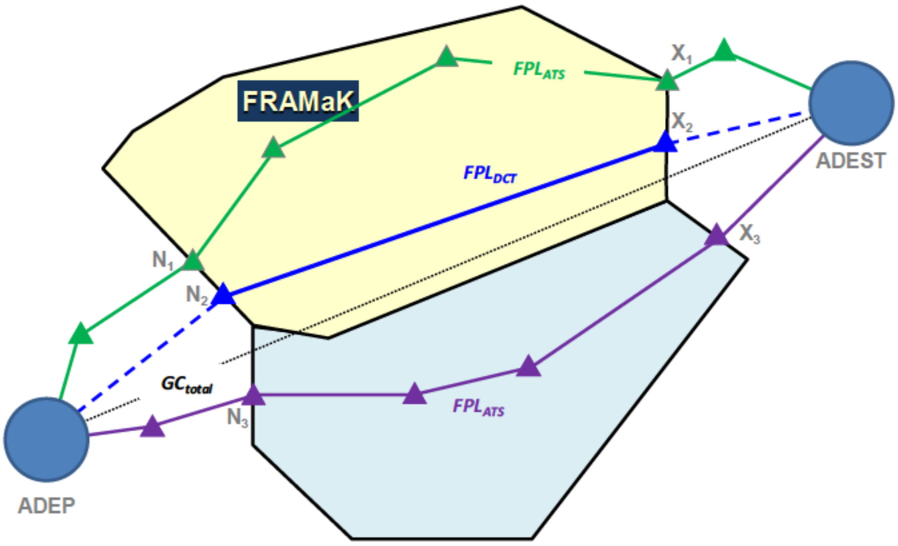

Figure 10: FRAMaK DCT and current ATS routes in FRAMaK and adjacent airspace

Thus, the benefits of the blue DCT routing vs. the green ATS-based routings can be expressed in terms of a route length difference in Nautical Miles within the FRAMaK airspace if and only if the DCT routing makes use of the same entry and exit points as the ATS-based routing. In any other case the new DCT routing will also affect the routing (and therefore route segments' lengths) within adjacent airspaces. From this perspective it seems reasonable to calculate route length (and related fuel burn and environmental parameters) differences between a FRAMaK DCT or UPR solution against the reference scenario with a reference to the total route length ADEP to ADES.

In addition to those Key Performance Indicators related to Efficiency which have been defined within SESAR additional indicators related to horizontal flight efficiency (REDES, RESTR) will be used (see section 4.1.5.3.1).

4.1.5.2.1 Optimum

The optimisation of horizontal flight efficiency, i.e. shorter route length, and vertical flight efficiency, i.e. optimal descent path, has to be accomplished in a balanced way since these two efficiency aspects are usually contrary in the Central European high density airspace. Thus, a shorter trajectory may be related to an earlier top of descent in order to avoid conflicts between arriving and departing traffic or other traffic flows. Vice versa, an optimal vertical profile may require a slight horizontal detour in order to de-conflict horizontal and vertical flows.

Following the approach of formalising daily ATCO behaviour related to the provision of tactical DCTs, DCT routing options which are developed in the FRAMaK project to a major extent aim for improving horizontal flight efficiency while 17 DCT routing options have been offered to allow for optimised descent paths, i.e. improved vertical flight efficiency.

Since the trade-off between horizontal and vertical flight efficiency is not well-known the approach for the assessment of flight efficiency has been different between those DCTs offered for improved horizontal and those offered for improved vertical flight efficiency: DCTs which offer an improved horizontal routing were exclusively assessed with regard to the horizontal flight efficiency referring to the lateral optimum.

Deviation 10 Modified approach for assessment of Vertical Optimization Directs

It was planned that in addition, those DCTs offering an improved vertical profile would be assessed with regard to vertical flight efficiency referring to a vertical descent optimum. However, the DCTs published with the aim of vertical flight efficiency improvements were designed in a way allowing for a late descent at a later stage in flight progress by separating arrival flows from other flows. Therefore, their impact is a kind of “indirect” to the vertical flight efficiency: The descent phase as such has not been necessarily affected by the DCT routing. Thus, the available data regarding the use of the DCT routing options did not allow for an evaluation of fuel burn on this routing with special emphasis on vertical deviations from the optimum. Furthermore, in this kind of analysis aircraft-related parameters like weight, cost index etc. have a major impact on the fuel burn. Such information was not available on ANSP side.

The project partners agreed to evaluate Vertical Optimization DCTs based on analyses of flights within the Public Live Trial (EXE-0201-D001) based on an average value for fuel burn saving calculated by means of the LIDO Flight Planning System, comparing the conventional routing and the FRAMaK DCT option.

In general while ignoring weather influences the Great Circle distance is assumed to be the lateral optimum for all operations in scope of the FRAMaK project.

The Great Circle (orthodromic) distance is the shortest distance between any two points on the surface of a sphere measured along a path on the surface of the sphere. With reference to [5] the relevant paths for FRAMaK analyses are defined as follows:

Table 9: Great Circle Determinations

	Definition	Rationale
GC_{total}	The direct path between the departure airport and the destination airport reduced by the TMA radius around each airport which is 40 NM. $GC_{total} = \left\|\overrightarrow{ADEP\,ADEST}\right\| - 2 \cdot 40NM$	The performance assessment shall consider effects with regard to overall routings. Referring to GC_{total} the contribution of FRAMaK DCTs/UPRs to the reduction of total route extension and the feasibility of FRAMaK routing options locations can be assessed.
GC_{NX}	The optimum path within the FRAMaK airspace assuming a given entry point (N) and a given exit point (X) $GC_{NX} = \left\|\overrightarrow{NX}\right\|$	The performance assessment shall consider effects limited to the FRAMaK area, i.e. not considering potentially non-optimal routings outside the FRAMaK area. Referring to GC_{NX} FRAMaK entry points are considered as being given.

4.1.5.2.2 Reference

As reference the current situation, i.e. flight operations based on the ATS network-related routings as well as already existing DCTs (e.g. from projects like FRAM, FRAK, FABEC Night Network) has to be assessed. Figure 11 illustrates the relevant routing conditions (Note: entry and/or exit points may also be located at the lower boundary of FRAMaK airspace towards subjacent airspace).

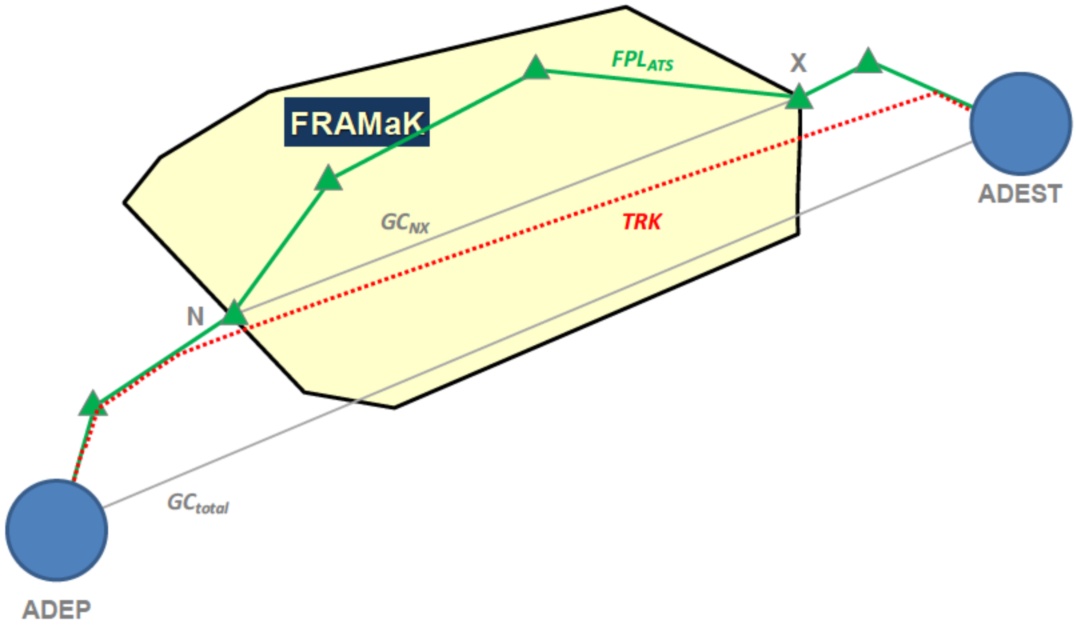

Figure 11: Graphical representation of routings to be analysed for the baseline situation

Referring to the graphical example illustrated in Figure 11 the routing to be analysed is

- the lateral optimum GC_{total},
- the FRAMaK airspace related optimum GC_{NX},
- the routing based on the filed flightplan FPL_{ATS} from ADEP via the KUAC/MUAC airspace entry point N, the KUAC/MUAC exit point X, to ADES,
- the actual flown track TRK;

Figure 12 illustrates which comparisons between routing conditions are foreseen.

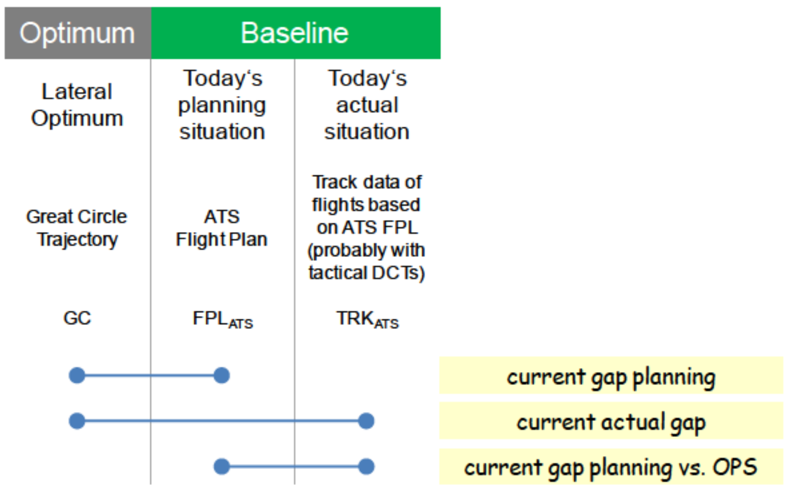

Figure 12: Comparisons foreseen for the analysis of the reference situation

In the following comparisons between routing conditions are explained in more detail:

FPL_{ATS} vs. GC — Indicator values resulting from a FPL which is based on the current ATS network vs. indicator values arising from the lateral optimum.

TRK_{ATS} vs. GC	Indicator values related to actual track data collected for a flight with an ATS-based FPL vs. indicator values arising from the lateral optimum.

4.1.5.2.3 Analyses related to FR-CAP-01

Figure 13 shows routings to be considered for the assessment of FR-CAP-01, Cross-Border DCTs (Note: entry and/or exit points may also be located at the lower boundary of FRAMaK airspace towards subjacent airspace, c.f. Figure 5.)

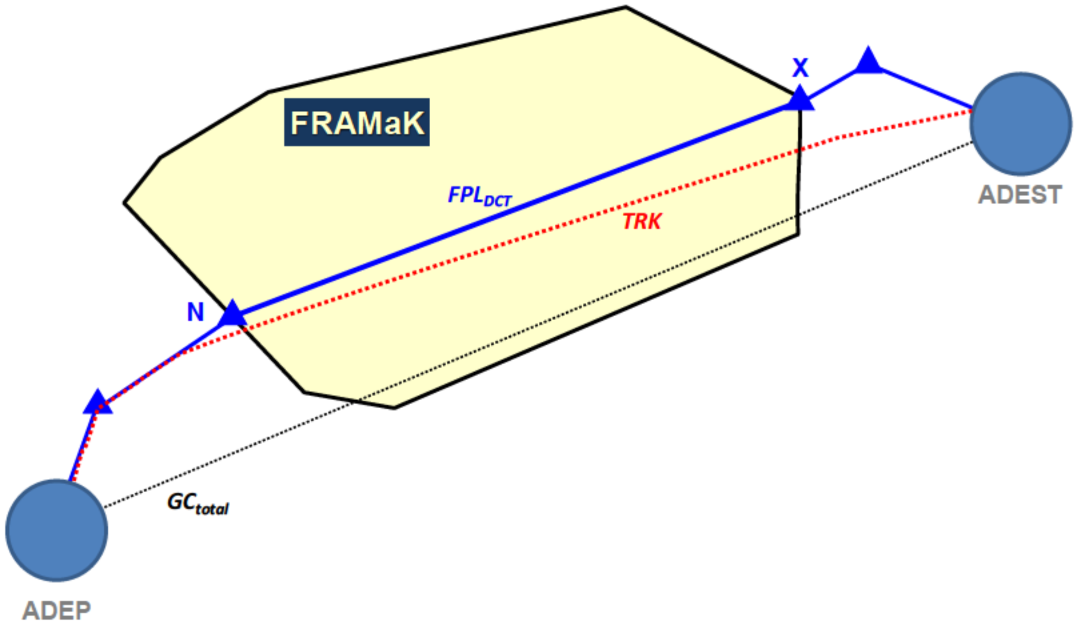

Figure 13: Graphical representation of the routing to be analysed regarding FR-CAP-01

For the assessment of Cross-Border DCTs connecting airports / hubs below FRAMaK airspace see Figure 14.

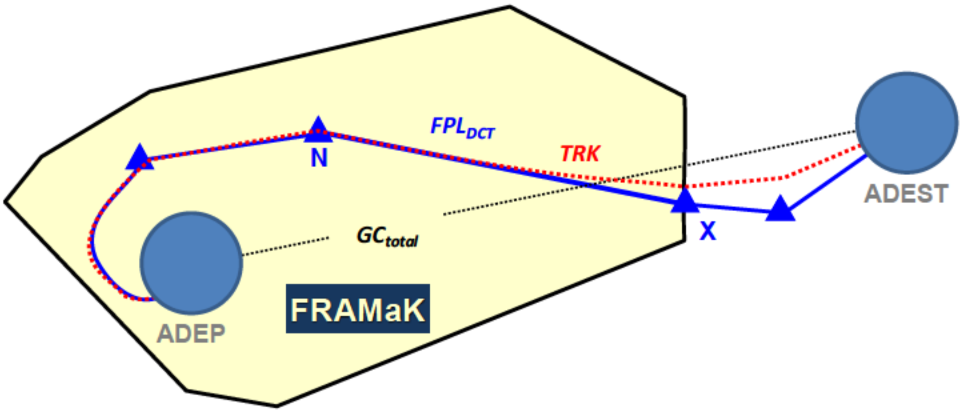

Figure 14: Graphical representation of routing conditions to be analysed regarding Cross-Border DCTs connecting airports / hubs below FRAMaK airspace

In both exercises the performance of Cross-Border DCTs will be compared with the lateral optimum GC_{total} and GC_{NX} and flight operations based on ATS related FPLs. This will be accomplished based on FTS, RTS and Live Trials.

Referring to the graphical example illustrated in Figure 13 and Figure 14 the routings to be analysed are

- the FRAMaK airspace related optimum GC_{NX},

- the routing based on the filed flightplan FPL_{DCT} from ADEP via the FRAMaK entry point N, the FRAMaK exit point X, to ADES,
- the actual flown track TRK_{DCT}.

Figure 15 illustrates which comparisons between routing conditions are foreseen.

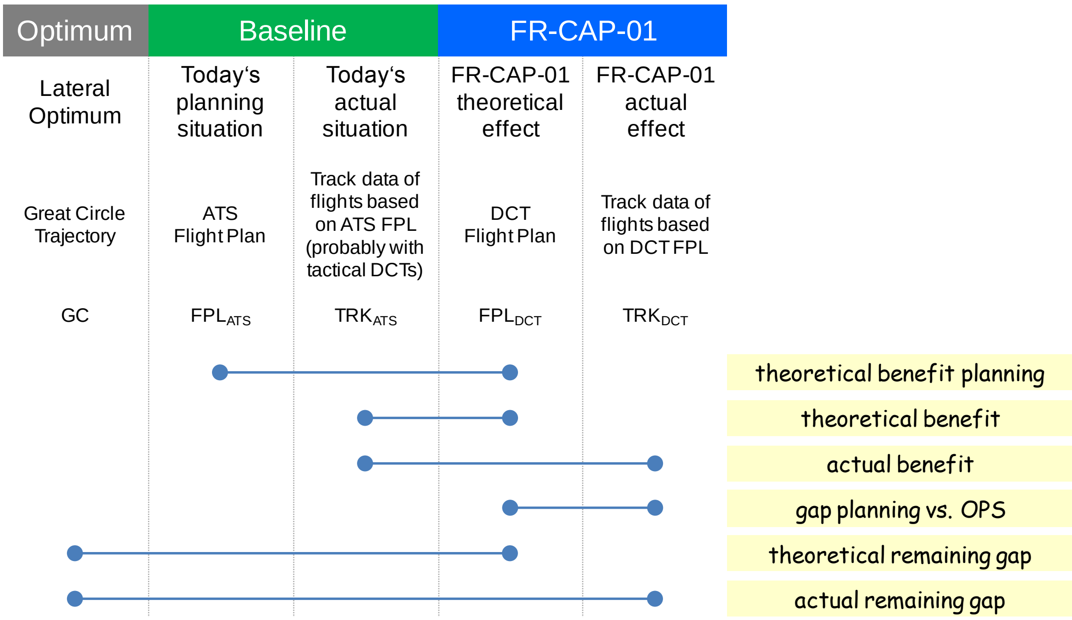

Figure 15: Comparisons foreseen for the analysis of Cross-Border Directs

In the following comparisons between routing conditions are explained in more detail:

FPL_{DCT} vs. FPL_{ATS} — Deviation of the indicator resulting from a Cross-Border DCT FPL (FR-CAP-01) from indicator values arising from a FPL based on the current ATS route network.

Purpose: To inform about the improvement to be theoretically achieved by FR-CAP-01 based on route planning data.

FPL_{DCT} vs. TRK_{ATS} — Deviation of indicator resulting from a Cross-Border DCT FPL (FR-CAP-01) from indicator values related to actual track data collected for a flight with a conventional ATS FPL.

Purpose: To inform about the improvement to be theoretically achieved by FR-CAP-01 in view of the today's actual situation, e.g. with respect to predictability and therefore better fuel uplift prediction.

TRK_{DCT} vs. TRK_{ATS} — Deviation of indicator related to actual track data collected for a flight with a Cross-Border DCT FPL (FR-CAP-01) from indicator values related to actual track data collected for a flight with a conventional ATS FPL.

Purpose: To inform about the actual improvement achieved by FR-CAP-01 in view of the today's actual situation.

TRK_{DCT} vs. FPL_{DCT} — Deviation of indicator related to actual track data collected for a flight with a Cross-Border DCT FPL (FR-CAP-01) from indicator values related to the underlying FPL.

Purpose: To inform about the gap between the theoretical (planning) and the actual effect. Thus, to inform about the new system's quality of prediction, e.g. RMS-error as indication on necessary reserve fuel.

FPL_{DCT} vs. GC	Deviation of the indicator resulting from a Cross-Border DCT FPL (FR-CAP-01) from indicator values arising from the lateral optimum.
	Purpose: To inform about the gap theoretically remaining for the Upper Airspace after implementation of FR-CAP-01. Referring to the hub connectivity (OBJ-0201-002) this comparison also informs about the suitability of newly created Transition Routes.
TRK_{DCT} vs. GC	Deviation of the indicator related to actual track data collected for a flight with a Cross-Border DCT FPL (FR-CAP-01) from indicator values arising from the lateral optimum.
	Purpose: To inform about the gap actually existing for the Upper Airspace after implementation of FR-CAP-01.

4.1.5.2.4 Analyses related to FR-CAP-02

For the assessment of FR-CAP-02, Cross-Border User Preferred Routes (UPRs), routing conditions depicted in Figure 16 are to be considered during FTS, RTS and Live Trials (Note: entry or exit point may also be located at the lower boundary of FRAMaK airspace towards subjacent airspace).

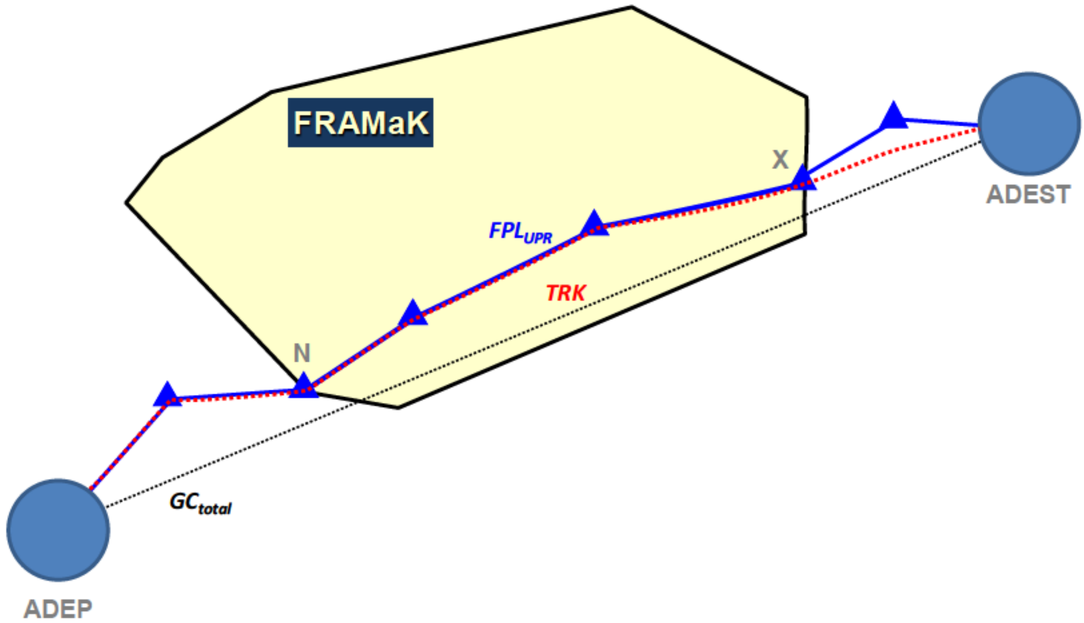

Figure 16: Graphical representation of routing conditions to be analysed regarding FR-CAP-02

The following Figure 17 illustrates which comparisons between routing conditions are foreseen.

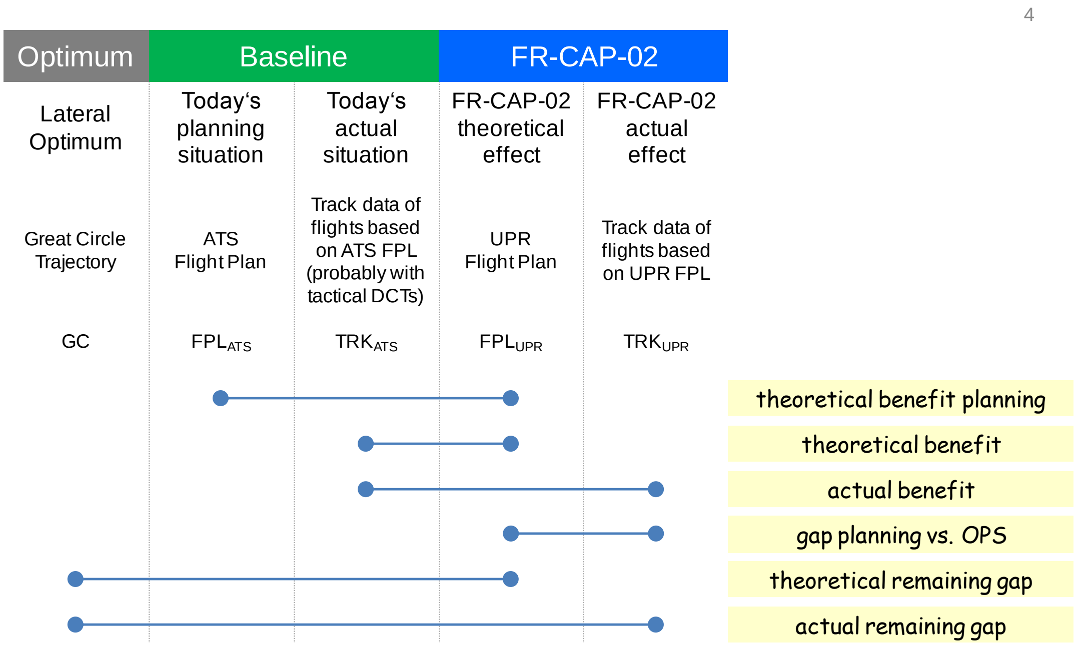

Figure 17: Comparisons foreseen for the analysis of Cross-Border User Preferred Routes

In the following comparisons between routing conditions are explained in more detail:

FPL_{UPR} vs. FPL_{ATS}
Deviation of the indicator resulting from a Cross-Border UPR FPL (FR-CAP-02) from indicator values arising from a FPL based on the current ATS route network.

Purpose: To inform about the effect theoretically arising from FR-CAP-02 based on route planning data.

FPL_{UPR} vs. TRK_{ATS}
Deviation of indicator resulting from a Cross-Border UPR FPL (FR-CAP-02) from indicator values related to actual track data collected for a flight with a conventional ATS FPL.

Purpose: To inform about the effect theoretically arising from FR-CAP-02 in view of the today's actual situation.

TRK_{UPR} vs. TRK_{ATS}
Deviation of indicator related to actual track data collected for a flight with a Cross-Border UPR FPL (FR-CAP-02) from indicator values related to actual track data collected for a flight with a conventional ATS FPL.

Purpose: To inform about the effect actually arising from FR-CAP-01 in view of the today's actual situation.

TRK_{UPR} vs. FPL_{UPR}
Deviation of indicator related to actual track data collected for a flight with a Cross-Border UPR FPL (FR-CAP-02) from indicator values related to the underlying FPL.

Purpose: To inform about the gap between the theoretical and the actual effect.

FPL_{UPR} vs. GC
Deviation of the indicator resulting from a Cross-Border UPR FPL (FR-CAP-02) from indicator values arising from a Great Circle track which forms the lateral optimum with regard to route length.

Purpose: To inform about the gap theoretically remaining after implementation of FR-CAP-02.

TRK_{UPR} vs. GC — Deviation of the indicator resulting from a Cross-Border UPR FPL (FR-CAP-02) from indicator values arising from a Great Circle track which forms the lateral optimum with regard to route length.

Purpose: To inform about the gap actually existing after implementation of FR-CAP-02.

4.1.5.2.5 Contrasts between FR-CAP-01 and FR-CAP-02

Clearly, the operational concept of Cross-Border Directs (FR-CAP-01) and Cross-Border User Preferred Routes (FR-CAP-02) aim for optimizing flight operations in different way, the first one towards a minimization of route length which will also affect other addicted/subsequent indicators, the second one directly towards a minimization of fuel burn through exploitation of e.g. tailwind effects. In order to analyse which operational concept results in the best benefits, probably taking into account different operational conditions, the routing conditions and related comparisons illustrated in Figure 18 are to be considered.

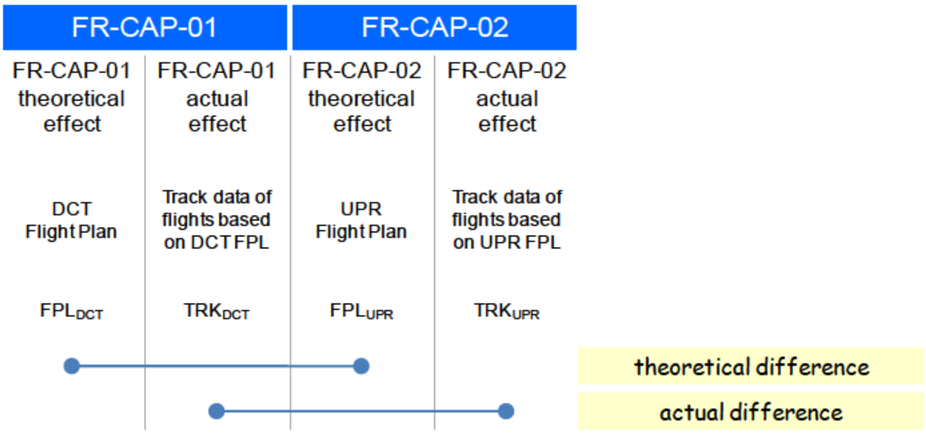

Figure 18: Comparisons foreseen for the analysis of contrasts between Cross-Border Directs and Cross-Border User Preferred Routes

In detail, the following comparisons are to be accomplished:

FPL_{DCT} vs. FPL_{UPR} — Deviation of the indicator resulting from a Cross-Border UPR FPL (FR-CAP-01) from indicator values arising from a User Preferred Route FPL (FR-CAP-02).

Purpose: To compare the theoretical effects of the two operational concepts.

TRK_{DCT} vs. TRK_{UPR} — Deviation of indicator resulting from actual track data collected for a flight with a Cross-Border DCT FPL (FR-CAP-01) from indicator values arising from actual track data collected for a flight with a Cross-Border DCT UPR (FR-CAP-02).

Purpose: To compare the actual effects of the two operational concepts.

4.1.5.3 Data Collection

4.1.5.3.1 Sources of Data

The following data were collected for analyses:

Table 10: Sources of Data

Routing	Required/Related data	Delivered by	Provided by tool
FPL data	Flight Plans for the measurement epoch (last filed FPL)	ECTRL DDR	-/-
	Flight Plans for the measurement of fuel consumption from LIDO flight (FR-CAP-02)	DLH	LIDO flight
GC data	GC-trajectories calculated from FPL data	ECTL DDR	SAAM
TRK	Trajectory data resulting from simulations with respective performance models, simulation behaviour (e.g. considering dynamic sector load balancing) and/or user interaction.	-/-	FTS (SAAM & AirTOp) RTS
	Trajectory data for the measurement epoch	ECTL DDR	SAAM
	Actual fuel burn data from FMS post flight reports (FR-CAP-02)	DLH	A/C FMS

4.1.5.3.2 FR-CAP-01 Public Live Trials: Sampling

4.1.5.3.2.1 Measurement / Analyses Periods

Data analyses has been accomplished based on flights within 4 measurement periods which were referenced against the respective period in the previous year. For measurement period 4 a second comparison has been accomplished with the respective period two years before which allows for a full comparison between the periods before and after FRAMaK DCT implementations. However, small sample sizes for paired comparisons between MP4 and REF1 led to the conclusion that analyses should be accomplished based on weighted averages of all four measurement.

Table 11: Measurement and Reference Periods

Period	Time	Reference
MP1	2013, Week 12, 18/03-24/03/2013	2012, Week 12, 19/03-25/03/2012
MP2	2013, Week 26, 24/06-30/06/2013	2012, Week 26, 25/06-01/07/2012
MP3	2013, Week 44, 28/10-03/11/2013	2012, Week 44, 29/10-04/11/2012
MP4	2014, Week 12, 17/03-23/03/2014	2013, Week 12, 18/03-24/03/2013
MP4b	2014, Week 12, 17/03-23/03/2014	2012, Week 12, 19/03-25/03/2012

Within the measurement period and the reference period respectively comparisons have been accomplished for

- complete weeks (MON – SUN), and
- weekends (SAT + SUN).

4.1.5.3.2.2 Geographical Coverage

FPL and track data were available at the EUROCONTROL Digital Data Repository (DDR). These data are regularly collected for all flights affecting the ECAC airspace (Figure 19).

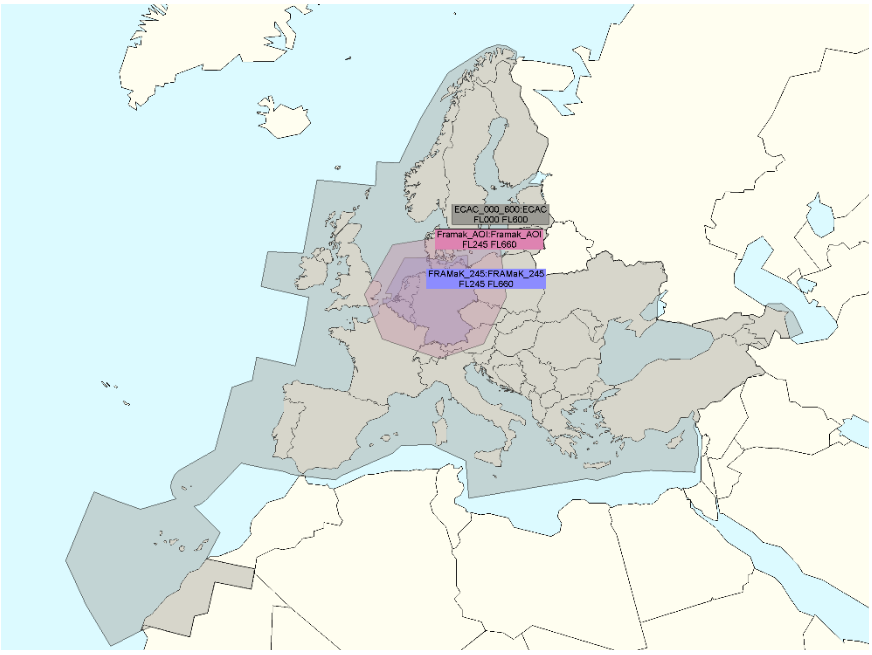

Figure 19: ECAC Area with data availability (GND – FL660)

In order to enhance the efficiency of query operation a database filter was applied which limits the airspace in which algorithms were looking for flights which have been eligible for a FRAMaK DCT. The filter corresponds to the FRAMaK Area of Interest shown in Figure 20.

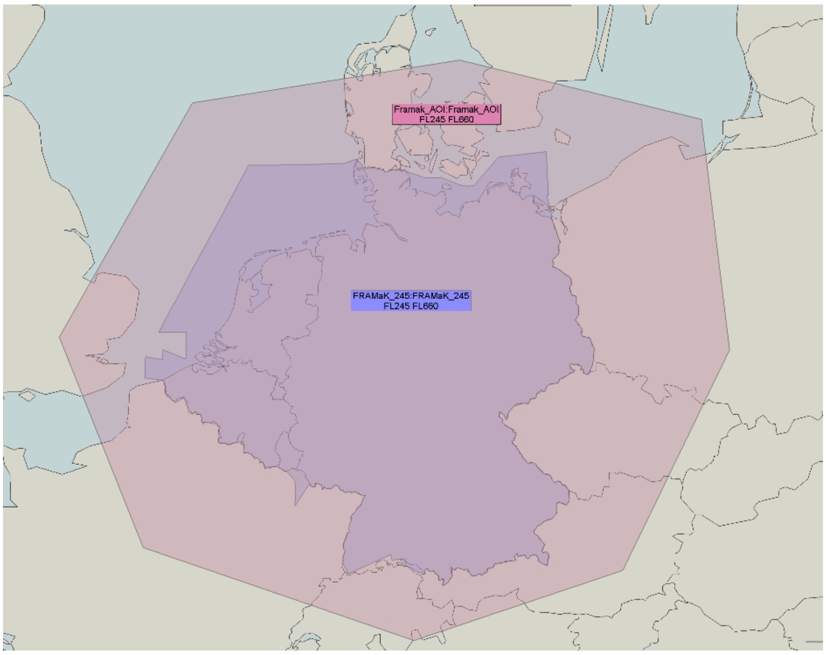

Figure 20: FRAMaK Area of Interest (FL245-FL660)

4.1.5.3.2.3 Matching Criteria between Measurement Period and Reference

For the identification of flights within the measurement period which are to be compared with the respective flight in the reference period the matching criteria listed in Table 12 were effective.

It has to be noted that even with a high identicalness of flights between the measurement period and the respective reference period (e.g. if matching criteria 1, 2, or 3 is met) the difference in routing might have been affected by strong influences of factors other than FRAMaK DCT availability, in particular by differences in weather conditions influencing wind directions en-route and/or the direction of runway-in-use at the aerodromes which were not considered in the analyses.

For analyses related to indicators depending on the aircraft type (e.g. fuel burn) only flights with matching criteria 1, 3, or 5 have been analysed.

Table 12: Matching criteria for flights

Criteria	Origin AND Destination	Operator	Aircraft Type	ICAO Callsign	SDT delta
1	X		X	X	< 3 h
2	X			X	< 3 h
3	X	X	X		< 3 h
4	X	X			< 3 h
5	X		X		< 1 h
6	X				< 1 h

Cancelled flights were pairwise eliminated from the analyses.

4.1.5.3.2.4 Data collection

FPL and track data (CPF) for data analysis were collected according to the following steps:

- Within each measurement period flights were identified which filed at least one FRAMaK DCT.
- Based on the collection of flights within the measurement period flights of the reference period were identified which meet one of the matching criteria listed in Table 12.

Doing so, the database for data analyses contained only flights operated during the measurement period and with a FPL comprising at least one FRAMaK DCT.

As a result the database comprised the number of flights shown in Table 13.

Table 13: Sample sizes

Measurement Period		Flights in FRAMaK area number	Flights filed DCT number
MP1	Complete Week	49,002	2,992
	Weekend	13,747	1,071
MP2	Complete Week	61,486	4,743
	Weekend	17,179	1,656
MP3	Complete Week	59,557	4,758
	Weekend	16,161	1,611
MP4	Complete Week	55,395	4,802
	Weekend	14,871	1,596
Total	Complete Week	225,440	17,295
	Weekend	61,958	5,934

For comparisons between measurement periods and reference periods flights were further filtered according to the aforementioned matching criteria.

4.1.5.4 Analyses Elements

Being a demonstration activity not starting from scratch but based on former Free Route activities like FRAM and FRAK there is no need for a solely sequential approach. Thus, the analyses subsequent to the route design and the network assessment, i.e. whether to accomplish a FTS, a RTS or a combination of both, depend upon the operational conditions to be considered and investigated. Therefore, it is possible that if mature background knowledge is available from former activities FRAM and/or FRAK new FRAMaK DCTs are published without preceding FTS (in excess of mandatory SAAM route validations prior to RAD publication) or RTS. At KUAC side simulation-based analyses in particular will deal with the so-called Karlsruhe Central sectors which form the maximum density airspace covering southwest Germany.

The validation of the FRAMaK operational concept with regard to FR-CAP-01 and FR-CAP-02 comprises the following validation activities:

Table 14: Analyses elements

Activity	Objective	Responsible
SAAM Network Assessment EXE-0201-D002	To study FRAMaK DCT routing proposals with regard to connectivity to adjacent/subjacent airspace, resulting traffic flows etc. and to analyse potential benefits.	ECTL NMD
KUAC Central FTS **SAAM/NEST Assessment** EXE-0201-D003	To study FRAMaK solutions for KUAC Central Sectors with regard to connectivity with adjacent westerly airspace in context of other FABEC activities (IP LUX, CBA Land/West); this FTS will be used as basis for the AirTOp FTS.	ECTL NMD

Activity	Objective	Responsible
KUAC Central FTS **AirTop** EXE-0201-D003	To study FRAMaK solutions for KUAC Central Sectors in specific sectors with regard to sector load at crossing points, workload; this FTS will be used as basis for the KUAC Central RTS.	DFS
KUAC Central RTS EXE-0201-D004	To study FRAMaK solutions for KUAC Central Sectors in a real time simulation.	DFS
MUAC RTS EXE-0201-D005	To study FRAMaK solutions in high density airspace of MUAC AoR.	ECTL MUAC
Live Trials EXE-0201-D001 EXE-0201-D006	To study AEM scenario economy (distance, time, fuel burn, CO_2, NO_x), attractiveness of route options (change of traffic flows) in real life operations based on FPLs and track information.	ECTL NMD
	To study operational impact on ANSP side.	DFS ECTL MUAC
	To study impact on flight efficiency based on real life flight planning data and a/c system data. To study operational impact on AO side (dispatch & flight crew).	DLH

The grouping and sequence of validation activities is illustrated in Figure 21

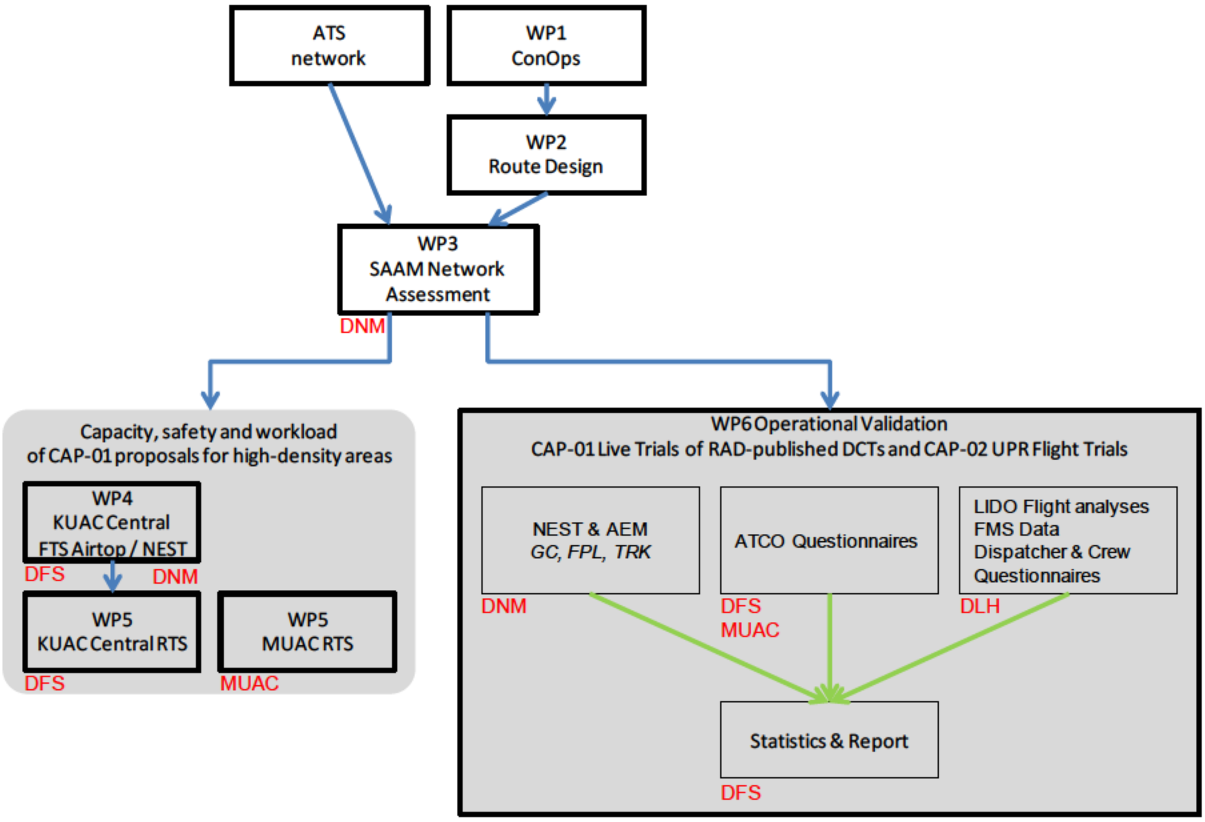

Figure 21: Analyses elements

The following table lists the necessary input information for the foreseen validation techniques and the expected output.

Table 15: Input and Output of Validation Techniques

Validation Technique	Input	Output
FTS	Initial Flight Plans (IFPLs, M1 data: last filed FPL) as demand, route assignments based on shortest route option for ▪ ATS-routes ▪ FRAMaK DCTs	▪ Calculated data based on Great Circle ▪ Calculated data based on the respective FPLs, shortest route option, RAD restrictions taken into account
RTS	Initial Flight Plans (IFPLs, M1 data: last filed FPL) based on ▪ ATS-routes ▪ FRAMaK DCTs ▪ FRAMaK UPRs	▪ Calculated data based on Great Circle ▪ Calculated data based on the respective FPLs ▪ Track data collected during simulation runs. Note: Geographical scope of data is limited to the measurement area (c.f. section 2.1.4.3, Deviation 5)

Validation Technique	Input	Output
Live Trial	Initial Flight Plans (IFPLs) based on ▪ ATS-routes ▪ FRAMaK DCTs (EXE-0201-D-001) ▪ FRAMaK UPRs (EXE-0201-D-006)	▪ Calculated data based on Great Circle ▪ Calculated data based on the respective FPLs ▪ Calculated data based on LIDO FPL processing ▪ Track data and aggregated A/C system data collected during the trials ▪ Results of questionnaires / workload assessments

4.2 Exercises Execution

Dealing with two innovative operational capabilities FR-CAP-01 (Cross-Border Direct Routings) and FR-CAP-02 (Cross-Border User Preferred Routings) for demonstrating the benefits and impacts associated with these capabilities the FRAMaK project envisaged two main demonstrations:

- Public Live Trials (EXE-0201-D001) demonstrating the benefits and impacts of Cross-Border DCT operations based on flights using publicly available DCT routing options published in RAD Appendix 4. The DCT routing options were elaborated in the course of 11 so-called "Route Design Workshops" which lead to the definition of implementation packages. Those packages have been published in successive AIRAC cycles, starting in October 2012 and ending in March 2014. In Table 16 below AIRAC 1211 (effective 18 OCT 2012) is considered to be the start date of the exercise execution.
- Flight Trials (EXE-0201-D006) demonstrating the benefits and impacts of Cross-Border UPR operations by execution of 62 revenue flights of DLH using a User Preferred Routing.

With regard to FR-CAP-01 additional demonstration activities have been executed in order to achieve complementary results:

- EXE-0201-D002 analysed the potential benefits of Cross-Border DCT routings based on SAAM Network Assessments. This type of analysis is the usual way in which Free Route Airspace projects and initiatives assess the benefits. Thus, in order to compare the outcome of FRAMaK with those of other projects this demonstration activity was foreseen.
- Cross-Border DCT routing options affecting the Karlsruhe UAC Core Area have not been made publicly available by publication in RAD Appendix 4 without prior analysis of operational feasibility by means of Real Time Simulations.

  To demonstrate the potential benefits and the operational feasibility two demonstration activities are complementing the Public Live Trials with regard to the Karlsruhe UAC Core Area:

  - EXE-0201-D003 analysed the potential benefits and operational impacts of Cross-Border DCT routing options affecting the Karlsruhe UAC Core Area by means of Fast Time Simulations (SAAM and AirTOp).
  - EXE-0201-D004 analysed the operational feasibility of Cross-Border DCT routing options affecting the Karlsruhe UAC Core Area by means of a Real Time Simulation. Additionally, specific simulation runs focussed on safety aspects.
- Similarly, Cross-Border DCT routing options affecting the Maastricht UAC Core Area have not been made publicly available by publication in RAD Appendix 4. In EXE-0201-D005 those DCT routing options have been analysed regarding their operational feasibility in a Real Time Simulation.

Table 16: Exercises execution/analysis dates

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise analysis start date	Actual Exercise analysis end date
EXE-0201-D001	Public Live Trial of Cross-Border DCTs	18/10/2012	30/04/2014	4 periods (week 12 2013, week 26 2013, week 44 2013, week 12, 2014)	n/a
EXE-0201-D-002	Simulation-based assessment of Cross-Border DCTs: Network Assessment	08/10/2012	04/02/2014	1 week winter traffic (28/10/2013-03/11/2013) 1 week summer traffic (24-30/06/2013)	n/a
EXE-0201-D-003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	02/09/2013	28/02/2014	n/a	n/a
EXE-0201-D-004	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Real Time Simulation	03/02/2014	27/03/2014	n/a	n/a
EXE-0201-D-005	Simulation-based assessment of Cross-Border DCTs: MUAC Core Area Real Time Simulation	14/01/2014	17/01/2014	n/a	n/a
EXE-0201-D-006	Cross-Border User Preferred Routes Flight Trial	05/10/2013	30/03/2014	05/10/2013	30/03/2014

4.3 Deviations from the planned activities

The following deviations from the Demonstration Plan have been explained in the text:

5 Exercises Results

5.1 Summary of Exercises Results

Table 17: Summary of Demonstration Exercises Results

Exercise ID EXE-0201-D...	Demonstration Objective Tittle	Demonstration Objective ID OBJ-0201-...	Success Criterion	Exercise Results	Demonstration Objective Status
001	Public Live Trial of Cross-Border DCTs	001	Reduction of FPL route length in Cross-Border DCT operations	Reduction by 6.8 NM per flight (-0.6%). For weekend traffic FPL routings have become shorter by 9.1 NM per flight (-0.8%).	OK
001	Public Live Trial of Cross-Border DCTs	001	Reduction of actual route length in Cross-Border DCT operations	Reduction by 3.7 NM (-0.3%) per flight. For weekend traffic actual flown routes per flight are 3.9 NM shorter (-0.3%).	OK
001	Public Live Trial of Cross-Border DCTs	001	Reduction of fuel burn in Cross-Border DCT operations	Based on FPL routings fuel burn decreased by 107.5 kg (-0.8%) per flight (weekend traffic: -145.1 kg / -1.1%). Based on actual flown routes fuel burn decreased by 56.4 kg (-0.4%) per flight (weekend: -95.3 kg / -0.7%).	OK
001	Public Live Trial of Cross-Border DCTs	001	Improvement of REDES in Cross-Border DCT operations	Based on FPL routings REDES was down to 1.035 by 0.4 percentage points (weekend: 1.037, -0.3 percentage points). REDES of actual flown routes decreased by 0.1 percentage points to 1.019 (weekend: 1.017 / -0.3 percentage points).	OK
001	Public Live Trial of Cross-Border DCTs	001	Improvement of RESTR in Cross-Border DCT operations	Based on FPL routings RESTR was down to 1.018 by 0.6 percentage points (weekend: 1.016, -0.5 percentage points). RESTR of actual flown routes decreased by 0.2 percentage points to 1.007 (weekend: 1.006 / -0.2 percentage points).	OK
001	Public Live Trial of Cross-Border DCTs	002	Reduction of fuel burn through use of DCTs offering optimized vertical profile	Reductions between 7 and 68 kg per flight.	OK
001	Public Live Trial of Cross-Border DCTs	003	Reduction of CO_2 emission in Cross-Border DCT operations	Based on FPL routings CO2 emissions decreased by 339.8 kg (-0.8%) per flight (weekend traffic: -458.5 kg / -1.1%). Based on actual flown routes CO2 emissions decreased by 178.1 kg (-0.4%) per flight (weekend: -301.0 kg / -0.7%).	OK

Exercise ID EXE-0201-D...	Demonstration Objective Tittle	Demonstration Objective ID OBJ-0201-...	Success Criterion	Exercise Results	Demonstration Objective Status
001	Public Live Trial of Cross-Border DCTs	003	Reduction of NO_x emission in Cross-Border DCT operations	Based on FPL routings NOx emissions decreased by 2.9 kg (-1.3%) per flight (weekend traffic: -3.1 kg / -1.3%). Based on actual flown routes NOx emissions decreased by 1.2 kg (-0.5%) per flight (weekend: -1.9 kg / -0.8%).	OK
001	Public Live Trial of Cross-Border DCTs	007	Reduction of ENR variability in Cross-Border DCT operations	A reduction of ENR variability was not demonstrated. Other than to expected from improved route efficiency indicators REDES and RESTR ENR variability increased with many entry-exit pairs. This may be due to potential reductions of cruising speeds.	NOK
001	Public Live Trial of Cross-Border DCTs	007	Improvement of FPL adherence	An improvement of FPL adherence was not demonstrated.	NOK
001	Public Live Trial of Cross-Border DCTs	008	No adverse results regarding sector occupancy in Cross-Border DCT operations	No effect on route length per sector.	OK
001	Public Live Trial of Cross-Border DCTs	008	No adverse results regarding sector occupancy in Cross-Border DCT operations	No effect on flight duration per sector	OK
001	Public Live Trial of Cross-Border DCTs	008	No adverse results regarding sector occupancy in Cross-Border DCT operations	No effect on number of sectors per flight	OK
001	Public Live Trial of Cross-Border DCTs	010	Good eligibility of Cross-Border DCT routing options	Eligibility of flights for FRAMaK DCTs (based on shortest route option) is 15%, i.e. for 15% of flights in the FRAMaK area one or more FRAMaK DCTs have been available. In weekend traffic the eligibility is 10%.	OK
001	Public Live Trial of Cross-Border DCTs	010	Good acceptability of Cross-Border DCT routing options	8% of all flights in the FRAMaK files one or more FRAMaK DCTs (weekend: 10%). Based on the eligibility for FRAMaK DCTs 50% of flights made use of them. In weekend traffic more flights used a FRAMaK than technically eligible assuming the shortest route option.	OK

Exercise ID EXE-0201-D...	Demonstration Objective Tittle	Demonstration Objective ID OBJ-0201-...	Success Criterion	Exercise Results	Demonstration Objective Status
002	Simulation-based assessment of Cross-Border DCTs: Network Assessment	001	Reduction of FPL route length in Cross-Border DCT operations	Potential reduction by 1,512,163 NM per year (weekend: 665,096 NM per year). Average reduction of FPL route length by 4.15 NM (weekend: 5.48 NM) per flight. Potential reduction of route extension from 2.01% to 1.70% during summer week, from 1.96% to 1.67% during winter week.	OK
002	Simulation-based assessment of Cross-Border DCTs: Network Assessment	001	Reduction of fuel burn in Cross-Border DCT operations	Potential reduction by 9,072,976 kg per year (weekend: 3,990,574 kg per year). Average reduction by 25 kg (33 kg) fuel per flight.	OK
002	Simulation-based assessment of Cross-Border DCTs: Network Assessment	003	Reduction of CO_2 emission in Cross-Border DCT operations	Potential reduction by 30,243,252 kg CO_2 per year (weekend: 13,301,912 kg per year). Average reduction by 83 kg (weekend: 110 kg) CO_2 per flight.	OK
002	Simulation-based assessment of Cross-Border DCTs: Network Assessment	005 006	No degradation regarding number of flights in Cross-Border DCT operations	No negative effects	OK
002	Simulation-based assessment of Cross-Border DCTs: Network Assessment	005 006	No adverse results regarding ENR Throughput in Cross-Border DCT operations	No negative effects	OK
002	Simulation-based assessment of Cross-Border DCTs: Network Assessment	010	Good eligibility of Cross-Border DCT routing options	Complete Week Summer 22.5% Winter 21.4% Weekend Summer 18.9% Winter 17.5%	OK
003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	001	Reduction of FPL route length in Cross-Border DCT operations	Reduction of route length per day: by 2,801 NM (5.56 NM per flight) for H24 DCTs ((Scen_1), by 4,294 NM (4.53 NM per flight) for WE DCTs (Scen_1a) by 4,430 NM (5.02 NM per flight)) for WE DCTs (Scen_3a) by 9,109 NM (6.77 NM per flight) for FRA 365+	OK
003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	001	Reduction of fuel burn in Cross-Border DCT operations	Reduction of fuel burn per day: by 24,198 kg (48 kg per flight) for H24 DCTs (Scen_1), by 35,674 kg (46 kg per flight) for WE DCTs (Scen_1a) by 38,127 kg (43 kg per flight) for WE DCTs (Scen_3a) by 70,424 kg (52 kg per flight) for FRA 365+	OK

Exercise ID EXE-0201-D...	Demonstration Objective Tittle	Demonstration Objective ID OBJ-0201-...	Success Criterion	Exercise Results	Demonstration Objective Status
003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	001	Improvement of REDES in Cross-Border DCT operations	Reduction of mean REDES by 0.01 to an average of 1.02.	OK
003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	001	Improvement of RESTR in Cross-Border DCT operations	Reduction of mean RESTR by 0.01 to an average of 1.01.	OK
003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	003	Reduction of CO_2 emission in Cross-Border DCT operations	Reduction of CO_2 emission per day: by 76,433 kg (152 kg per flight) for H24 DCTs (Scen_1), by 112,730 kg (145 kg per flight) for WE DCTs (Scen_1a) by 120,482 kg (137 kg per flight) for WE DCTs (Scen_3a) by 222,570 kg (166 kg per flight) for FRA 365+	OK
003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	003	Reduction of NO_x emission in Cross-Border DCT operations	Reduction of NO_x emission per day: by 336.2 kg (0.67 kg per flight) for H24 DCTs (Scen_1), by 524.5 kg (0.67 kg per flight) for WE DCTs (Scen_1a) by 571.3 kg (0.65 kg per flight) for WE DCTs (Scen_3a) by 831.9 kg (0.62 kg per flight) for FRA 365+	OK
003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	004	No increase of complexity in Cross-Border DCT operations	No significant rise of counted conflicts in evaluation area in consequence of cross-border DCTs, except in the sector group WEST of free route -scenario (FRA365+).	OK
003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	005 006	No adverse results regarding number of flights in Cross-Border DCT operations	Number of movements remains on a comparable level in cross-border DCT-operations.	OK
003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	005 006	No adverse results regarding ENR Throughput in Cross-Border DCT operations	The occupancy of each sector (maximum number of simultaneously controlled aircraft) is not negatively affected generally. Only an indication of traffic-flow-shifts can be noted when comparing the different scenarios.	OK
003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	008	No adverse results regarding sector occupancy in Cross-Border DCT operations	The average flight times of aircraft in the evaluated sectors do not change significantly by implementing DCTs. Only differences in sector group South - especially in sectors ISA, CHI in scenario FRA365+ - are noticed.	OK

Exercise ID EXE-0201-D...	Demonstration Objective Tittle	Demonstration Objective ID OBJ-0201-...	Success Criterion	Exercise Results	Demonstration Objective Status
003	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Fast Time Simulation	009	No increase in operator workload in Cross-Border DCT operations	The simulation provided acceptable average workload values but predominantly too high peak values, particularly in WE-option. A significant increase in operator workload due to cross-border DCT-operations is not given.	NOK
004	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Real Time Simulation	004	No increase of complexity in Cross-Border DCT operations	ATCO feedback showed increased complexity in certain sectors, especially in scenario FRA 365. More route options increased the number of multiple conflicts thus complexity in certain sectors.	partly NOK
004	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Real Time Simulation	004	No degradation of the perceived level of safety in Cross-Border DCT operations	Reduction of number of flights within the sector were recommended by ATCOs to keep safety level (similar to thunderstorms). Safety impacts were mentioned concerning less precise MTCD on manual updated trajectories for traffic on radar vectors, especially in scenario FRA 365.	partly NOK
004	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Real Time Simulation	004	No degradation of the perceived level of situation awareness in Cross-Border DCT operations	In certain sectors situation awareness decreased significantly due to new and multiple crossing / conflicts. (this can be overcome by staggered introduction of new DCTs, but maybe not with a “full FRA365”)	partly NOK
004	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Real Time Simulation	005	No adverse results regarding number of flights in Cross-Border DCT operations	Subjective feedback from ATCO was to require a capacity reduction like done for thunderstorms in certain sectors, especially in scenario FRA 365.	partly NOK
004	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Real Time Simulation	008	No adverse results regarding sector occupancy in Cross-Border DCT operations	Subjective feedback from ATCO was to require a capacity reduction like done for thunderstorms in certain sectors, especially in scenario FRA 365.	partly NOK
004	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Real Time Simulation	009	No increase in operator workload in Cross-Border DCT operations	Problems for coordination concerning directs crossing 3 sectors (sector snapper) were reported, especially in scenario FRA 365. Increased workload for updating trajectories (vectoring more often required due to missing intermediate points).	partly NOK

Exercise ID EXE-0201-D...	Demonstration Objective Tittle	Demonstration Objective ID OBJ-0201-...	Success Criterion	Exercise Results	Demonstration Objective Status
004	Simulation-based assessment of Cross-Border DCTs: KUAC Core Area Real Time Simulation	010	No adverse operator feedback regarding Cross-Border DCT operations	Intermediate points on direct routings were recommended for the core area to keep sector sequence and responsibilities for separation between dedicated major flows. With FRA365 this becomes more randomly and for certain sectors difficult.	partly NOK
005	Simulation-based assessment of Cross-Border DCTs: MUAC Core Area Real Time Simulation	004	No increase of complexity in Cross-Border DCT operations	No exercise was rejected due to excessive complexity. Design improvements introduced during the RTS improved handling of traffic.	OK
005	Simulation-based assessment of Cross-Border DCTs: MUAC Core Area Real Time Simulation	004	No degradation of the perceived level of safety in Cross-Border DCT operations	No exercise was rejected due to perceived loss of safety. Design improvements introduced during the RTS improved safe handling of traffic.	OK
005	Simulation-based assessment of Cross-Border DCTs: MUAC Core Area Real Time Simulation	009	No increase in operator workload in Cross-Border DCT operations	No exercise was rejected due to excessive operator workload. Design improvements introduced during the RTS improved workload.	OK
005	Simulation-based assessment of Cross-Border DCTs: MUAC Core Area Real Time Simulation	010	No adverse operator feedback regarding Cross-Border DCT operations	No exercise was rejected by ATCOs.	OK
006	Cross-Border User Preferred Routes Flight Trial	011 018	Reduction of FPL route length in Cross-Border UPR operations	Short-haul: 1 NM … 16 NM Long-haul: 12-25 NM	OK
006	Cross-Border User Preferred Routes Flight Trial	011 018	Reduction of actual route length in Cross-Border UPR operations	Short-haul: 1 NM … 16 NM Long-haul: 12-25 NM	OK
006	Cross-Border User Preferred Routes Flight Trial	011 018	Reduction of fuel burn in Cross-Border UPR operations	Short-haul: 5.6 kg per NM saved Long-haul: 23.6 kg per NM saved	OK
006	Cross-Border User Preferred Routes Flight Trial	011 018	Improvement of REDES in Cross-Border UPR operations	Actual flown UPR tracks: 1.015 (improvement vs. FR-CAP-01)	OK
006	Cross-Border User Preferred Routes Flight Trial	011 018	Improvement of RESTR in Cross-Border UPR operations	Actual flown UPR tracks: 1.007 (no improvement vs. FR-CAP-01)	NOK
006	Cross-Border User Preferred Routes Flight Trial	012 018	Reduction of CO_2 emission in Cross-Border UPR operations	Not measured but due to fuel burn reduction a reduction of CO_2 emission is to be assumed.	OK
006	Cross-Border User Preferred Routes Flight Trial	013	No increase of complexity in Cross-Border UPR operations	ATCOs reported higher complexity of work, especially for continental flights.	NOK
006	Cross-Border User Preferred Routes Flight Trial	013	No degradation of the perceived level of safety in Cross-Border UPR operations	Crews and Dispatchers reported no safety issues. 14% of ATCOs reported safety hazards linked to UPR flights.	NOK

Exercise ID EXE-0201-D...	Demonstration Objective Tittle	Demonstration Objective ID OBJ-0201-...	Success Criterion	Exercise Results	Demonstration Objective Status
006	Cross-Border User Preferred Routes Flight Trial	013	No degradation of the perceived level of situation awareness in Cross-Border UPR operations	UPR routings had to be checked and monitored continuously in order to maintain situation awareness. A clear labelling of UPR flights would be required.	NOK
006	Cross-Border User Preferred Routes Flight Trial	014 015 018	No adverse results regarding number of flights in Cross-Border UPR operations	On a case-by-case basis no capacity degradations were demonstrated. However, ATCOs stated that a high number of UPR flights would reduce capacity.	OK
006	Cross-Border User Preferred Routes Flight Trial	016	No increase in operator workload in Cross-Border UPR operations	Dispatchers reported an increase in workload, especially in route construction, manual flight planning and filing. ATCOs reported an increase in workload due to the need for continuous checks of routings and the instruction not to deviate the flight from the FPL route.	NOK
006	Cross-Border User Preferred Routes Flight Trial	017	No adverse operator feedback regarding Cross-Border UPR operations respectively	Approx. 77% of flight crews reported no irregularities. The major irregularity was ATCO not informed (offered DCTs).	partly NOK

5.2 Choice of metrics and indicators

Table 18 provides an overview of all metrics and indicators used in the framework of FRAMaK demonstration activities. (Note: being an overview on KPAs and metrics columns foreseen in the template related to results were deleted). In subsequent chapters the indicators are described in detail and assigned to demonstration exercises.

Table 18: Summary of metrics and indicators

Objective ID	KPA	Metric
OBJ-0201-001 OBJ-0201-011 OBJ-0201-018	Efficiency (horizontal)	ENR Great Circle Path FPL Route Length Actual Route Length Route Extension REDES RESTR
OBJ-0201-002	Efficiency (vertical)	Fuel Burn

Objective ID	KPA	Metric
OBJ-0201-001 OBJ-0201-003 OBJ-0201-011 OBJ-0201-012 OBJ-0201-018	Efficiency (horizontal) Environmental Sustainability	Fuel Burn
OBJ-0201-003 OBJ-0201-012 OBJ-0201-018	Environmental Sustainability	CO_2 emission NO_x emission
OBJ-0201-004 OBJ-0201-013	Safety	Complexity Perceived Level of Safety Perceived Level of Situation Awareness
OBJ-0201-005 (local) OBJ-0201-006 (Network) OBJ-0201-014 (local) OBJ-0201-015 (Network) OBJ-0201-018	Capacity	Number of Flights ENR Throughput Operator feedback
OBJ-0201-007	Predictability	Planned Flight Duration Actual Flight Duration ENR Variability Delay Length (FPL Adherence)
OBJ-0201-008	Cost Effectiveness (Sectorization)	Route Length per Sector Flight Duration per Sector Number of Sectors per Flight
OBJ-0201-009 OBJ-0201-016	Other - Workload	Number of A/C interventions Number of inter-sector coordinations ATCO questionnaire ATCO feedback
OBJ-0201-010 OBJ-0201-017 OBJ-0201-018	Other – Operational Feasibility	Acceptability Eligibility Operator feedback

5.2.1 Key Performance Areas' Influence Diagrams & related Indicators and Metrics

The following influence diagrams illustrate which variable(s) are related to the different Key Performance Areas covered by FRAMaK and which planning aspect(s) or actual flight data might affect these variable(s). Note: Influences of weather conditions (wind effects etc.) are not taken into account due to lack of respective information.

5.2.1.1 Horizontal Efficiency

Subject to	EXE-0201-D001 (Public DCT Live Trials)	OBJ-0201-001
	EXE-0201-D002 (Network Assessment)	OBJ-0201-011
	EXE-0201-D003 (KUAC FTS)	OBJ-0201-018
	EXE-0201-D006 (UPR Flight Trials)	

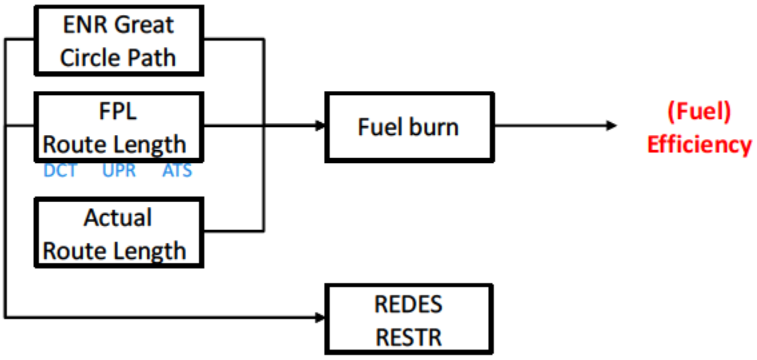

Figure 22: Influence diagram for KPA Horizontal Efficiency

Table 19: Performance Indicators for KPA Horizontal Efficiency

Indicator / Metric	Routing	Accessibility				Measurement
		FTS	RTS	LT DCT	FT UPR	
ENR Great Circle Path	GC	+		+	+	calculated based on FPLs
FPL Route Length	FPL	+		+	+	calculated from FPLs, distinction between utilisation of ATS route network, RAD App. 4 DCT (FR-CAP-01) or User Preferred Trajectory (FR-CAP-02)
Actual Route Length	TRK			+	+	measured real-life aggregated track data (ECTL DDR M3)
Route extension	FPL	+				calculated SAAM/NEST

Indicator / Metric	Routing	Accessibility FTS	Accessibility RTS	Accessibility LT DCT	Accessibility FT UPR	Measurement
Fuel burn	GC FPL TRK	o[5,6]		o[7]/+[8]	+[8]	calculated ▪ FTS: o Based on GC and FPL only o A/C performance models ▪ LT_{DCT}: o A/C performance models o enhanced performance models to be provided by DLH Note: for DLH flights aggregated data Note: LT DCT - for flights compliant to matching criteria 1 (c.f. 4.1.5.3.2.3) only ▪ LT_{UPR}: aggregated data
REDES	FPL TRK	+		+	+	see below
RESTR	FPL TRK	+		+	+	see below

Note: For all routings (GC, FPL, TRK) routings within the TMA radius of 40 NM around ADEP and ADES respectively shall not be considered.

Referring to the Eurocontrol Horizontal Flight Efficiency Analysis Framework (Eurocontrol, 2009) the following route efficiency ratios will be calculated (Figure 23):

- REDES Route Efficiency related to the effective approach (approximation) towards the destination. REDES informs about the directness of the routing.

$$REDES = \frac{\text{route length}}{\text{effective approach}} = \frac{l}{a} = \frac{l}{GC_{NE} - GC_{XE}}$$

$$\text{where} \quad l = \begin{cases} \text{actual flown route length (TRK), or} \\ \text{planned route length (FPL)} \end{cases}$$

$$a = \text{effective approach from any point towards the destination}$$

A REDES of 1 means a perfectly direct routing from the airspace entry point along the Great Circle Path towards the destination (GC_{NE}) to the airspace exit point, i.e. each mile flown in the airspace would be optimally directed towards ADES.

5 Estimates based on A/C performance models, e.g. BADA, provided by the simulation tool (e.g. SAAM w/ AEM BATCH) or additional tools e.g. the new ECTL IMPACT
6 TRK data not available
7 Estimates based on A/C performance models, e.g. BADA
8 Aggregated data from DLH flights

- RESTR Route Efficiency related to the lateral optimum within the concerned airspace. RESTR informs about the straightness of the routing within the particular airspace.

$$RESTR = \frac{\text{route length}}{\text{sector optimum}} = \frac{l}{GC_{NX}}$$

$$\text{where } \quad l = \begin{cases} \text{actual flown route length (TRK), or} \\ \text{planned route length (FPL)} \end{cases}$$

$$GC_{NX} = \text{locally optimal path between entry and exit point}$$

A RESTR of 1 means a perfectly direct routing through the airspace in consideration between a given airspace entry point and a given airspace exit point (GC_{NX}), i.e. each mile flown in the airspace would be optimally directed towards X.

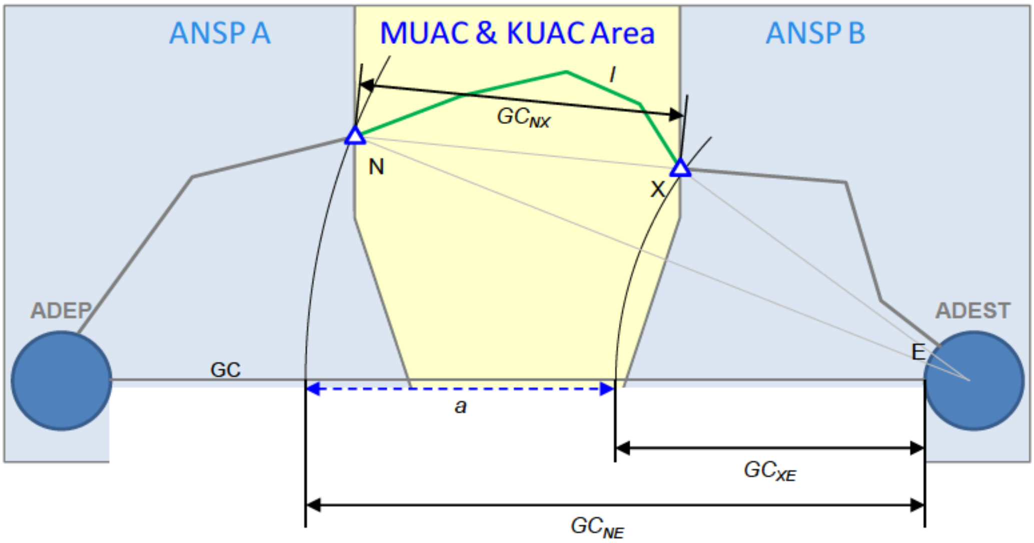

Figure 23: Geometric construction of Route Efficiency Indicators REDES and RESTR

In order to obtain a complete picture about the resulting route efficiency which allows for consideration of adjacent ANSP's modifications REDES and RESTR can be calculated for the complete routing ADEP-ADES as depicted in the following for two adjacent airspace volumes (see also Figure 24). Indicators related to any intermediate airspace volume are to be calculated analogue to the calculation explained for the FRAMaK area. Since out of the scope of the FRAMaK project the calculation of route efficiency indicators is limited to the FRAMaK airspace.

$$REDES_A = \frac{l_A}{a_A} = \frac{l_A}{GC - GC_{NE}} \qquad REDES_{FRAMaK} = \frac{l_{FRAMaK}}{a_{FRAMaK}} = \frac{l_{FRAMaK}}{GC_{NE} - GC_{XE}} \qquad REDES_B = \frac{l_B}{a_B} = \frac{l_B}{GC_{XE}}$$

$$RESTR_A = \frac{l_A}{GC_{SN}} \qquad RESTR_{FRAMaK} = \frac{l_{FRAMaK}}{GC_{NX}} \qquad RESTR_B = \frac{l_B}{GC_{XE}}$$

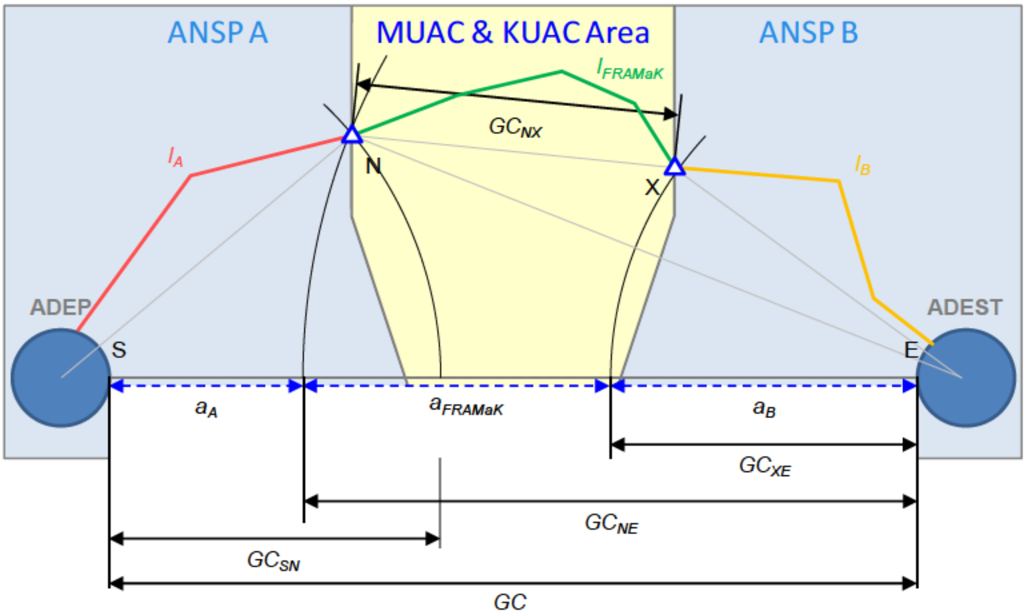

Figure 24: Geometric construction of Route Efficiency Indicators REDES and RESTR considering the complete routing

5.2.1.2 Vertical Efficiency

Subject to	EXE-0201-D001 (Public DCT Live Trials)	OBJ-0201-002

Note: Due to Deviation 10 the assessment approach was substantially modified.

Table 20: Performance Indicators for KPA Vertical Efficiency

Indicator / Metric	Routing	Accessibility				Measurement
		FTS	RTS	LT DCT	FT UPR	
Fuel Burn	FPL			+		The fuel burn saving resulting from a late descent using a FRAMaK Vertical Optimisation Direct. Average fuel burn saving per flight calculated by means of LIDO.

5.2.1.3 Environmental Sustainability

Subject to	EXE-0201-D001 (Public DCT Live Trials)	OBJ-0201-003
	EXE-0201-D002 (Network Assessment)	OBJ-0201-012
	EXE-0201-D003 (KUAC FTS)	OBJ-0201-018
	EXE-0201-D006 (UPR Flight Trials)	

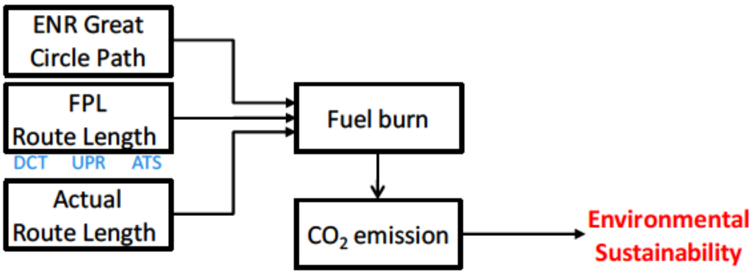

Figure 25: Influence diagram for KPA Environmental Sustainability

Table 21: Performance Indicators KPA Environmental Sustainability

Indicator / Metric	Routing	Accessibility				Measurement
		FTS	RTS	LT DCT	FT UPR	
Fuel burn	GC FPL TRK					see 5.2.1.1
CO_2 emission	GC FPL TRK	○[9]		○[9]	○[9]	<u>calculated</u> ▪ BADA performance model or ▪ enhanced performance models derived from information provided by DLH
NO_x emission	GC FPL TRK	○[9]		○[9]	○[9]	<u>calculated</u> ▪ BADA performance model or ▪ enhanced performance models derived from information provided by DLH

<u>Note:</u> LT DCT - for flights compliant to matching criteria 1 (c.f. 0) only

[9] Estimates based on A/C performance models, e.g. BADA, provided by the simulation tool (e.g. SAAM w/ AEM BATCH) or additional tools

5.2.1.4 Safety

Subject to	EXE-0201-D003 (KUAC FTS)	OBJ-0201-004
	EXE-0201-D004 (KUAC RTS)	OBJ-0201-013
	EXE-0201-D005 (MUAC RTS)	
	EXE-0201-D006 (UPR Flight Trials)	

Table 22: Performance Indicators KPA Safety

Indicator / Metric	Routing	Accessibility				Measurement
		FTS	RTS	LT DCT	FT UPR	
Complexity	FPL	+	+			SAAM / AirTop: ▪ Number of conflicts ▪ PRU sector complexity
Perceived Level of Safety	-/-		+		+	to be derived from ▪ RTS / FT: Questionnaires
Perceived Level of Situation Awareness	-/-		+		+	to be derived from ▪ RTS / FT: Questionnaires

5.2.1.5 Capacity

Subject to	EXE-0201-D001 (Public DCT Live Trials)	OBJ-0201-005
	EXE-0201-D002 (Network Assessment)	OBJ-0201-006
	EXE-0201-D003 (KUAC FTS)	OBJ-0201-014
	EXE-0201-D004 (KUAC RTS)	OBJ-0201-015
	EXE-0201-D006 (UPR Flight Trials)	OBJ-0201-018

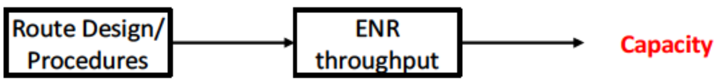

Figure 26: Influence diagram for KPA Capacity

Table 23: Performance Indicators KPA Capacity

Indicator / Metric	Routing	Accessibility				Measurement
		FTS	RTS	LT DCT	FT UPR	
Number of Flights	FPL TRK	+		+	+	Number of flights per specified airspace unit (e.g. sector, AoR)

ENR Throughput	FPL TRK	+		o[10]		calculated $\frac{\text{Number of flights}}{\text{unit of time}}$
Operator Feedback	TRK		+		+	ATCO Questionnaire

5.2.1.6 Predictability

Subject to	EXE-0201-D001 (Public DCT Live Trials)	OBJ-0201-007

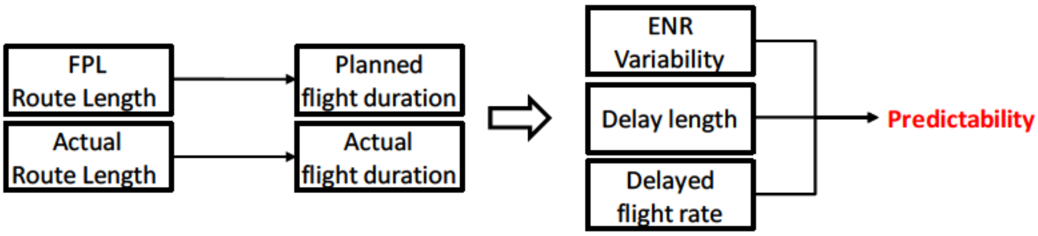

Figure 27: Influence diagram for KPA Predictability

In order to minimize effects other than those stemming from the Cross-Border DCT route design the predictability of flights was analysed with reference to the scheduled FRAMaK entry and exit times.

Table 24: Performance Indicators for KPA Predictability

Indicator / Metric	Routing	Accessibility				Measurement
		FTS	RTS	LT DCT	FT UPR	
FPL Route Length	FPL					see 5.2.1.1
Actual Route Length	TRK					see 5.2.1.1
Planned Flight Duration	FPL			+	+	calculated ▪ based on A/C performance model
Actual Flight Duration	TRK			+	+	calculated ▪ LT: real-life aggregated track data (CFMU M3)

[10] Due to the expectation of mixed mode operations Capacity for 100% usage of the operational concept under investigation cannot be assessed

Indicator / Metric	Routing	Accessibility FTS	RTS	LT DCT	FT UPR	Measurement
ENR Variability	TRK			+	+	measured Number of flights handled by the specified airspace unit calculated $\sigma = \sqrt{Var(Actual\ flightduration)}$
Delay Length **Here: FPL Adherence**	FPL TRK			+	+	calculated Δ (Planned flight duration; Actual flight duration)
Deviation 11 Delayed Flight Rate not measured with regard to Predictability For the evaluation of quality of the available route network a sufficient basis is given by the indicators ENR Variability and FPL Adherence. The indicator delayed flight rate in contrast does not take into account "positive delays", i.e. flights being ahead of schedule.						

Note: LT DCT - for flights compliant to matching criteria 1 (c.f. 0) only

5.2.1.7 Cost Effectiveness (Sectorization)

Subject to	EXE-0201-D001 (Public DCT Live Trials) EXE-0201-D002 (Network Assessment) EXE-0201-D003 (KUAC FTS)	OBJ-0201-008

Since "Cost Effectiveness" is influenced by many factors other than route design the FRAMaK project will focus on potential benefits of DCTs regarding sector sequence (number of sectors → number of hand-overs) and the feasibility of the current sectorization (optimised for the ATS route network) for DCT operations.

Table 25: Performance Indicators for KPA Cost Effectiveness

Indicator / Metric	Routing	Accessibility FTS	RTS	LT DCT	FT UPR	Measurement
Route Length per Sector	FPL TRK	o[11]		+		Route length per specified airspace unit (e.g. sector, AoR)
Flight Duration per Sector	FPL TRK	o[11]		+		Flight duration per specified airspace unit (e.g. sector, AoR)
Number of Sectors per Flight	FPL TRK	o[11]		+		Number of sectors per individual flight

[11] Based on FPL only

5.2.1.8 Other – Workload

Subject to	EXE-0201-D003 (KUAC FTS) EXE-0201-D004 (KUAC RTS) EXE-0201-D005 (MUAC RTS) EXE-0201-D006 (UPR Flight Trials)	OBJ-0201-009 OBJ-0201-016

Table 26: Performance Indicators for Workload

Indicator / Metric	Routing	Accessibility				Measurement
		FTS	RTS	LT DCT	FT UPR	
Number of A/C interventions	GC FPL TRK	+[12]				Number of interactions between ATCO and aircrafts (usually expressed in terms of RT push-to-talk actions) is used as an indicator for workload.
Number of inter-sector coordinations (Workload)	GC FPL TRK	+[12]				Number of coordination between ATCO and adjacent ATC units (usually expressed in terms of telephony actions) is used as an indicator for workload.
Operator Feedback	TRK		+		+	Operator feedback collected through questionnaires may contain elements related to operator workload experienced.

5.2.1.9 Other – Operational Feasibility

Subject to	EXE-0201-D001 (Public Live Trial) EXE-0201-D002 (SAAM Network Assessment) EXE-0201-D004 (KUAC RTS) EXE-0201-D005 (MUAC RTS) EXE-0201-D006 (UPR Flight Trials)	OBJ-0201-010 OBJ-0201-017

[12] TRK data not available

Table 27: Performance Indicators for Operational Feasibility

Indicator / Metric	Routing	Accessibility				Measurement
		FTS	RTS	LT DCT	FT UPR	
Acceptability	FPL			+		The utilisation indicator *u* shall inform about the extent to which FRAMaK DCTs – if offered for a relation – are being used by airline operators, i.e. to what degree they have been accepted.[13]
Eligibility	FPL	+		+		The eligibility *e* of an individual DCT informs about the extent to which a newly offered DCT is eligible for flights. The indicator is to be calculated by means of SAAM using the "shortest route option".[14]
Operator Feedback	TRK		+		+	Operator feedback collected through questionnaires may contain elements related to operational feasibility of specific concept elements.

13 $u = \frac{\text{Number of flights which have used} \geq 1 \text{ DCT}}{\text{Number of flights for which} \geq 1 \text{ DCT has been available}}$ [%]

14 $e = \text{Number of flights eligible for the DCT}$

5.3 Summary of Assumptions

There are no issues to be reported regarding to the assumptions specified in the Demonstration Plan.

5.3.1 Results per KPA

Table 28: Results per KPA

KPA	Demonstration Objective ID OBJ-0201-	Exercise ID EXE-0201-D...	Success Criterion	Exercise Results
Efficiency (horizontal)	001	001	Reduction of FPL route length in Cross-Border DCT operations	Reduction by 6.8 NM per flight (-0.6%). For weekend traffic FPL routings have become shorter by 9.1 NM per flight (-0.8%).
Efficiency (horizontal)	001	001	Reduction of actual route length in Cross-Border DCT operations	Reduction by 3.7 NM (-0.3%) per flight. For weekend traffic actual flown routes per flight are 3.9 NM shorter (-0.3%).
Efficiency (horizontal)	001	001	Reduction of fuel burn in Cross-Border DCT operations	Based on FPL routings fuel burn decreased by 107.5 kg (-0.8%) per flight (weekend traffic: -145.1 kg / -1.1%). Based on actual flown routes fuel burn decreased by 56.4 kg (-0.4%) per flight (weekend: -95.3 kg / -0.7%).
Efficiency (horizontal)	001	001	Improvement of REDES in Cross-Border DCT operations	Based on FPL routings REDES was down to 1.035 by 0.4 percentage points (weekend: 1.037, -0.3 percentage points). REDES of actual flown routes decreased by 0.1 percentage points to 1.019 (weekend: 1.017 / -0.3 percentage points).
Efficiency (horizontal)	001	001	Improvement of RESTR in Cross-Border DCT operations	Based on FPL routings RESTR was down to 1.018 by 0.6 percentage points (weekend: 1.016, -0.5 percentage points). RESTR of actual flown routes decreased by 0.2 percentage points to 1.007 (weekend: 1.006 / -0.2 percentage points).
Efficiency (horizontal)	001	002	Reduction of FPL route length in Cross-Border DCT operations	Potential reduction by 1,512,163 NM per year (weekend: 665,096 NM per year). Average reduction of FPL route length by 4.15 NM (weekend: 5.48 NM) per flight. Potential reduction of route extension from 2.01% to 1.70% during summer week, from 1.96% to 1.67% during winter week.
Efficiency (horizontal)	001	002	Reduction of fuel burn in Cross-Border DCT operations	Potential reduction by 9,072,976 kg per year (weekend: 3,990,574 kg per year). Average reduction by 25 kg (33 kg) fuel per flight.
Efficiency (horizontal)	001	003	Reduction of FPL route length in Cross-Border DCT operations	Reduction of route length per day: by 2,801 NM (5.56 NM per flight) for H24 DCTs ((Scen_1), by 4,294 NM (4.53 NM per flight) for WE DCTs (Scen_1a) by 4,430 NM (5.02 NM per flight)) for WE DCTs (Scen_3a) by 9,109 NM (6.77 NM per flight) for FRA 365+
Efficiency (horizontal)	001	003	Reduction of fuel burn in Cross-Border DCT operations	Reduction of fuel burn per day: by 24,198 kg (48 kg per flight) for H24 DCTs (Scen_1), by 35,674 kg (46 kg per flight) for WE DCTs (Scen_1a) by 38,127 kg (43 kg per flight) for WE DCTs (Scen_3a) by 70,424 kg (52 kg per flight) for FRA 365+

KPA	Demonstration Objective ID OBJ-0201-	Exercise ID EXE-0201-D…	Success Criterion	Exercise Results
Efficiency (horizontal)	001	003	Improvement of REDES in Cross-Border DCT operations	Reduction of mean REDES by 0.01 to an average of 1.02.
Efficiency (horizontal)	001	003	Improvement of RESTR in Cross-Border DCT operations	Reduction of mean RESTR by 0.01 to an average of 1.01.
Efficiency (vertical)	002	001	Reduction of fuel burn through use of DCTs offering optimized vertical profile	Reductions between 7 and 68 kg per flight.
Environmental Sustainability	003	001	Reduction of CO_2 emission in Cross-Border DCT operations	Based on FPL routings CO2 emissions decreased by 339.8 kg (-0.8%) per flight (weekend traffic: -458.5 kg / -1.1%). Based on actual flown routes CO2 emissions decreased by 178.1 kg (-0.4%) per flight (weekend: -301.0 kg / -0.7%).
Environmental Sustainability	003	001	Reduction of NO_x emission in Cross-Border DCT operations	Based on FPL routings NOx emissions decreased by 2.9 kg (-1.3%) per flight (weekend traffic: -3.1 kg / -1.3%). Based on actual flown routes NOx emissions decreased by 1.2 kg (-0.5%) per flight (weekend: -1.9 kg / -0.8%).
Environmental Sustainability	003	002	Reduction of CO_2 emission in Cross-Border DCT operations	Potential reduction by 30,243,252 kg CO2 per year (weekend: 13,301,912 kg per year). Average reduction by 83 kg (weekend: 110 kg) CO2 per flight.
Environmental Sustainability	003	003	Reduction of CO2 emission in Cross-Border DCT operations	Reduction of CO2 emission per day: by 76,433 kg (152 kg per flight) for H24 DCTs (Scen_1), by 112,730 kg (145 kg per flight) for WE DCTs (Scen_1a) by 120,482 kg (137 kg per flight) for WE DCTs (Scen_3a) by 222,570 kg (166 kg per flight) for FRA 365+
Environmental Sustainability	003	003	Reduction of NOx emission in Cross-Border DCT operations	Reduction of NOx emission per day: by 336.2 kg (0.67 kg per flight) for H24 DCTs (Scen_1), by 524.5 kg (0.67 kg per flight) for WE DCTs (Scen_1a) by 571.3 kg (0.65 kg per flight) for WE DCTs (Scen_3a) by 831.9 kg (0.62 kg per flight) for FRA 365+
Safety	004	003	No increase of complexity in Cross-Border DCT operations	No significant rise of counted conflicts in evaluation area in consequence of cross-border DCTs, except in the sector group WEST of free route -scenario (FRA365+).
Safety	004	004	No increase of complexity in Cross-Border DCT operations	ATCO feedback showed increased complexity in certain sectors, especially in scenario FRA 365. More route options increased the number of multiple conflicts thus complexity in certain sectors.
Safety	004	004	No degradation of the perceived level of safety in Cross-Border DCT operations	Reduction of number of flights within the sector were recommended by ATCOs to keep safety level (similar to thunderstorms). Safety impacts were mentioned concerning less precise MTCD on manual updated trajectories for traffic on radar vectors, especially in scenario FRA 365.
Safety	004	004	No degradation of the perceived level of situation awareness in Cross-Border DCT operations	In certain sectors situation awareness decreased significantly due to new and multiple crossing / conflicts. (this can be overcome by staggered introduction of new DCTs, but maybe not with a “full FRA365”)

KPA	Demonstration Objective ID OBJ-0201-	Exercise ID EXE-0201-D...	Success Criterion	Exercise Results
Safety	004	005	No increase of complexity in Cross-Border DCT operations	No exercise was rejected due to excessive complexity. Design improvements introduced during the RTS improved handling of traffic.
Safety	004	005	No degradation of the perceived level of safety in Cross-Border DCT operations	No exercise was rejected due to perceived loss of safety. Design improvements introduced during the RTS improved safe handling of traffic.
Capacity	005 006	002	No degradation regarding number of flights in Cross-Border DCT operations	No negative effects
Capacity	005 006	002	No adverse results regarding ENR Throughput in Cross-Border DCT operations	No negative effects
Capacity	005 006	003	No adverse results regarding number of flights in Cross-Border DCT operations	Number of movements remains on a comparable level in cross-border DCT-operations.
Capacity	005 006	003	No adverse results regarding ENR Throughput in Cross-Border DCT operations	The occupancy of each sector (maximum number of simultaneously controlled aircraft) is not negatively affected generally. Only an indication of traffic-flow-shifts can be noted when comparing the different scenarios.
Capacity	005	004	No adverse results regarding number of flights in Cross-Border DCT operations	Subjective feedback from ATCO was to require a capacity reduction like done for thunderstorms in certain sectors.
Predictability	007	001	Reduction of ENR variability in Cross-Border DCT operations	A reduction of ENR variability was not demonstrated. Other than to expected from improved route efficiency indicators REDES and RESTR ENR variability increased with many entry-exit pairs. This may be due to potential reductions of cruising speeds.
Predictability	007	001	Improvement of FPL adherence	An improvement of FPL adherence was not demonstrated.
Cost Effectiveness (Sectorization)	008	001	No adverse results regarding sector occupancy in Cross-Border DCT operations	No effect on route length per sector.
Cost Effectiveness (Sectorization)	008	001	No adverse results regarding sector occupancy in Cross-Border DCT operations	No effect on flight duration per sector.
Cost Effectiveness (Sectorization)	008	001	No adverse results regarding sector occupancy in Cross-Border DCT operations	No effect on number of sectors per flight.

KPA	Demonstration Objective ID OBJ-0201-	Exercise ID EXE-0201-D...	Success Criterion	Exercise Results
Cost Effectiveness (Sectorization)	008	003	No adverse results regarding sector occupancy in Cross-Border DCT operations	The average flight times of aircraft in the evaluated sectors do not change significantly by implementing DCTs. Only differences in sector group South - especially in sectors ISA, CHI in scenario FRA365+ - are noticed.
Cost Effectiveness (Sectorization)	008	004	No adverse results regarding sector occupancy in Cross-Border DCT operations	Subjective feedback from ATCO was to require a capacity reduction like done for thunderstorms in certain sectors, especially in scenario FRA 365.
Other - Workload	009	003	No increase in operator workload in Cross-Border DCT operations	The simulation provided acceptable average workload values but predominantly too high peak values, particularly in WE-option. A significant increase in operator workload due to cross-border DCT-operations is not given.
Other - Workload	009	004	No increase in operator workload in Cross-Border DCT operations	Problems for coordination concerning directs crossing 3 sectors (sector snapper) were reported, especially in scenario FRA 365. Increased workload for updating trajectories (vectoring more often required due to missing intermediate points)
Other - Workload	009	005	No increase in operator workload in Cross-Border DCT operations	No exercise was rejected due to excessive operator workload. Design improvements introduced during the RTS improved workload.
Other – Operational Feasibility	010	001	Good eligibility of Cross-Border DCT routing options	Eligibility of flights for FRAMaK DCTs (based on shortest route option) is 15%, i.e. for 15% of flights in the FRAMaK area one or more FRAMaK DCTs have been available. In weekend traffic the eligibility is 10%.
Other – Operational Feasibility	010	001	Good acceptability of Cross-Border DCT routing options	8% of all flights in the FRAMaK files one or more FRAMaK DCTs (weekend: 10%). Based on the eligibility for FRAMaK DCTs 50% of flights made use of them. In weekend traffic more flights used a FRAMaK than technically eligible assuming the shortest route option.
Other – Operational Feasibility	010	002	Good eligibility of Cross-Border DCT routing options	Complete Week Summer22.5% Winter 21.4% Weekend Summer 18.9% Winter 17.5%
Other – Operational Feasibility	010	004	No adverse operator feedback regarding Cross-Border DCT operations	Intermediate points on direct routings were recommended for the core area to keep sector sequence and responsibilities for separation between dedicated major flows. With FRA365 this becomes more randomly and for certain sectors difficult.
Other – Operational Feasibility	010	005	No adverse operator feedback regarding Cross-Border DCT operations	No exercise was rejected by ATCOs.
Efficiency (horizontal)	011 018	006	Reduction of FPL route length in Cross-Border UPR operations	Short-haul: 1 NM … 16 NM Long-haul: 12-25 NM
Efficiency (horizontal)	011 018	006	Reduction of actual route length in Cross-Border UPR operations	Short-haul: 1 NM … 16 NM Long-haul: 12-25 NM

KPA	Demonstration Objective ID OBJ-0201-...	Exercise ID EXE-0201-D...	Success Criterion	Exercise Results
Efficiency (horizontal)	011 018	006	Reduction of fuel burn in Cross-Border UPR operations	Short-haul: 5.5 kg per NM saved Long-haul: 23.6 kg per NM saved
Efficiency (horizontal)	011 018	006	Improvement of REDES in Cross-Border UPR operations	Actual flown UPR tracks: 1.015 (improvement vs. FR-CAP-01)
Efficiency (horizontal)	011 018	006	Improvement of RESTR in Cross-Border UPR operations	Actual flown UPR tracks: 1.007 (no improvement vs. FR-CAP-01)
Environmental Sustainability	012 018	006	Reduction of CO2 emission in Cross-Border UPR operations	Not measured but due to fuel burn reduction a reduction of CO_2 emission is to be assumed.
Safety	013	006	No increase of complexity in Cross-Border UPR operations	ATCOs reported higher complexity of work, especially for continental flights.
Safety	013	006	No degradation of the perceived level of safety in Cross-Border UPR operations	Crews and Dispatchers reported no safety issues. 14% of ATCOs reported safety hazards linked to UPR flights.
Safety	013	006	No degradation of the perceived level of situation awareness in Cross-Border UPR operations	UPR routings had to be checked and monitored continuously in order to maintain situation awareness. A clear labelling of UPR flights would be required.
Capacity	014 015 018	006	No adverse results regarding number of flights in Cross-Border UPR operations	On a case-by-case basis no capacity degradations were demonstrated. However, ATCOs stated that a high number of UPR flights would reduce capacity.
Other - Workload	016	006	No increase in operator workload in Cross-Border UPR operations	Dispatchers reported an increase in workload, especially in route construction, manual flight planning and filing. ATCOs reported an increase in workload due to the need for continuous checks of routings and the instruction not to deviate the flight from the FPL route.
Other – Operational Feasibility	017	006	No adverse operator feedback regarding Cross-Border UPR operations respectively	Approx. 77% of flight crews reported no irregularities. The major irregularity was ATCO not informed (offered DCTs).

5.3.2 Impact on Safety, Capacity and Human Factors

Public Live Trials related to FR-CAP-01 “Cross-Border Direct Routings” brought no evidence for impact of such kind of operations on Safety, Capacity or Human Factors. New DCT options for the KUAC Core Area which have been evaluated in fast time simulations (EXE-0201-D003) and real time simulations (EXE-0201-D004) demonstrated capacity impacts and degradations of situational awareness if too many routing options have been available at the same time resulting in multiple conflicts.

Live Trials related to FR-CAP-02 “Cross-Border User Preferred Route” and the scenario FRA365 of the KUAC RTS have demonstrated by means of ATCO feedback an increased complexity. This has been stated for single UPR flights accomplished in EXE-0201-D006 but in particular in KUAC RTS scenario FRA365 (EXE-0201-D004) and – in general – if ATCOs were asked to consider a wide-spread application of UPR operations. From both demonstration activities a need for advanced controller support tools can be derived.

5.3.3 Description of assessment methodology

Regarding the assessment of Environmental Sustainability the project has been supported by WP16.06.03.

For the description of the assessment methodology please refer to chapter 4.1.5

5.3.4 Results impacting regulation and standardisation initiatives

- According to ICAO DOC 4444, the change of cruise flight level can be initiated and indicated at published waypoints or by stating the Latitude / Longitude position in field 15 of the ICAO flight plan. As flight level changes at coordinates cannot be processed by all ATM systems, flight planning systems are currently designed to initiate a change of cruise flight level at a published waypoint only. If segments within a Free Route environment are very long, it can occur that the descent due to flight profile restrictions has to be initiated way too early in the flight plan compared to the actual ATC clearance (e.g. the distance between two waypoints is 500 nm and a profile restriction is applicable at the end of this segment, the descent is initiated about 500nm too early). This has negative implications on the planned fuel consumption and requires general solution for long segments (published or within Free Route areas) which has to be coordinated on Eurocontrol / ICAO level. This limitation of ATC systems can be solved by allowing intermediate waypoints with less distance to a waypoint with profile constraints so that an appropriate Top of Descent point can be determined.
- ICAO requirement to keep distance of 2.5 NM to sector boundaries should be verified. With new systems (including MTCD) at least in some sectors (e.g. Karlsruhe East sectors - large and with less complex and less traffic) this regulation could be adapted. For Central sectors Karlsruhe it would be a no-go item for full use of UPR.
- Future DCT implementations, especially in the scope of FAB-wide or Cross-FAB activities, probably have to rely on a COP-less transfer of flights between ACCs/UACs. With the given OLDI standard this system functionality is not ensured even if systems are labelled “OLDI compliant”.
- Airblock swapping between operational sectors affect external interfaces, system-wise such as OLDI and operational such as telephone connection. In addition, ATC frequency usage becomes non-trivial, and must be managed in a way that ensures that ATCO-Pilot voice communications are never impaired.

5.4 Analysis of Exercises Results

For an overview of results related to Key Performance Indicators please refer to 5.3.1.

5.4.1 Unexpected Behaviours/Results

- As is has been shown in technical tests, although ATM systems of Karlsruhe UAC and Maastricht UAC should be in principle compliant to the usage of LAT/LON information and although both systems are characterised as “OLDI compliant” both the usage of LAT/LON-determined points and the usage of the “nearby COP solution” could not demonstrate the functional capabilities regarding the interaction between MADAP and P1/VAFORIT which are needed for the implementation of Cross-Border DCTs. As a consequence for the FRAMaK project, in particular the implementation of COP-less Cross-Border DCTs, the project had to consider that flights using COP-less Cross-Border DCTs require manual coordination which clearly was not possible for DCTs serving major traffic flows. Therefore the implementation of COP-less Cross-Border DCTs had to remain limited to low and medium density flows. As a workaround DCTs supporting major traffic flows were published as segmented DCTs comprising a COP in the vicinity of the AoR boundary between Karlsruhe UAC and Maastricht UAC.

- Since, e.g. due to protection of privacy of flight crews, many airlines are not able to provide fuel burn data from real life flights it became obvious that there is a need for more accurate performance models regarding the analysis of vertical flight efficiency.
- ENR variability can only be calculated for pairs of identical entry-exit points, otherwise different routings would be mixed. Since CPF data used for track information do not provide a reference to FPL waypoints for this analysis only FPL information could be used.
- As improvements were found in route efficiency indicators REDES and RESTR a reduction of flight duration in the FRAMaK area was to be expected, too. Therefore, the partly increase of flight durations and ENR variability might be caused by factors other than the route length. In particular it is to be assumed that some AOs decreased cruising speeds of flights in the course of Cost Index reductions due to high fuel prices.
- As the long range UPR flights were dependent on the North Atlantic Track System on several occasions with southerly routings, flights which have been planned in the monthly schedule could not participate in the trial as they did not cross the reserved airspace anymore.
- As UPR flights could not be planned by the LIDO system automatically some flights had to be cancelled due to the lack of manpower within DLH dispatch. This was for example the case during days of industrial action in European countries.
- Vertical step climbs could only be planned and filed at waypoints. Therefore the optimum vertical profile could not be followed as closely as on (RAD conform) routes with a higher number of waypoints.
- Some ATM systems of adjacent / subjacent ACCs have demonstrated not being capable for automatic processing of UPR flightplans. In order to allow UPR flights from Munich e.g. the UPR flight had to be laterally outside the AoR of Munich ACC (even if well above Munich ACCs vertical limit, i.e. FL 315) or the respective DCT has to be implemented in the system. Due to the use of company route for FRAMaK UPR flights the problem could be solved easily by system adaptations. However, “real UPR” in terms of random routeings would not have been possible with the present ATM systems.
- The exchange, update and integration of traffic data was never executed before in that extensive way in DFS integrating two different FTS and one RTS (SAAM, AirTOp and KASIM). Already the data preparation in SAAM took much more resources as initially planned. SAAM itself is not yet the perfect tool for such detailed studies and it required huge resources for validating and correcting the data (e.g. implemented RAD restriction or PTR for correct trajectories). Therefore, some workload studies for sub-scenarios with AirTOp were skipped if a certain potential overload (in terms of traffic count on a routing) was already indicated by SAAM. Comparison between different DCTs for similar flows were just done with SAAM and the scenarios 1a and 3a were finally built according to the traffic shift onto each new DCT. The data exchange to the subjacent simulators went as well not as perfect as planned as certain corrections in the traffic data (e.g. correction for odd / even segments or some flows e.g. ARR EBBR which were wrongly forced via ADKUK by SAAM) did not always reach the next simulator and had to be done once again.

5.5 Confidence in Results of Demonstration Exercises

5.5.1 Quality of Demonstration Exercises Results

Overall the project assumes the quality of results being on a – at least – sufficient level.

Regarding individual exercises results’ quality please refer to the respective sub-chapters in chapter 6.

5.5.2 Significance of Demonstration Exercises Results

In general it is to be noted that statistical significance (in the scientific meaning) has not been tested in this framework which was as a Live Trial activity – other than a laboratory experiment – operationally driven thus showing a variety of uncontrollable influencing factors.

Overall the six FRAMaK demonstrations based on Fast Time Simulations, Real Time Simulations, Flight Trials and Public Lice Trials provided fruitful results which are relevant for further steps via Direct route options towards a Full Free Route Airspace.

Regarding the significance of individual exercises please refer to the respective sub-chapters in chapter 6.

5.5.3 Conclusions and recommendations

5.5.3.1 Conclusions

5.5.3.1.1 Cross-Border Direct Routes

Based on the analysis of FPL and track data of 17,295 flights within four measurement periods of each one week duration the results of the FRAMaK Cross-Border DCT Public Live Trials (EXE-0201-D001) provide evidence for the benefits of Cross-Border Direct routing options. Reductions of FPL route length (-6.8 NM per flight or -0.6%) and actual flown track length (-3.7 NM per flight or -0.3%) provide important contributions for the enhancement of ATM performance in terms of efficiency and environmental sustainability.

These results were confirmed by EXE-0201-D002. The results of the SAAM Network Assessment show that – despite the high number of rather straight if not direct routing options already available prior to FRAMaK DCT implementations – the newly implemented FRAMaK Direct routing options provide a potential of more than 1.5 million NM route savings per year (4.2 NM per flight) corresponding to a potential reduction of fuel consumption of more than 9 million tons (25 kg per flight) and a reduction of CO_2 emission of more than 30 million tons (83 kg per flight). Thus, if airline operators make use of the new FRAMaK Direct routing options they might save up to 7.5 million Euro per year which are the estimated direct cost savings caused by fuel consumption, not taking into account potential but individual indirect cost benefits due to less flight time affecting maintenance, staffing etc.

As the initial aim of the project has been to demonstrate DCT routing options which "formalise day-to-day ATCO behaviour" in terms of the provision of tactical shortcuts an important finding is that within the FRAMaK area the FPL coherence, i.e. the accordance between FPL route and actual flown route, was improved by 4% and 5% for weekend traffic. Reflecting well-known flows these DCTs were easily implemented without preceding real time simulations. Clearly, the implementation of DCTs creating new flows – as if developing new ATS routes – might require simulations preferably focussing on a limited number of additional route options.

In addition to this initial approach the project succeeded in developing new Cross-Border DCT routing options which offer completely new connections. Results show that actual route length savings – taking into account tactical DCTs in the past of 3.1 NM (difference to FPL route length saving of 6.8 NM) – are 3.7 NM per flight which show the additionally created potential. Route efficiency indicators REDES and RESTR calculated based on FPL and actual track data from Public Live Trials confirm these improvements indicating that the network available in the FRAMaK area now offers routing options more directed towards the destination and with more straightness than before.

Although efficiency indicators REDES and RESTR show improvements towards more straightened and directed routing options indicators related to Predictability did not reflect a potential for better accuracy of predictions; in contrast even an increase in ENR variability was observed.

The analyses related to sectorisation show no differences between operations using FRAMaK DCTs and the baseline condition. This is a consequence of the design process seeking for avoidance of too small route segments' lengths per sector.

The so-called Vertical Optimisation Directs, i.e. DCT routing options which were designed for improved vertical profiles by allowing for a late descent, have demonstrated an enormous potential for fuel burn savings. Especially if the new routing is not affected by flight level constraints potential savings reach up to 68 kg per flight.

An important finding is that there are certain lateral very small non-AMC manageable areas with high vertical extensions which – although regularly seldom used above FL245 – prevent the introduction of an unexpected high number of efficient direct routes.

While the project originally was aiming for the implementation of Cross-Border DCTs which do not rely on a Coordination Point on/at the AoR boundary between the UACs involved in this demonstration it became obvious that at this stage the exchange of flight information via the OLDI interface does not support such COP-less operations. Although both ATC systems involved have been OLDI-compliant it was found that the OLDI standard allows for different ways of implementing such functionality. Since the current situation requires a manual coordination of flight between UACs as a consequence such COP-less Cross-Border DCTs were only published supporting low to medium traffic flows. As a recommendation for future DCT implementations (e.g. in the scope of FAB-wide or Cross-FAB activities) it can be concluded that there is a need for a harmonised implementation of this functionality. An alternative to LAT/LON-based dynamic COPs is the usage of a nearby-COP mechanism. However, if completely new DCTs are designed additional 5LNC waypoints might be needed.

As demonstrated in the successional exercises EXE-0201-D003 EXE-0201-004 a set of new weekend DCT routings for the KUAC core area (developed from KUAC FTS/RTS scenarios 1a and 3a) can be made available for early implementation e.g. in DEC2014 (still final agreement with MUAC for certain new route options required).

For the time being the development of individually designed (tailor made) new (cross-border) DCT route options in the core area represents a cost beneficial way to optimize horizontal flight efficiency while avoiding negative operational impacts (capacity or vertical flight efficiency) and offering the safe opportunity for stepwise introduction.

As a first investigation about strategies to mitigate unwanted effects from sector clipping related to (cross-border) Direct Routing EXE-0201-D005 was conducted. It was shown that sector design and dynamic sectorisation concepts appear promising and feasible strategies, once fully validated and on-line implemented, allowing to focus Free Route design on maximum benefits for Airspace Users without high need to compromise for ATC performance.

5.5.3.1.2 Cross-Border User Preferred Routes

From an Airspace User's perspective the UPR demonstration showed with promising fuel and time savings that the further UPR development and implementation is desirable. As capacity constraints can already be found throughout Europe, technical improvements like a useable planning tool, FPL filing standards, i4D trajectories etc. have to be established beforehand.

On the other side ANSPs experienced throughout the FRAMaK UPR trials, that airspace capacity and efficiency might be reduced in particular in complex sectors of the Core Area if full Free Route with UPR (comprising entry, exit, and intermediate points) is implemented today.

Therefore, as an overall result ANSPs consider UPR operations possible in low to medium complexity areas or even in (usually) more dense areas at certain times, such as winter season, night. An implementation in more dense airspace will require further investigation and the availability of enhanced technical means, e.g. controller support tools, and enhanced working procedures / positions.

The FRAMaK trials based on the original UPR Test Area have shown that the size of FRAMaK is near the minimum size to allow for UPR optimization within a single FRA. Through the support of Avinor, LFV, NATS, and Naviair it was possible to significantly enlarge the UPR Test Area in order to properly accomplish the UPR demonstrations. However, due to the restricted size of the demonstration area, the shortness of some routings within this area, the finite amount of waypoints and routings, the limitations of LIDO and the variability in airway charges, it was not possible to demonstrate significant savings due to wind effects and full free flight routings.

In the course of the demonstration deficiencies of today's flight planning tools were identified and possible solutions have been outlined.

Where mainly long directs have been planned vertical step climbs could be planned and filed only at waypoints. Due to lacking intermediate points the optimum vertical profile could not be followed as closely as on RAD conform routes comprising a higher number of waypoints.

The trial showed that for the majority of UPR flights DCT routing options were available or have been made available as new FRAMaK Cross-Border DCTs which in most cases properly matched the respective UPR routing for the specific citypair. Therefore, improvements in available DCT connections should be feasible as interim solution for the near future.

Special Use Airspace (SUA) may prevent the establishment of optimized routing options in various places. SUAs have been avoided within the FRAMaK trials by executing flights on weekend or in areas clear of those areas.

UPR Live Trials have been useful in order to identify specific issues related to the compatibility of UPR routings with existing systems and structures. However, since UPR has been demonstrated on a case-by-case basis with a maximum of three flights per day this FRAMaK demonstration did only partly show operational issues and impacts not considering a large-scale application of this operational concept.

From the beginning of the project a conflict became visible between flight crews and ATCOs both aiming for shortest routes and shortcuts in order to straighten the routing on the one side and dispatch staff trying to find the best routing from an economical point of view which is not necessarily the shortest on the other side.

From ANSPs' perspective there is in general no positive contribution of UPRs to Capacity. The challenge for ANSPs is to find the right balance between freedom of routing selection and Capacity. Due to crossing flows and/or sector issues, FRA capabilities might be limited to existing (local/regional, non-Cross-Border) Entry-Exit DCTs in some sectors / sector groups.

Complex and small sectors with a lot of vertical movements are not conducive to UPR operations on a large scale although individual UPR flights are manageable with pre-notification.

A UPR flight demands a lot of attention from the ATCO. As the ATCO needs to stick to the flightplan, a lot of time is needed to fit the flight into the actual air picture. This can involve taking other measures for the other flights, just to avoid touching the UPR. As a result, the workload goes up significantly. If the number of UPRs would increase, it could become very cumbersome to follow what the UPRs are doing especially when the flights are climbing or descending combined with some unexpected turns in or at the boundary of the sector. Complete awareness of what the other aircraft are doing is then essential.

Regarding sectorization it was found that UPRs along the ANSP unit's (zig-zag) boundary cause multiple re-entering situations (e.g. EDDM-ENGM). In addition, some UPRs do not represent actual flown tracks, but create completely new flows. This might cause issues with sectors that are already to the limit of their capacity and complexity.

For UPR flight planning it has to be ensured that waypoints (navigation aids, 5LNCs etc.) used in the flight plan are known in the affected ACCs' / UACs' systems. In the FRAMaK demonstrations this was achieved by the publication of the respective Test Plan with waypoint information.

The system of Compulsory Transition Routes connecting aerodromes' SIDs and STARs with the UPR Test Area applied for UPR trials has shown good results in terms of operational feasibility.

The accomplishment of dry-runs by means of the LIDO Flight Planning Systems supported the development of the operational concept.

As demonstrated as part of EXE-0201-D003 / D004 (scenario FRA365) in the core area of KUAC Free Route Airspace above FL 365 is not an option for a mid-term implementation, as many mitigations for mentioned safety concerns are required. The results for FRA365 showed that some very high dense and complex areas / sectors are bottlenecks for implementation what need to be respected (otherwise capacity and vertical flight efficiency is reduced). It should be more feasible to initially develop a FRA above a certain MIN FL within the less complex and dense KUAC East sectors not dealing with operational issues (complexity and much more new conflicts as in the core area) and procedural issues (such as distance to boundaries) at the same time. Cross-border FRA in same less complex and less dense airspaces in Northern Europe seems to be more promising for mid-term implementation.

5.5.3.2 Recommendations

5.5.3.2.1 Cross-Border Direct Routes

Design recommendations

A sufficient acceptance by ATCOs can be achieved by following a stepwise approach comprising a sequence of several implementation packages. The number, sequence and in particular the extent of implementation packages has to be considered carefully.

Turning points at or close to sector boundaries should be avoided. Long direct routes clearly avoid turns in the sectors in between.

In view of a high number of available routing options it should become a best practice of ATCOs to check flight trajectories in order to be aware of such turns.

Very long direct routes should be implemented as segmented DCTs in order to provide intermediate points which can be used as anchor points in tactical vectoring and which allow AOs for FPL filing stepped climbs.

The final aim should be the availability of COP-less Cross-Border DCTs which offer the opportunity for Cross-Border DCTs between entry and exit points not only at the boundary but even in the centre of individual UACs' AoRs. As such active military airspace can be easily circumnavigated.

Selected tested direct route options from the KUAC FTS / RTS (finally updated and tested during KUAC RTS safety runs in March 2014) should be implemented after final coordination and agreements with Maastricht UAC (target AIRAC DEC2014).

Field trials for certain flows on certain new potential DCTs or the implementation of "Seasonal DCTs" are recommended to overcome safety concerns (which often do not apply for the winter season) and to further give daily practice to ATCOs.

Previous stepwise introduction of (initially night) DCTs and timely expansion (extended by morning and/or evening hours) gives ATCO the chance to gain experiences and to accept a daytime DCT during simulation.

Sector Clipping effects from (cross-border) DCT and other Free Route applications, should be duly investigated as they may cause operational issues and negatively affect controller workload and thus capacity. Sector Design and dynamic sectorisation concepts should be investigated as mitigation means.

Technical Considerations

For the realisation of long direct routes with COP-less functionalities the following technical implications have to be considered:

OLDI exchange should support an automatic FPL processing based on dynamic COPs; in this context interoperable OLDI ACT implementations are required.

ACT should be correctly sent based on system boundary, instead of national boundary.

OLDI message formats like OLDI SDM (Supplementary Data Message) / SCO (Skip Communication Message) which inform on new frequencies if sector sequence is modified should be available.

HMIs should cope with dynamic LAT/LONG-defined COPs.

In current system it was observed that if the exit point is too far outside the own AoR, this point and the trajectory are not calculated and displayed on the HMI. Therefore, for long-range DCTs the exit points need to be represented in the system.

Other recommendations

All Special Used Areas above a certain FL (e.g. FL245 as this was the vertical limit in this project) should be AMC-manageable in order to optimise flight efficiency of civilian airspace users.

Since SAAM Fast Time Simulations are considered more and more a standard step in airspace design projects the capabilities of SAAM should be enhanced with regard to

- Utilization of data available in the Enhanced Tactical Flow Management System (ETFMS), i.e. operational data comprising RAD constraints etc., for the generation of traffic examples,
- Optimisation of flights based on different criteria such as wind, route charges, airspace availability etc.

5.5.3.2.2 Cross-Border User Preferred Routes

Free Route Airspace Design

In order to ensure beneficial UPR operations the connectivity between FRA and Non-FR airspaces as well as between multiple (possibly smaller) FRA cells shall support UPR operations in a way that available routeing options approximate the optimal path, e.g. by offering a sufficient number of waypoints to pass from one cell to the other.

During the development ATCOs, AOs, NMOC and computer flight planning service providers should work together, as common problems like intermediate waypoint definitions have to be elaborated.

In order to make use of large scale wind fields a FRA feasible for UPR operations needs a minimum size in terms of DCT segment lengths and clearly the highest benefits are to be expected in big airspaces.

For a widespread implementation of UPR operations more flexible handling options (A-FUA) regarding Special Use Airspace have to be in place. Operational needs of the stakeholders, for example preceding handling time of the flightplan and of fuel calculations have to be considered in order to implement operationally significant route changes.

For DCT planning it would be helpful, but for UPR route planning it is essential to have common regulations regarding the safety buffer around restricted/danger areas. The reserved airspace should comprise the safety buffer.

UPR operations at all levels at night could be a possibility in the future but a Cost Benefit Analysis has to prove whether the effort is a good investment.

UPRs will only be possible if the flights are not climbing and/or descending within the airspace and they have to be at the highest flight levels. Traffic that is departing or arriving close or within the area of responsibility would have to be on transition routes while climbing or descending.

Further developments for “Full FRA” above a certain MIN FL should be initially focused within the less complex and dense KUAC East sectors and furthermore within Northern Europe.

For FRA in the core area more SAAM validations and cost benefit analyses are required, as the further development of DCT segments seems to be more tailor made for the customer avoiding negative impacts on vertical efficiency and capacity.

For future UPR operations (e.g. northbound zig-zag routing) the flight level allocation (odd/even) might cause problems both for AOs because of too many intermediate FL changes, and for ATC due to incompliance in case of intended deviations from FLOS for flow separation purposes (e.g. track 010° might be required to be even instead odd).

Operational Considerations

Under certain meteorological conditions tactical DCTs might jeopardize benefits of (planning-based) User Preferred Routings. Therefore under UPR operations ATCOs and pilots should stick to the FPL routeing. In order to evaluate potential benefits of tactical DCTs offered by ATC the cockpit crew would need a tool in the cockpit which makes use e.g. of real-time weather information.

Flight Planning Tools

To calculate and file UPR routes flight planning tools have to be developed further. As a basis for the development of such Free Flight planning tools a framework of commonly agreed requirements is needed. For this purpose general rules have to be determined and published in AIP or RAD which should not be of local or temporary nature.

Flight planning systems need to be capable to cope with restrictions arising from e.g. a step-wise implementation of FRA concepts.

ATM Systems

In mixed mode operation an indication to the controller in the label would be required for UPR operations to indicate which aircrafts are following a UPR.

ATCO feedback showed that conflict detection might become an issue and as such more system support might be required in the future.

6 Demonstration Exercises Reports

6.1 Demonstration Exercise EXE-0201-D001 "Public Live Trial of Cross-Border DCTs" Report

EXE-0201-D-001 is seen as the primary demonstration activity related to FRAMaK Cross-Border DCTs (FR-CAP-01).

By means of publication of FRAMaK Cross-Border DCTs in the Route Availability Document (RAD) Appendix 4 these DCTs are publicly available for flight planning and persist after project's close-out. Therefore, this exercise is referred to as a Public Live Trial.

The project started with the publication of new DCT routing options in SEP 2012. With the progress in FRAMaK WP2 Route Design several Implementation Packages have been published until the last one in MAR 2014. In total, 466 new DCT routing options have been labelled "FRAMaK" in RAD App 4.

The connectivity between the FRAMaK airspace with the arrival/departure route system of these airports (STARs, SIDs, RNAV Transitions) may be facilitated by means of Compulsory Transition Routes. Such new routes outside the FRAMaK airspace are not subject to performance assessment.

In order to demonstrate the effects and to investigate the validation objectives in the course of the FRAMaK project data from real world flights (both FPL and track data) were analysed in 4 measurement periods of one week duration each, thus reflecting the progress in DCT publication. For the statistical analyses data from 17,295 flights have been investigated.

For a detailed description of the exercise please refer to [13].

6.1.1 Exercise Scope

The geographical scope of EXE-0202-D001 was determined by the combined AoR of Karlsruhe UAC and Maastricht UAC. For the statistical analyses FPL and track data of the ECAC airspace have been assessed for flights affecting the FRAMaK airspace either in one of the measurement periods or in the respective reference period.

6.1.1.1 Exercise Scenario

The underlying demonstration scenario is referred to as SCN-0201-001 "Cross-Border Entry-Exit DCTs" which in return refers to FR-CAP-01.

The determination of Cross-Border entry-exit DCTs has been accomplished in WP 2 Route Design. DCTs have been published in the Route Availability Document (RAD), Appendix 4 "En-route DCT limits – DCT limits". FRAMaK entry and exit points have been defined as connecting points between the Cross-Border Direct routes developed in the project and the surrounding ATS Route System or Free Route airspaces both adjacent and subjacent to the FRAMaK airspace.

SCN-0201-001 is related to

- MUAC/KUAC overflights, i.e. transfers through the combined Maastricht & Karlsruhe airspace, and
- flights to and from hubs and major airports affected by airspace design activities in the FRAMaK airspace, i.e. flights
    - arriving from a destination outside the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace,
    - departing from a hub within/below the FRAMaK airspace directed towards a destination outside the FRAMaK airspace, and
    - between hubs within/below the FRAMaK airspace, i.e. departing from a hub within/below the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace.

6.1.1.2 Exercise Objectives

The exercise contributed to the investigation of objectives listed in Table 29.

Table 29: Demonstration Objectives EXE-0201-D001

Objective ID	Description	KPAs
OBJ-0201-001	Horizontal Flight Efficiency of Cross-Border DCTs It is to be demonstrated that FPL routings and flight trajectories based on published DCT routings are closer to the optimum compared with FPL routings based on the existing ATS-route network. Therefore, they are beneficial in terms of flight efficiency. The reduced deviation from the optimum positively affects flight duration and fuel burn. The reduced FPL route length results in weight reductions and again fuel burn due to lower amounts of contingency fuel.	Efficiency
OBJ-0201-002	Vertical Flight Efficiency of Cross-Border DCTs It is to be demonstrated that FPL routings and flight trajectories based on published DCT routings which offer optimized vertical profiles are closer to the optimum compared with FPL routings based on the existing ATS-route network. Therefore, they are beneficial in terms of flight efficiency. The reduced deviation from the optimum positively affects fuel burn.	Efficiency
OBJ-0201-003	Environmental Sustainability of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs due to improved flight efficiency positively affect CO_2 emission.	Environmental Sustainability
OBJ-0201-007	Predictability related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs improve the predictability of flights.	Predictability
OBJ-0201-008	Cost Effectiveness related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs improve the cost effectiveness of flight handling through ANSPs.	Cost Effectiveness
OBJ-0201-010	Operational Feasibility of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs provide a sufficient feasibility for operational usage.	Other

6.1.2 Conduct of Exercise

6.1.2.1 Exercise Preparation

For details regarding the preparation of demonstration activities related to FR-CAP-01 ("Cross-Border Direct Routing Options") please refer to section 4.1.3.

6.1.2.2 Exercise execution

Public Live Trials (EXE-0201-D001) demonstrating the benefits and impacts of Cross-Border DCT operations based on flights using publicly available DCT routing options published in RAD Appendix 4. The Public Live Trial started with the first publication of FRAMaK Cross-Border DCTs in RAD Appendix 4. Publications took place in

- AIRAC cycle 1211 effective 18OCT2012,
- AIRAC cycle 1213 effective 13 DEC2012,
- AIRAC cycle 1306 effective 30MAY2013,
- AIRAC cycle 1311 effective 17OCT2013,
- AIRAC cycle 1313 effective 12DEC2013,
- AIRAC cycle 1401 effective 09JAN2014, and
- AIRAC cycle 1403 effective 06MAR2014

Due to the amount of flights passing Karlsruhe and/or Maastricht airspace and thereby potentially making use of FRAMaK DCTs it was considered to be useful not to analyse all flights from October 2012 up to the end of the FRAMaK project in May 2014 but to determine 4 measurement periods of one week duration each and to compare flight data from these measurement periods with those from respective reference periods which are formed by the same week in the previous year. For details please refer to section 4.1.5.3.2.1.

6.1.2.3 Deviation from the planned activities

Please refer to

Deviation 3: No assessment of Capacity effects (OBJ-0201-005 and OBJ-0201-006) in EXE-0201-D001, page 28

Deviation 8: Technical Limitations for Implementation of COP-less DCTs, page 52

6.1.3 Exercise Results

6.1.3.1 Summary of Exercise Results

6.1.3.1.1 Results per KPA

Table 30: Results per KPA EXE-0201-D001

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Efficiency (horizontal)	OBJ-0201-001	Reduction of FPL route length in Cross-Border DCT operations	Reduction by 6.8 NM per flight (-0.6%). For weekend traffic FPL routings have become shorter by 9.1 NM per flight (-0.8%).
Efficiency (horizontal)	OBJ-0201-001	Reduction of actual route length in Cross-Border DCT operations	Reduction by 3.7 NM (-0.3%) per flight. For weekend traffic actual flown routes per flight are 3.9 NM shorter (-0.3%).

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Efficiency (horizontal)	OBJ-0201-001	Reduction of fuel burn in Cross-Border DCT operations	Based on FPL routings fuel burn decreased by 107.5 kg (-0.8%) per flight (weekend traffic: -145.1 kg / -1.1%). Based on actual flown routes fuel burn decreased by 56.4 kg (-0.4%) per flight (weekend: -95.3 kg / -0.7%).
Efficiency (horizontal)	OBJ-0201-001	Improvement of REDES in Cross-Border DCT operations	Based on FPL routings REDES was down to 1.035 by 0.4 percentage points (weekend: 1.037, -0.3 percentage points). REDES of actual flown routes decreased by 0.1 percentage points to 1.019 (weekend: 1.017 / -0.3 percentage points).
Efficiency (horizontal)	OBJ-0201-001	Improvement of RESTR in Cross-Border DCT operations	Based on FPL routings RESTR was down to 1.018 by 0.6 percentage points (weekend: 1.016, -0.5 percentage points). RESTR of actual flown routes decreased by 0.2 percentage points to 1.007 (weekend: 1.006 / -0.2 percentage points).
Efficiency (vertical)	OBJ-0201-002	Reduction of fuel burn through use of DCTs offering optimized vertical profile	Reductions between 7 and 68 kg per flight.
Environmental Sustainability	OBJ-0201-003	Reduction of CO_2 emission in Cross-Border DCT operations	Based on FPL routings CO_2 emissions decreased by 339.8 kg (-0.8%) per flight (weekend traffic: -458.5 kg / -1.1%). Based on actual flown routes CO_2 emissions decreased by 178.1 kg (-0.4%) per flight (weekend: -301.0 kg / -0.7%).
Environmental Sustainability	OBJ-0201-003	Reduction of NO_x emission in Cross-Border DCT operations	Based on FPL routings NO_x emissions decreased by 2.9 kg (-1.3%) per flight (weekend traffic: -3.1 kg / -1.3%). Based on actual flown routes NO_x emissions decreased by 1.2 kg (-0.5%) per flight (weekend: -1.9 kg / -0.8%).

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Predictability	OBJ-0201-007	Reduction of ENR variability in Cross-Border DCT operations	A reduction of ENR variability was not demonstrated. Other than to expected from improved route efficiency indicators REDES and RESTR ENR variability increased with many entry-exit pairs. This may be due to potential reductions of cruising speeds.
Predictability	OBJ-0201-007	Improvement of FPL adherence	An improvement of FPL adherence was not demonstrated.
Cost Effectiveness (Sectorization)	OBJ-0201-008	No adverse results regarding sector occupancy in Cross-Border DCT operations	No effect on route length per sector.
Cost Effectiveness (Sectorization)	OBJ-0201-008	No adverse results regarding sector occupancy in Cross-Border DCT operations	No effect on flight duration per sector.
Cost Effectiveness (Sectorization)	OBJ-0201-008	No adverse results regarding sector occupancy in Cross-Border DCT operations	No effect on number of sectors per flight.
Other – Operational Feasibility	OBJ-0201-010	Good eligibility of Cross-Border DCT routing options	Eligibility of flights for FRAMaK DCTs (based on shortest route option) is 15%, i.e. for 15% of flights in the FRAMaK area one or more FRAMaK DCTs have been available. In weekend traffic the eligibility is 10%.
Other – Operational Feasibility	OBJ-0201-010	Good acceptability of Cross-Border DCT routing options	8% of all flights in the FRAMaK files one or more FRAMaK DCTs (weekend: 10%). Based on the eligibility for FRAMaK DCTs 50% of flights made use of them. In weekend traffic more flights used a FRAMaK than technically eligible assuming the shortest route option.

6.1.3.1.2 Results impacting regulation and standardisation initiatives

Future DCT implementations, especially in the scope of FAB-wide or Cross-FAB activities, probably have to rely on a COP-less transfer of flights between ACCs/UACs. With the given OLDI standard this system functionality is not ensured even if systems are labelled “OLDI compliant”.

6.1.3.1.3 Unexpected Behaviours/Results

- As is has been shown in technical tests, although ATM systems of Karlsruhe UAC and Maastricht UAC should be in principle compliant to the usage of LAT/LON information and although both systems are characterised as “OLDI compliant” both the usage of LAT/LON-determined points and the usage of the “nearby COP solution” could not demonstrate the functional capabilities regarding the interaction between MADAP and P1/VAFORIT which are needed for the implementation of Cross-Border DCTs. As a consequence for the FRAMaK project, in particular the implementation of COP-less Cross-Border DCTs, the project had to consider that flights using COP-less Cross-Border DCTs require manual coordination which clearly was not possible for DCTs serving major traffic flows. Therefore the implementation of COP-less Cross-Border DCTs had to remain limited to low and medium density flows. As a workaround DCTs supporting major traffic flows were published as segmented DCTs comprising a COP in the vicinity of the AoR boundary between Karlsruhe UAC and Maastricht UAC.
- Since, e.g. due to protection of privacy of flight crews, many airlines are not able to provide fuel burn data from real life flights it became obvious that there is a need for more accurate performance models regarding the analysis of vertical flight efficiency.
- ENR variability can only be calculated for pairs of identical entry-exit points, otherwise different routings would be mixed. Since CPF data used for track information do not provide a reference to FPL waypoints for this analysis only FPL information could be used.
- As improvements were found in route efficiency indicators REDES and RESTR a reduction of flight duration in the FRAMaK area was to be expected, too. Therefore, the partly increase of flight durations and ENR variability might be caused by factors other than the route length. In particular it is to be assumed that some AOs decreased cruising speeds of flights in the course of Cost Index reductions due to high fuel prices.

6.1.3.1.4 Quality of Demonstration Results

By combining FPL information and actual track data the quality of results is considered to be higher than results from conventional approaches relying exclusively on FPL information. It has to be stated though that the complexity of work is much higher with this amplified approach.

6.1.3.1.5 Significance of Demonstration Results

Due to the number of 17,295 flights considered in the analyses the significance of results can be assumed.

6.1.4 Conclusions and recommendations

6.1.4.1 Conclusions

In the course of the Public Live Trials (EXE-0201-D001) related to the demonstration of FR-CAP-01 “Cross-Border Directs” comprising four measurement periods of each one week duration on average 15% of flights (34,818 out of 225,440 flights) in the FRAMaK area have been eligible to the use of FRAMaK DCTs assuming the shortest route option possible. In these periods 17,295 flights, i.e. 8% of all flights, actually filed at least one FRAMaK DCT in the flightplan routing. At weekends this usage rate is slightly higher at 10%.

The results of the Public Live Trials provide evidence for the benefits of Cross-Border Direct routing options. Reductions of FPL route length (-6.8 NM per flight or -0.6%) and actual flown track length (-3.7

NM per flight or -0.3%) provide important contributions for the enhancement of ATM performance in terms of efficiency and environmental sustainability.

As the initial aim of the project has been to demonstrate DCT routing options which "formalise day-to-day ATCO behaviour" in terms of the provision of tactical shortcuts an important finding is that within the FRAMaK area the FPL coherence, i.e. the accordance between FPL route and actual flown route, was improved by 4% and 5% for weekend traffic. Reflecting well-known flows these DCTs were easily implemented without preceding real time simulations. Clearly, the implementation of DCTs creating new flows – as if developing new ATS routes – might require simulations preferably focussing on a limited number of additional route options.

In addition to this initial approach the project succeeded in developing new Cross-Border DCT routing options which offer completely new connections. Results show that actual route length savings – taking into account tactical DCTs in the past of 3.1 NM (difference to FPL route length saving of 6.8 NM) – are 3.7 NM per flight which show the additionally created potential. The route efficiency indicators REDES and RESTR confirm these improvements both for FPL routings and actual flown tracks indicating that the network available in the FRAMaK area now offers routing options more directed towards the destination and with more straightness than before.

Although efficiency indicators REDES and RESTR show improvements towards more straightened and directed routing options indicators related to Predictability did not reflect a potential for better accuracy of predictions; in contrast even an increase in ENR variability was observed.

The analyses related to sectorisation show no differences between operations using FRAMaK DCTs and the baseline condition. This is a consequence of the design process seeking for avoidance of too small route segments' lengths per sector.

The so-called Vertical Optimisation Directs, i.e. DCT routing options which were designed for improved vertical profiles by allowing for a late descent, have demonstrated an enormous potential for fuel burn savings. Especially if the new routing is not affected by flight level constraints potential savings reach up to 68 kg per flight.

An important finding is that there are certain lateral very small non-AMC manageable areas with high vertical extensions which – although regularly seldom used above FL245 – prevent the introduction of an unexpected high number of efficient direct routes.

While the project originally was aiming for the demonstration of Cross-Border DCTs which do not rely on a Coordination Point on/at the AoR boundary between the UACs involved in this demonstration it became obvious that at this stage the exchange of flight information via the OLDI interface does not support such COP-less operations. Although both ATC systems involved have been OLDI-compliant it was found that the OLDI standard allows for different ways of implementing such functionality. Since the current situation requires a manual coordination of flight between UACs as a consequence such COP-less Cross-Border DCTs were only published supporting low to medium traffic flows. As a recommendation for future DCT implementations (e.g. in the scope of FAB-wide or Cross-FAB activities) it can be concluded that there is a need for a harmonised implementation of this functionality. An alternative to LAT/LON-based dynamic COPs is the usage of a nearby-COP mechanism. However, if completely new DCTs are designed additional 5LNC waypoints might be needed.

6.1.4.2 Recommendations

A sufficient acceptance by ATCOs was achieved by following a stepwise approach comprising several implementation packages. For future implementations the number, sequence and in particular the extent of additional implementation packages has to be considered carefully.

As a recommendation regarding design of new DCT routing options turning points at or close to the sector boundary should be avoided. Cross-Border DCTs clearly avoid turns in the sectors in between. Closely related to this recommendation is the need that in view of a high number of routing options ATCOs should check flight trajectories in order to be aware of such turns.

Very long direct routes should be implemented as segmented DCTs in order to provide intermediate points which can be used as anchor points in tactical vectoring and which allow AOs for FPL filing stepped climbs.

Special Use Airspace above a certain FL (e.g. FL245 as this was the vertical limit in this project) should be AMC-manageable in order to optimise flight efficiency of civilian airspace users.

The final aim should be the COP-less Cross-Border DCT. The availability of COP-less functionalities based on interoperable OLDI ACT implementations offer the opportunity for Cross-Border DCTs between entry and exit points not only at the boundary but even in the centre of individual UACs' AoRs and as such active military airspace can be easily circumnavigated. Technical implications have to be solved

- ACT should be correctly sent based on system boundary, instead of national boundary,
- OLDI exchange should support an automatic FPL processing based on dynamic COPs,
- OLDI message formats like OLDI SDM (Supplementary Data Message) / SCO (Skip Communication Message) which inform on new frequencies if sector sequence is modified should be available.
- HMIs should cope with LAT/LONG-defined COPs.
- In current system it was observed that if the exit point is too far outside the own AoR, this point and the trajectory are not calculated and displayed on the HMI. Therefore, for long-range DCTs the exit points need to be represented in the system.

6.2 Demonstration Exercise EXE-0201-D002 "Simulation-based assessment of Cross-Border DCTs – Network Assessment" Report

In the framework of FRAMaK Work Package 3 "SAAM Network Assessment" Eurocontrol NMD has analysed the impact of FRAMaK Direct routing options on the network and has accomplished basic performance assessments. In the line of FRAMaK demonstration activities this assessment is referred to as "EXE-0201-D002 Simulation-based assessment of Cross-Border DCTs – Network Assessment".

Complementing EXE-0201-D001 this exercise had a focus on the overall, especially network related, effects of Cross-Border DCTs in the Central European airspace.

Furthermore, the results of this exercise inform about the potential savings of implemented FRAMaK DCT routing options for Airspace Users, based on the assumption that the Airspace User files the shortest route available. An additional objective of EXE-0201-D002 was to study FRAMaK DCT routing proposals with regard to connectivity to adjacent/subjacent airspace, resulting traffic flows etc. Therefore, it will focus on the overall, especially network related, effects of Cross-Border DCTs in the Central European airspace.

6.2.1 Exercise Scope

The geographical scope of EXE-0202-D002 was determined by the combined AoR of Karlsruhe UAC and Maastricht UAC.

6.2.1.1 Exercise Scenario

The underlying demonstration scenario is referred to as SCN-0201-001 "Cross-Border Entry-Exit DCTs" which in return refers to FR-CAP-01.

The determination of Cross-Border entry-exit DCTs has been accomplished in WP 2 Route Design. DCTs have been published in the Route Availability Document (RAD), Appendix 4 "En-route DCT limits – DCT limits". FRAMaK entry and exit points have been defined as connecting points between the Cross-Border Direct routes developed in the project and the surrounding ATS Route System or Free Route airspaces both adjacent and subjacent to the FRAMaK airspace.

SCN-0201-001 is related to

- MUAC/KUAC overflights, i.e. transfers through the combined Maastricht & Karlsruhe airspace, and
- flights to and from hubs and major airports affected by airspace design activities in the FRAMaK airspace, i.e. flights
  - arriving from a destination outside the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace,
  - departing from a hub within/below the FRAMaK airspace directed towards a destination outside the FRAMaK airspace, and
  - between hubs within/below the FRAMaK airspace, i.e. departing from a hub within/below the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace.

6.2.1.2 Exercise Objectives

The exercise shall contribute to the investigation of objectives listed in Table 31.

Table 31: Exercise Objectives EXE-0201-D002

Objective ID	Description	KPAs
OBJ-0201-001	Horizontal Flight Efficiency of Cross-Border DCTs It is to be demonstrated that FPL routings and flight trajectories based on published DCT routings are closer to the optimum compared with FPL routings based on the existing ATS-route network. Therefore, they are beneficial in terms of flight efficiency. The reduced deviation from the optimum positively affects flight duration and fuel burn. The reduced FPL route length results in weight reductions and again fuel burn due to lower amounts of contingency fuel.	Efficiency
OBJ-0201-003	Environmental Sustainability of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs due to improved flight efficiency positively affect CO_2 emission.	Environmental Sustainability
OBJ-0201-005	Capacity related to Cross-Border DCTs It is to be demonstrated that based on a suitable route design the usage of Cross-Border Directs will not negatively affect capacity of the FRAMaK airspace.	Capacity
OBJ-0201-006	Network effects related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect capacity demand in the adjacent centres/sectors serving the connecting ATS routes.	Capacity

6.2.2 Conduct of Exercise

6.2.2.1 Exercise Preparation

The SAAM Network Assessment has been prepared with regard to the following aspects:

6.2.2.1.1 Network

The simulation model comprised available routeing options (both ATS network and FRAMaK DCTs referred to in [7] as "New FRAMaK" and "New w/o Label") as of AIRAC 1404 (effective from 03APR2014) (Figure 28). The exclusion of FRAMaK DCTs which were existing prior to the FRAMaK project and which have been amended ("re-labelled") as described in [7] has been done due to the need for a clear distinction of FRAMaK benefits from those of other FRA projects of DFS and Eurocontrol, like Free Route Airspace Karlsruhe (FRAK), Free Route Airspace Maastricht (FRAM) or the FABEC Night Network project.

The route network resulting from the ATS network in connection with the FRAMaK DCT routeing options (ORG) was compared with the reference (REF) which is the ATS route network and all non-FRAMaK DCT routeing options available with AIRAC 1401. Doing so, the effects of FRAMaK DCTs which have been added to the existing routeing options (both ATS network and other DCTs) could be analysed.

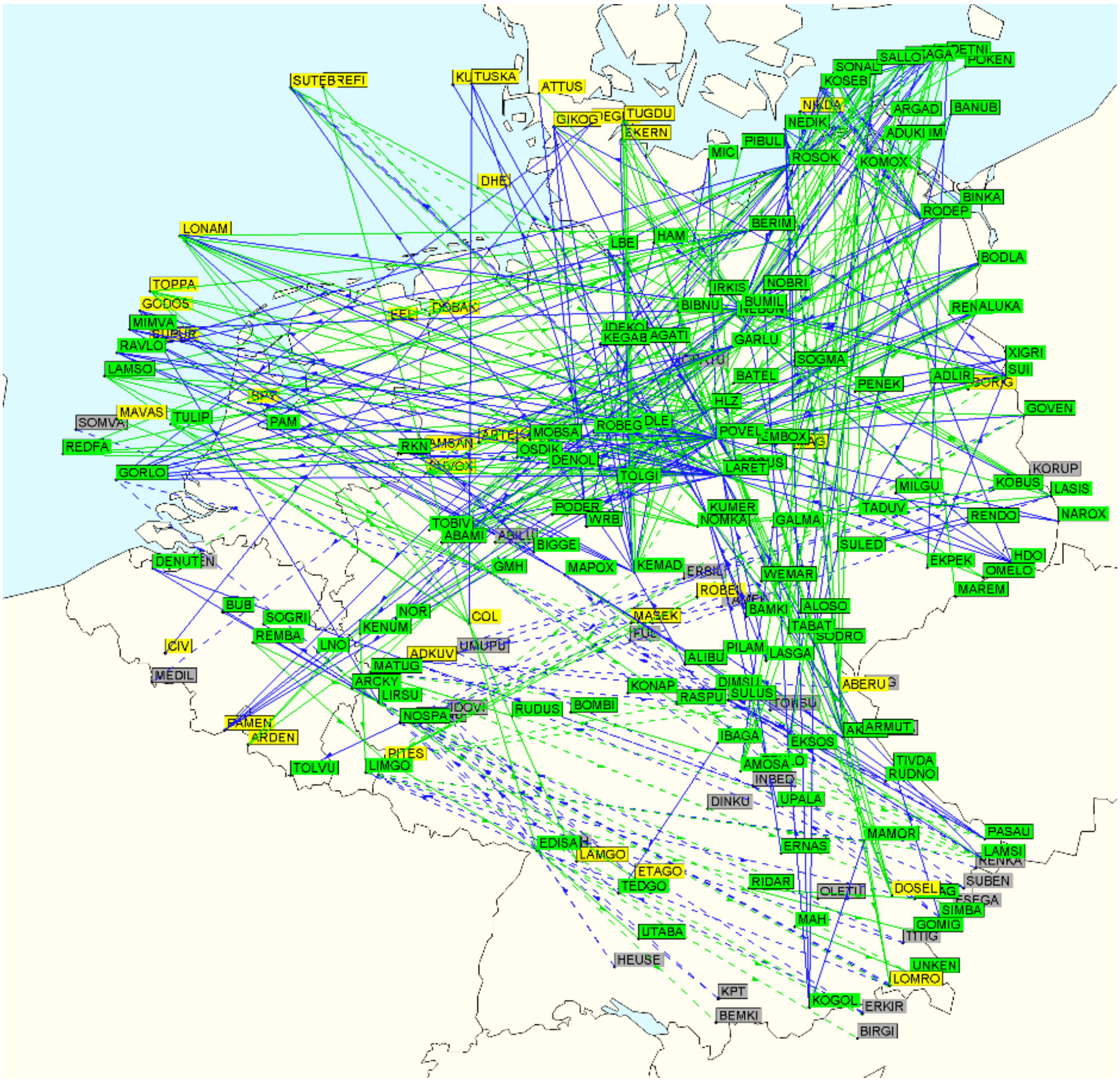

Figure 28: FRAMaK Direct routeing options as of AIRAC 1404 referred to in the SAAM Network Assessment

The availability of the FRAMaK Direct routeing options available in AIRAC 1404 are described in [7]. It is evident that the number of DCT routeing options is significantly higher during night and weekends. This is due to the fact that in general FRAMaK Direct routeing options are designed to be clear of AMC manageable airspace. Since those areas are usually not activated during night and weekend the availability for civil usage of airspace is higher during these times.

Table 32: Availability of DCT routing options

Availability	Count
H24	213
Night + Weekend	161
Night only	87
Weekend only	5
Total	**466**

6.2.2.1.2 Traffic Example

In order to calculate the effects of the FRAMaK DCTs over a period of one year, the assessment was accomplished based on two traffic examples of one week each:

- sub-sample 1 is reflecting higher density summer traffic in the week 24-30 June 2013,
- sub-sample 2 was taken from the lower density winter traffic in week 28 October - 03 November 2013.

From both periods all last filed Flight Plans available at ECTL NMD from real world traffic were assigned to the simulation route network following the "shortest route option".

6.2.2.1.3 Analysis periods

Within the periods of the traffic examples described above results have been calculated for the complete week, i.e. MON-SUN, and in addition partially for the weekend, SAT+SUN, in order to demonstrate effects of those DCTs available exclusively during weekends.

6.2.2.1.4 Important Considerations

The assignment of flights according to the shortest route option aims for minimizing the route length. Though, in real-life aircraft operators take into account other factors when selecting economical FPL routings like avoidance of heavy weather, adaptation to the wind situation (exploitation of tail wind), avoidance of delay in congested airspace, or minimisation of route charges. Furthermore, especially with regard to the reference scenario it is to be noted that the simulation does not take into account real-life behaviour of Air Traffic Controllers in terms of provision of Direct routings on a tactical basis. Thus, the route lengths calculated by the simulations model may be overestimated.

As they do not take into account real-life flight planning mechanisms as well as real-life ATCO decisions simulation results addressing effects in terms of route length, fuel consumption etc. have to be handled with caution. When referring to the shortest route option the results are limited to the potential effects in terms of route length only.

However, since this way of analysing route design proposals is to be seen as a common standard within the area of Eurocontrol member states, it is feasible in order to compare the effects of FRAMaK DCTs with those of other route design activities.

6.2.2.2 Exercise execution

The exercise comprised a Fast Time Simulation using the "System for traffic assignment and analysis on a macroscopic scale" (SAAM) simulation tool based on the determinations described in chapter 6.2.2.1 .

6.2.2.3 Deviation from the planned activities

See Deviation 4:No assessment of Cost Effectiveness in the SAAM Network Assessment

6.2.3 Exercise Results

6.2.3.1 Summary of Exercise Results

The results of the SAAM Network Assessment show that – despite the high number of rather straight if not direct routeing options already available prior to FRAMaK DCT implementations – the newly implemented FRAMaK Direct routeing options bring a potential of more than 1.5 million NM route savings per year corresponding to a potential reduction of fuel consumption of more than 9 million tons and a reduction of CO_2 emission of more than 30 million tons. The route extension of the shortest route possible can be reduced from 2.0% to 1.7%. Depending on seasonal effects FRAMaK DCT routing options are eligible for approx. 20% of the flights taken into account in the statistical analysis.

The simulation-based assessment has not shown any evidence for negative effects on Capacity or overall Network performance.

When comparing the results calculated for the complete week with those calculated for the weekend only it can be concluded that more flexibility in civil-military airspace utilisation could bring significant additional benefits.

6.2.3.1.1 Results per KPA

Table 33: Results per KPA EXE-0201-D002

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Efficiency (horizontal)	OBJ-0201-001	Reduction of FPL route length in Cross-Border DCT operations	Potential reduction by 1,512,163 NM per year (weekend: 665,096 NM per year). Average reduction of FPL route length by 4.15 NM (weekend: 5.48 NM) per flight. Potential reduction of route extension from 2.01% to 1.70% during summer week, from 1.96% to 1.67% during winter week.
Efficiency (horizontal)	OBJ-0201-001	Reduction of fuel burn in Cross-Border DCT operations	Potential reduction by 9,072,976 kg per year (weekend: 3,990,574 kg per year). Average reduction by 25 kg (33 kg) fuel per flight.
Environmental Sustainability	OBJ-0201-003	Reduction of CO_2 emission in Cross-Border DCT operations	Potential reduction by 30,243,252 kg CO_2 per year (weekend: 13,301,912 kg per year). Average reduction by 83 kg (weekend: 110 kg) CO_2 per flight.
Capacity	OBJ-0201-005 OBJ-0201-006	No degradation regarding number of flights in Cross-Border DCT operations	No negative effects

KPA	Objective Identifier	Success Criterion	Result of the demonstration		
Capacity	OBJ-0201-005 OBJ-0201-006	No adverse results regarding ENR Throughput in Cross-Border DCT operations	No negative effects		
Other – Operational Feasibility	OBJ-0201-010	Good eligibility of Cross-Border DCT routing options	Complete Week	Summer	22.5%
				Winter	21.4%
			Weekend	Summer	18.9%
				Winter	17.5%

6.2.3.1.1.1 Flight Efficiency and Environmental Sustainability

6.2.3.1.1.1.1 Complete Week

Potential performance effects were calculated based on the results for a single summer week and a single winter week which were then extrapolated to a complete year.

Table 34: Potential performance effects during the week

	Summer Week	Winter Week
Number of flights (FL315+)	34,270	29,350
Number of eligible flights	7,727	6,286
Eligibility	22.5%	21.4%
Route length savings [NM]	32,189	25,971
Route length savings in two weeks [NM]	58,160	
Route length savings per year [NM]	1,512,163	
Average route length savings per flight [NM]	4.15	
Fuel savings [kg] (1 NM ≙ 6 kg fuel)	9,072,976	
Average fuel savings per flight [kg]	24.90	
CO_2 savings [kg] (1 NM ≙ 20 kg CO_2)	30,243,252	
Average CO_2 savings per flight [kg]	83.01	
Direct cost savings [EUR] (1 NM ≙ EUR 5)	7,560,813	
Average Direct cost savings per flight [EUR]	20.75	

By using a FRAMaK DCT the route extension of eligible flights could be reduced from 2.01% to 1.70% during the summer week (Table 35) and from 1.96% to 1.67% during the winter week (Table 36) respectively.

Table 35: Route extension analysis, Summer Week

SAAM
Route Length Extension Analysis (V2.1)
Airport-circle radix (NM): 40.00
Filter used : No filter

File: C:/DATA Restore/STUDY/Free Route/FRAMaK/FRAMAK_2014_APR/COMP/Summer_Winter_Comp/Summer_week_24_30JUN2013_before.so6

Distance ranges(NM)	Number of Flt	Route Distance	Direct Distance	Extension (%)
[0 - 150[	5	444.05	424.07	4.71%
[150 - 300[	220	60280.57	55743.31	8.14%
[300 - 500[	709	290988.59	279407.60	4.14%
[500 - 800[	1617	1057735.94	1029005.98	2.79%
[800 - 1200[	1504	1477962.18	1442489.00	2.46%
[1200 - more[	3672	8719002.37	8570768.09	1.73%
Total:	7727	11606413.70	11377838.04	2.01%

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File: C:/DATA Restore/STUDY/Free Route/FRAMaK/FRAMAK_2014_APR/COMP/Summer_Winter_Comp/Summer_week_24_30JUN2013_after.so6

Distance ranges(NM)	Number of Flt	Route Distance	Direct Distance	Extension (%)
[0 - 150[	6	565.18	548.67	3.01%
[150 - 300[	220	60069.50	55919.52	7.42%
[300 - 500[	725	297454.60	287073.24	3.62%
[500 - 800[	1608	1051586.35	1026474.08	2.45%
[800 - 1200[	1512	1485262.58	1455316.98	2.06%
[1200 - more[	3656	8676367.26	8552017.13	1.45%
Total:	7727	11571305.47	11377349.61	1.70%

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Table 36: Route extension analysis, Winter Week

SAAM
Route Length Extension Analysis (V2.1)
Airport-circle radix (NM): 40.00
Filter used : No filter

File: C:/DATA Restore/STUDY/Free Route/FRAMaK/FRAMAK_2014_APR/COMP/Summer_Winter_Comp/Winter_week_28OCT_03NOV2013_before.so6

Distance ranges(NM)	Number of Flt	Route Distance	Direct Distance	Extension (%)
[0 - 150[	2	254.66	233.17	9.22%
[150 - 300[	196	53881.64	49699.86	8.41%
[300 - 500[	633	258701.38	248559.09	4.08%
[500 - 800[	1469	968106.73	942468.31	2.72%
[800 - 1200[	1039	1017419.91	993662.55	2.39%
[1200 - more[	2947	7440099.82	7316572.26	1.69%
Total:	6286	9738464.14	9551195.26	1.96%

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File: C:/DATA Restore/STUDY/Free Route/FRAMaK/FRAMAK_2014_APR/COMP/Summer_Winter_Comp/Winter_week_28OCT_03NOV2013_after.so6

Distance ranges(NM)	Number of Flt	Route Distance	Direct Distance	Extension (%)
[0 - 150[	2	231.81	220.48	5.14%
[150 - 300[	194	52986.12	49177.29	7.75%
[300 - 500[	644	262603.66	253500.77	3.59%
[500 - 800[	1465	963638.49	941409.84	2.36%
[800 - 1200[	1038	1014176.30	994592.33	1.97%
[1200 - more[	2943	7416787.15	7311718.36	1.44%
Total:	6286	9710423.53	9550619.08	1.67%

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6.2.3.1.1.1.2 Weekend

Potential performance effects were calculated based on the results for a single summer weekend and a single winter weekend which were then extrapolated to the weekends of a complete year.

Table 37: Potential performance effects during weekends

	Summer Weekend	Winter Weekend
Number of flights	13,919	11,572
Number of eligible flights	2,638	2,029
Eligibility	18.9%	17.5%
Route length Savings [NM]	14,532	11,049
Route length savings at two weekends [NM]	25,581	
Route length savings per year [NM]	665,096	
Average route length savings per flight [NM]	5.48	
Fuel savings [kg] (1 NM ≙ 6 kg fuel)	3,990,574	
Average fuel savings per flight [kg]	32.89	
CO_2 savings [kg] (1 NM ≙ 20 kg CO_2)	13,301,912	
Average CO_2 savings per flight [kg]	109.62	
Direct cost savings [EUR] (1 NM ≙ EUR 5)	3,325,478	
Average Direct cost savings per flight [EUR]	27.41	

6.2.3.1.1.2 Capacity

The SAAM Network Assessment does not show any evidence for Capacity degradations neither on local level nor on Network level.

In general the FRAMaK Direct routeing options have been designed in a way “reflecting daily-life operational behaviour of ATCOs”. The route design experts have carefully analysed which tactical Directs are usually provided to the aircrews and these tactical Directs were transformed into RAD App 4 Directs available for flight planning. Thus, in general the FRAMaK DCTs do not form any kind of “synthetic routeing” but should be fully compliant to daily operations. Furthermore, due to both UAC-internal and cross-UAC coordination, e.g. in the course of RNDSG or bilateral communication with adjacent ANSPs, it has been ensured prior to RAD publication that the proposals do not cause any objections from adjacent/subjacent ACCs/UACs. As a consequence, it is not to be expected that those RAD App 4 Directs negatively affect Capacity.

Contrariwise, since typical tactical Directs are being moved into the FPL routeing the predictability is no longer jeopardised by shortcuts on a tactical level which allows for a more accurate forecast of demand and planning of capacity.

6.2.3.1.1.3 Cost Effectiveness

During the definition phase of the FRAMaK project it has been assumed that the SAAM Network Assessment could inform about Cost Effectiveness. However, since we have to stress that the assessment only informs about potential route length savings and does not account for real-life flight planning it has been decided that effects of FRAMaK DCTs on Cost Effectiveness shall be assessed based on real-life data collected in the Public Live Trials.

6.2.3.1.1.4 Potential DCT usage

6.2.3.1.1.4.1 Complete Week

In the summer week 22.5% (winter 21.4%) of all flights above FL315 in the Karlsruhe / Maastricht airspace have been eligible to at least one FRAMaK DCT segment (see Table 34).

In Figure 29 and Figure 30 the potential DCT usage based on SAAM shortest route assignment is shown based on complete weeks' traffic, i.e. MON 00:00z to SUN 23:59z for the summer week and the winter week respectively. Route availability may be limited to the night and/or weekend based on the operational availability (see Table 32).

It becomes visible that many traffic flows could benefit, especially those making use of DCTs from/to the United Kingdom continuing towards Austria. Also DCTs from/to Scandinavia and in particular from/to ALUKA and SUI for traffic from Poland to the South-West show high loads.

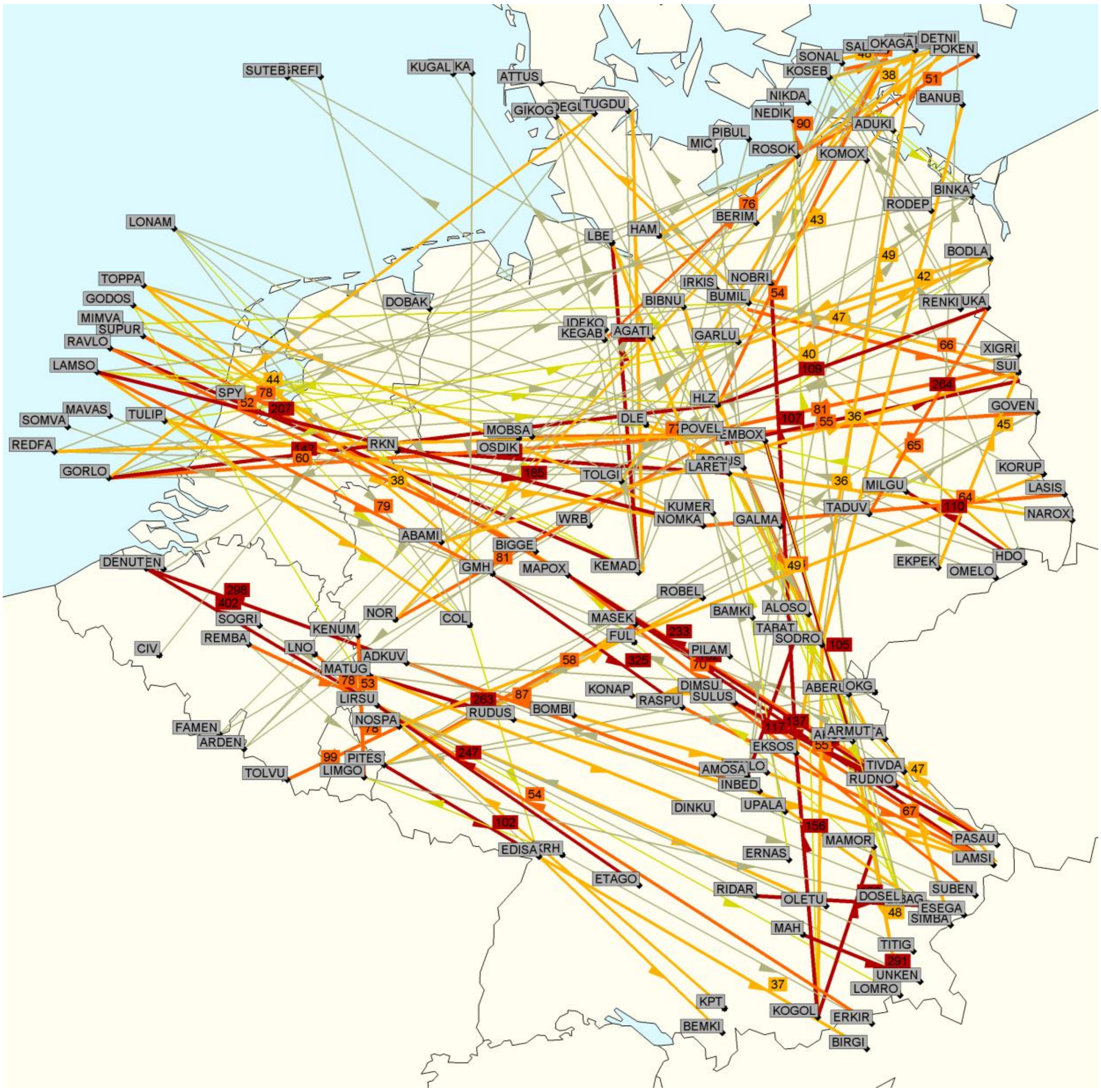


Figure 29: Potential usage of FRAMaK Direct routing options based on SAAM shortest route assignment; summer week, MON-SUN, 24 June – 30 June 2013.

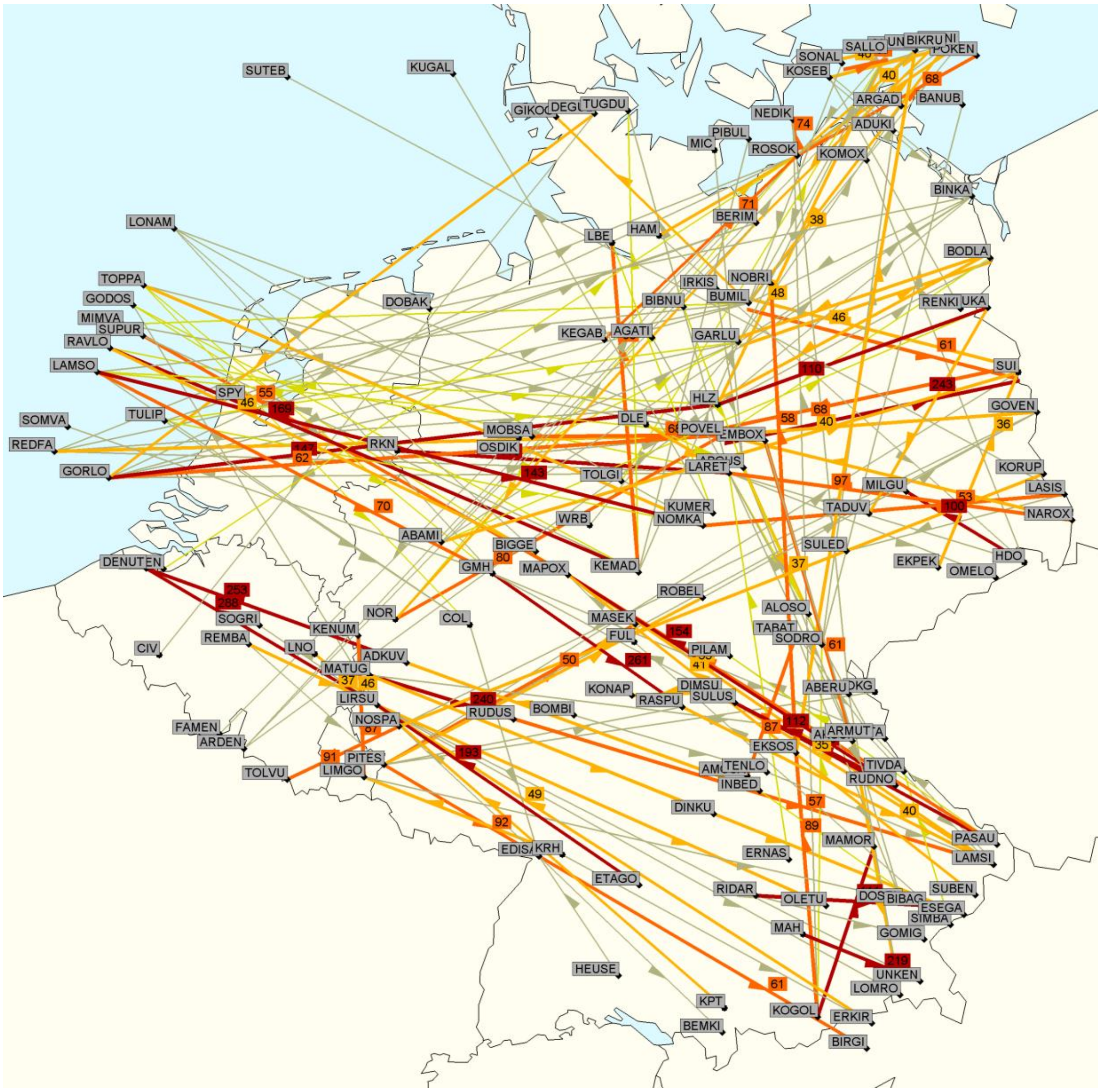


Figure 30: Potential usage of FRAMaK Direct routing options based on SAAM shortest route assignment; winter week, MON-SUN, 30 October – 03 November 2013.

6.2.3.1.1.4.2 Weekend

In the summer weekend 18.9% (winter weekend 17.5%) of all flights above FL315 in the Karlsruhe / Maastricht airspace have been eligible to at least one FRAMaK DCT segment (see Table 37).

In Figure 31 and Figure 32 the potential DCT usage based on SAAM shortest route assignment is shown based on weekend traffic, i.e. SAT 00:00z to SUN 23:59z for the summer week and the winter week respectively. Route availability may be limited to the night based on the operational *availability* (see Table 32).

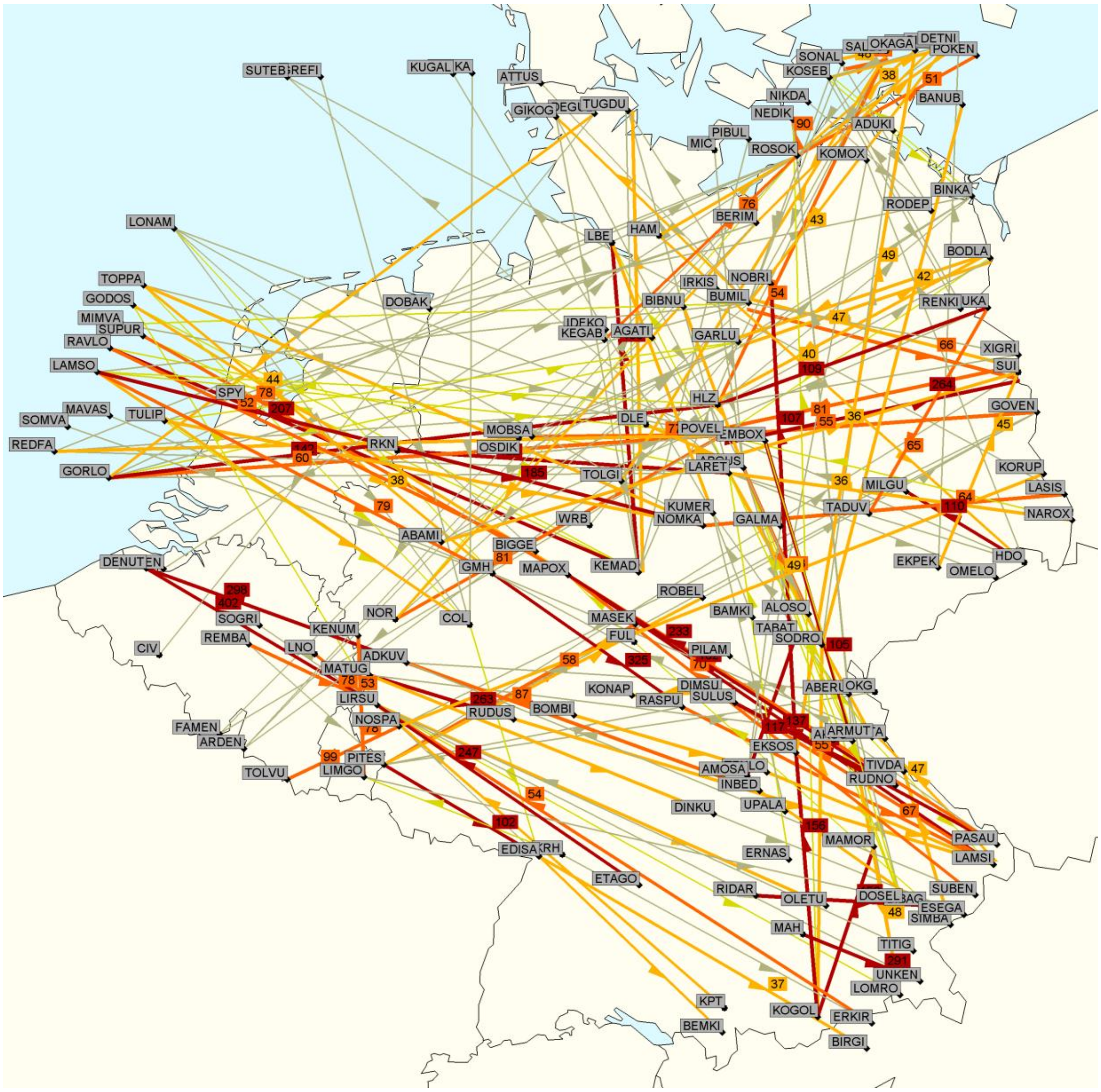


Figure 31: Potential usage of FRAMaK Direct routing options based on SAAM shortest route assignment; summer weekend, SAT-SUN, 29 June – 30 June 2013.

Figure 32: Potential usage of FRAMaK Direct routing options based on SAAM shortest route assignment; winter weekend, SAT-SUN, 02 November – 03 November 2013.

6.2.3.1.2 Results impacting regulation and standardisation initiatives

n/a

6.2.3.1.3 Unexpected Behaviours/Results

n/a

6.2.3.1.4 Quality of Demonstration Results

It has to be noted that results of the SAAM Network Assessment do inform about the potential gains of DCTs published in the course of the FRAMaK project. These potential gains are predicted based on the assumption that Airline Operators will make use of the shortest route option available for flight planning. Though, it is well-known that there are other factors, e.g. weather (in particular wind) situation, avoidance of severe weather, avoidance of congested airspace, or differences in route charges, affect the route selection in the flight planning process. Therefore, in real-life even if a (shortest) DCT routing option might be available a different routing making use of ATS routes or other DCT routing options is frequently filed.

Nevertheless, this way of FTS-based performance assessment currently has to be seen as the "best practice" for the assessment of route design projects. The results of EXE-0201-D002 allow for a general estimation of effects and provide a means for comparisons between the FRAMaK project and other route design activities.

6.2.3.1.5 Significance of Demonstration Results

Taking the validity of the underlying simulation models as granted and based on the sample size the performance benefits in terms of route length, fuel burn and CO_2 emission can be assumed being statistically significant.

Regarding the operational significance please refer to chapter 6.2.3.1.4.

6.2.4 Conclusion and Recommendations

6.2.4.1 Conclusions

The results of the SAAM Network Assessment show that – despite the high number of rather straight if not direct routing options already available prior to FRAMaK DCT implementations – the newly implemented FRAMaK Direct routing options bring a potential of more than 1.5 million NM route savings per year (4.2 NM per flight) corresponding to a potential reduction of fuel consumption of more than 9 million tons (25 kg per flight) and a reduction of CO_2 emission of more than 30 million tons (83 kg per flight). Thus, if airline operators make use of the new FRAMaK Direct routing options they might save up to 7.5 million Euro per year which are the estimated direct cost savings caused by fuel consumption, not taking into account potential but individual indirect cost benefits due to less flight time affecting maintenance, staffing etc.

When comparing the results calculated for the complete week with those calculated for the weekend only it becomes obvious that about 44% of the total savings are generated during the weekend. This is despite the fact that the traffic density in KUAC and MUAC airspace in general is lower during the weekend than during weekdays. However, as shown in Table 32, due to the (in general) absence of active military areas during weekends the number of DCT routing options available for flight planning is significantly higher than during weekdays. It can be concluded that more flexibility in civil-military airspace utilisation could bring significant additional benefits.

6.2.4.2 Recommendations

Since SAAM Fast Time Simulations are considered more and more a standard step in airspace design projects the capabilities of SAAM should be enhanced with regard to

- Utilization of data available in the Enhanced Tactical Flow Management System (ETFMS), i.e. operational data comprising RAD constraints etc., for the generation of traffic examples,
- Optimisation of flights based on different criteria such as wind, route charges, airspace availability etc.

6.3 Demonstration Exercise EXE-0201-D003 "Simulation-based assessment of Cross-Border DCTs - KUAC Core Area Fast Time Simulation" Report

Complementing EXE-0201-D001 this exercise studied by means of Fast Time Simulation effects of different setups of FRAMaK Cross-Border DCTs in case of implementation in Karlsruhe Central Sectors with high traffic density.

In this exercise the real traffic demand for the simulation area with FPLs calculated by SAAM ("cheapest routes") were analysed for several DCT scenarios and compared with the ATS route and DCT network anticipated for the future AIRAC APR2014 (including H24 FRA Vienna and Southeast Europe, planned FRAMaK changes, opening of KFOR sector, but also parts of future FABEC CW package) as a reference.

Potential flight efficiency benefits have been investigated by using SAAM, while by means of AirTOp also workload effects have been evaluated.

6.3.1 Exercise Scope

The geographical scope of EXE-0202-D003 was limited to the Karlsruhe UAC Core Area.

6.3.1.1 Exercise Scenario

The underlying demonstration scenario is referred to as SCN-0201-001 "Cross-Border Entry-Exit DCTs" which in return refers to FR-CAP-01.

The determination of Cross-Border entry-exit DCTs has been accomplished in WP 2 Route Design. DCTs have been published in the Route Availability Document (RAD), Appendix 4 "En-route DCT limits – DCT limits". FRAMaK entry and exit points have been defined as connecting points between the Cross-Border Direct routes developed in the project and the surrounding ATS Route System or Free Route airspaces both adjacent and subjacent to the FRAMaK airspace.

SCN-0201-001 is related to

- MUAC/KUAC overflights, i.e. transfers through the combined Maastricht & Karlsruhe airspace, and
- flights to and from hubs and major airports affected by airspace design activities in the FRAMaK airspace, i.e. flights
  - arriving from a destination outside the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace,
  - departing from a hub within/below the FRAMaK airspace directed towards a destination outside the FRAMaK airspace, and
  - between hubs within/below the FRAMaK airspace, i.e. departing from a hub within/below the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace.

6.3.1.2 Exercise Objectives

The exercise shall contribute to the investigation of objectives listed in Table 38.

Table 38: Demonstration Objectives EXE-0201-D003

Objective ID	Description	KPAs
OBJ-0201-001	Horizontal Flight Efficiency of Cross-Border DCTs It is to be demonstrated that FPL routings and flight trajectories based on published DCT routings are closer to the optimum compared with FPL routings based on the existing ATS-route network. Therefore, they are beneficial in terms of flight efficiency. The reduced deviation from the optimum positively affects flight duration and fuel burn. The reduced FPL route length results in weight reductions and again fuel burn due to lower amounts of contingency fuel.	Efficiency
OBJ-0201-003	Environmental Sustainability of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs due to improved flight efficiency positively affect CO_2 emission.	Environmental Sustainability
OBJ-0201-004	Safety of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs do not negatively affect Safety.	Safety
OBJ-0201-005	Capacity related to Cross-Border DCTs It is to be demonstrated that based on a suitable route design the usage of Cross-Border Directs will not negatively affect capacity of the FRAMaK airspace.	Capacity
OBJ-0201-006	Network effects related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect capacity demand in the adjacent centres/sectors serving the connecting ATS routes.	Capacity
OBJ-0201-008	Cost Effectiveness related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs improve the cost effectiveness of flight handling through ANSPs.	Cost Effectiveness
OBJ-0201-010	Operator Workload related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect operator workload and situational awareness of both ATCOs and crews. Contrariwise, based on a suitable route design a reduction of workload and an increase of situational awareness might be achievable.	Other

6.3.2 Conduct of Exercise

6.3.2.1 Exercise Preparation

6.3.2.1.1 The simulation tool AirTOp

The simulation was carried out with the fast-time simulation tool AirTOp – Air Traffic Optimizer. The software was developed by Airtopsoft and is used in the simulation department of DFS for airport and airspace simulations.

Unlike other simulation tools, simulations with AirTOp enable to display the movements of aircraft in a manner similar to the display on a radar scope.

It is possible to provide an overview of the status of the simulation and/or of the project at any time.

In the simulation phase the following functions are dynamically superposed on each individual aircraft whose flight plan was entered during the definition phase:

- Calculation of the actual flight profile from the overall traffic situation for positioning in landing sequence
- Calculation of the actual take-off sequence by placing each departure in a ‘take-off window’ which is determined by the traffic situation
- Generation of holding procedures in cases where landings cannot be organized with delaying procedures (radar vectors, speed control)
- Calculation of and compliance with the prescribed separation minima (separation criteria) taking into account wake vortices.

The actual flight profile for each individual aircraft is determined in this manner. However, the differing simulation scenarios (routing, etc.) may result for the same traffic sample in different timings and changes in the results of the conflict frequency.

Flexible and continuously adjustable views permit both individual aircraft and complex traffic structures to be displayed.

6.3.2.1.2 Task-based workload model in detail

One of the major goals of the fast-time simulation was to evaluate the workload resulting from new routing structures in different scenarios. The workload is measured with a task-based workload model, which was developed by the simulation department of DFS and which is the basis for several capacity analyses within DFS. With the workload model it is possible to measure and highlight workload peaks, to identify complex airspace structures and it enables to draw conclusions from movement numbers in a specific sector or airspace. As the name of the model says, the workload composes of different tasks, both for the executive and the planning controller. To comprehend the model and to keep it simple the number of actions is limited due to the following tasks:

- Monitoring task

  Workload for the repetitive activity of radar monitoring as well as other routine activities like strip marking
- Radio telephony task

  Workload for the air traffic controller by routine radio telephony, for the main part initial and transfer call when aircraft are changing sectors
- Coordination task

  Workload for coordination procedures between different sectors and control centers, which are mainly conducted by the planning controller and defined individually in conjunction with a specific area control center or client

- Clearance task

  Workload for giving a pilot a clearance for start climbing or descending in relation with level changes of an aircraft

- Conflict detection task

  Workload for detection of a conflict, based on the distance between two aircraft (300% of minimum separation: e.g. 15NM, if prescribed separation minima is 5NM), their vertical behavior (cruising, one in vertical, both in vertical) and conflict heading (succeeding, crossing, opposite tracks)

- Conflict resolution task

  Workload for dissolving the conflict between two aircraft when the distance is reduced to 120% of minimum separation (6NM) and when it is assumed that the air traffic controller has not just to monitor but also to take action for conflict solution, independent on the conflict type

For TMA-studies and airport simulations the workload model is completed by two further tasks for sequencing and holding procedures.

By accumulating the times of the different tasks a workload for every aircraft and furthermore for every sector is measured. From this results that capacities with movement numbers for different sectors and sector configurations in simulation scenarios. Because EUROCONTROL defined that a maximum amount of 70% of the working hour can be used for tasks there exists a workload threshold of 42 minutes per air traffic controller hour. Further planning efforts are not considered by the listed tasks.

6.3.2.1.3 Basic Conditions

6.3.2.1.3.1 Weather Conditions

The fast-time simulation was conducted under ISA standard weather conditions without wind influences.

6.3.2.1.3.2 Traffic Sample

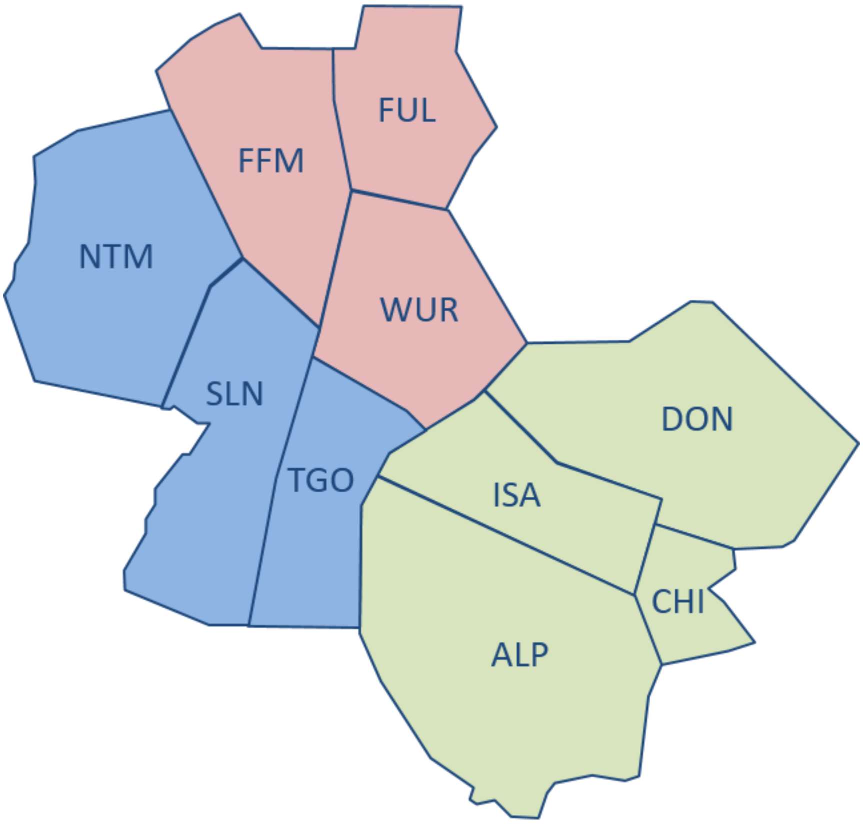
The traffic samples, which had been used for the simulation, present two successive days in 2013 with high traffic load. For the H24-traffic sample June 28, 2013 (Friday) and for the WE-traffic sample June 29, 2013 (Saturday) were chosen. The traffic samples were part of the SAAM-analyses and exported to AirTOp.

6.3.2.1.3.3 Simulation- and Evaluation Area

Figure 33 shows the evaluation area of the fast-time simulation. Nearly every sector of Karlsruhe UAC was evaluated from FL345 and above. The grey marked sectors display the evaluation sectors.

To guarantee, that no traffic flow is missing inside this core area and to simulate realistic entry and exit conditions for all sectors, a simulation area around the evaluation area was created consisting of the adjacent airspaces of the area control centers of EDYY, LFRR, EPWW, LKAA, LOVV, LSAZ and LIPP.

Lateral View
(EBG East not depicted)



Vertical View
(EBG EAST only partly depicted)

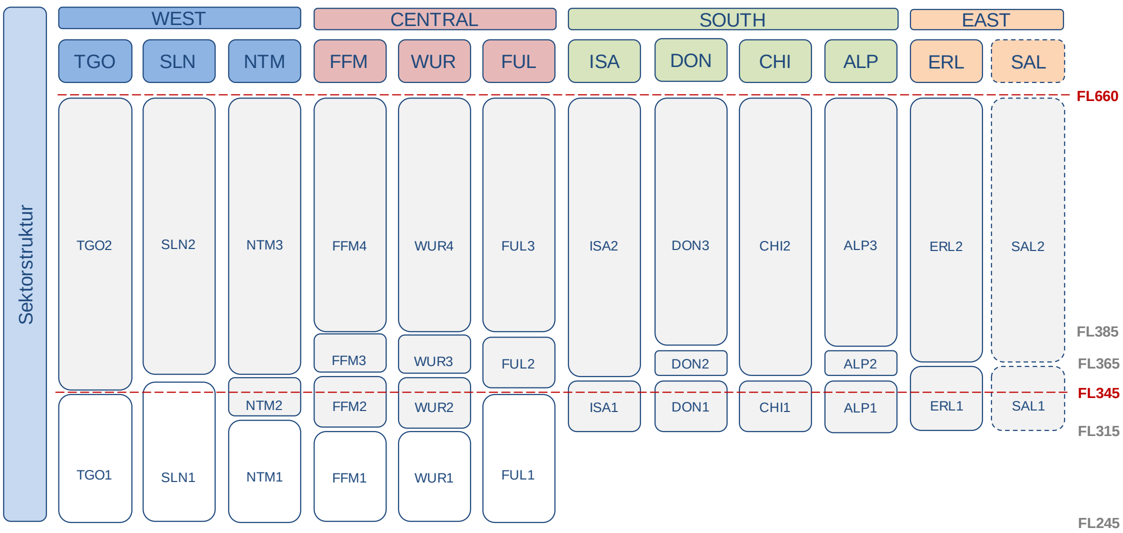


Figure 33: Sector structure of Karlsruhe UAC with evaluation sectors (grey marked sector blocks)

6.3.2.1.3.4 Airspace Structure

The basis of the ATS-route-structure and RAD-DCT-Network is the AIRAC-cycle October 2013. The AIP-Amendment with date October 17, 2013 and the RAD-APP4-changes, which had also been part of the SAAM-analyses, were incorporated. Finally changes resulting from the SENEKA-Project with AIRAC-cycle September 2013 and not yet published changes resulting from sector reconfiguration between FUL and FFM were considered.

6.3.2.1.3.5 Separation Criteria

In the entire simulation area a lateral separation value of 5 NM was established. The vertical separation between aircraft is 1000ft up to FL410. Above FL410 the default vertical separation value is 2000ft.

6.3.2.1.3.6 Handover Procedures

For all evaluation sectors and also for the entire simulation area the specific handover procedures were applied from the appropriate Letters of Agreement and Operational Orders with AIRAC-cycle July 2013.

6.3.2.1.3.7 Import of Trajectories from SAAM

The flightplans of each simulation scenario were converted after SAAM-analyses to AirTOp. In order to shorten trajectories laterally, they were cut to the dimensions of the simulation area. Vertical trajectories were depicted from GND to UNL.

Karlsruhe UAC together with EUROCONTROL provided additional segment-files (ASE-files) for each scenario containing information about the flight level allocation on each DCT (even/odd Information).

6.3.2.1.3.8 Airports and SID- and STAR-Structure

The main hubs (EDDF, EDDM, EDDL) and major airports (EDDK, EDDS, EDDN) located in or nearby the evaluation area were simulated with runways, departure- and arrival-routes (SIDs and STARs). All other airports were connected as “point-airports” in the simulation.

6.3.2.1.3.9 Evaluation Period

The evaluation period for H24- and WE-scenarios is between 03:00 UTC and 22:00 UTC.

6.3.2.2 Exercise execution

6.3.2.2.1 Content of AirTOp fast-time simulation

After testing different scenarios by the tool SAAM, the aim of the AirTOp-fast-time simulation in context of FRAMaK was to choose three scenarios, which were used for real-time simulations afterwards. The aim was to analyse scenarios with both traffic samples, WE- and H24.

In order to achieve more significant results, the target of the AirTOp fast-time simulation was moreover the evaluation of parameters like sector movements, workload, conflicts, average flight time and occupancy for each sector located within the evaluation area. Therefore several scenarios with a various number of DCT-routings with different geographical allocations had to be evaluated. The criteria for the selection of certain DCTs are illustrated in Table 39. A detailed survey of used DCT-routings is attached in [10]. The xlsx-tables were provided by Karlsruhe UAC and contain:

- H24- und WE-DCTs: RAD-APP4_FRAMaK_CoreFTS_scenario_selection.xlsx
- Free route airspace: FRA365_all_08AUG2013.xlsx

Table 39: Criteria for selection of Directs

GROUP DCTs	DESCRIPTION
xxxx	Most reasonable and wanted DCTs to be implemented
aaaa	More attractive flows to KOSVO-area (EDISA-BIRGI), further on-load ALP (actually other SENEKA DCTs and DCT shift flows to ISA) Also ETAGO-BETEX as new ARR LFP* flow in west sectors or KORUP-NOSPA As new ARR LFP* flow on-loading FUL and west sectors
yyyy1	Critical northwest bound DCTs in VIBOM/VALAR-area opposite SENEKA-flows
yyyy2	Critical northwest bound DCTs in LOMRO-area
yyyy3	Critical northbound DCTs ETAGO-GALMA direction
zzzz1	Northeast bound DCTs TRA-TIKNI and possible critical DITON-DONAL (diagonal LS_LK)
zzzz2	SIMBA DCTs

In a first step three evaluation scenarios with WE-traffic were analysed and compared to a reference scenario representing the actual route structure. Afterwards two scenarios with H24-traffic-sample (one reference and one evaluation scenario) were simulated. The differences between the scenarios are illustrated in Table 40.

Table 40: AirTOp scenarios

SCENARIO	TRAFFIC-SAMPLE	DESCRIPTION
REF1	WE	Reference scenario representing the actual (AIRAC DEC2013) route structure (including published RAD DCTs) added by the planned changes for AIRAC MAR2014 (e.g. H24 DCTs LOVV and a FRAMaK RAD DCT implementation package) and AIRAC APR2014 (e.g. further FRA changes in southeast Europe as opening of new "KFOR sector"). The reference scenario included also planned changes of FABEC project "Central West" with realignments of ARR EHAM (VEXIL-SOPOD-INDAM) and ARR EG** via ROBEL-GORLO.
SCEN1A	WE	Evaluation scenario containing **all** DCTs as delivered by Karlsruhe UAC to the AirTOp-team with RAD_APP4_FRAMaK_CoreFTS_scenario_selection.xlsx. According this document SCEN1A contains all DCTs except those named aaaa and except DCT DITOM-DOMAL The SCEN1A included also planned changes of FABEC project "Central West" with realignments of ARR EHAM (VEXIL-SOPOD-INDAM) and ARR EG** via ROBEL-GORLO.

SCENARIO	TRAFFIC-SAMPLE	DESCRIPTION
SCEN3A	WE	Evaluation scenario containing **all** directs as delivered by Karlsruhe UAC to the AirTOp-team. SCEN3A contains all DCTs of group xxxx, several DCTs of group yyyy1 (MAMOR-VALAR-VIBOM-BETEX-TOLVU) and one DCT from the aaaa-group (KORUP-NOSPA). In SCEN3A the mentioned flows of FABEC project "Central West" (REF, SCEN1A, FRA365+) were changed to VARIK-HMM-GORLO (ARR EG** via GORLO, reducing the number of flights towards GORLO on this route/sector) and to ROBEL-INDAM (ARR EHAM).
FRA365+	WE	Evaluation scenario for a "completely" free route airspace above FL365 without additional RAD DCTs except those RAD DCTs already published. The scenario contains entry and exit fixes, which have been linked by SAAM. Therefore the entire evaluation area has been divided into a northern part (FRAN) with lower level FL335 and a southern part (FRAS) with lower level FL365. The internal boundary between northern and southern part is located approximately along the line VARIK-WRB. Additionally departure and arrival fixes have been established to ensure vertical flows to airports, e.g. LSZH. To circumnavigate France, an intermediate fix has been established at EDISA. An overview of used fixes is given in [10]. The scenario FRA365+ included also planned changes of FABEC project "Central West" with realignments of ARR EHAM (VEXIL-SOPOD-INDAM) and ARR EG** via ROBEL-GORLO.
REF	H24	Same scenario as REF1 but with H24-traffic-sample
SCEN1	H24	Evaluation scenario containing **all** H24-DCTs as delivered by Karlsruhe UAC to the AirTOp-team with RAD-APP4_FRAMaK_CoreFTS_scenario_selection.xlsx.

6.3.2.3 Deviation from the planned activities

As shown in Chapter 6.3.2.2.1 it was planned to simulate several scenarios with both traffic samples. Thus a broad basis for selection of scenarios used later in real-time simulation should be provided. Due to problems during SAAM-analyses (e.g. calculation problems of re-routings) the delivery of the scenarios was delayed. Initially it was agreed for September and October 2013. Finally the delivery of the simulation scenarios took place in late November for the WE-option and in late January for the H24-traffic.

Due to late delivery the following agreements were made:

- The number of scenarios, which had to be simulated by AirTOp, was reduced (see Table 40)
- The simulation of scenarios with H24-traffic-sample had to be skipped for real-time simulation.
- The evaluation area has been reduced, sectors ERL and SAL skipped for analysis.
- For each scenario two analyses will be provided (split sector configuration as depicted in Figure 34 vs. combined sector configuration as depicted in Figure 35)

In regard to evaluation of AirTOp-simulation, it has been agreed that AirTOp only focusses partly on the objectives (KPA) as listed in Table 41. The objectives OBJ-0201-001 and OBJ-0201-003 have been analysed by SAAM.

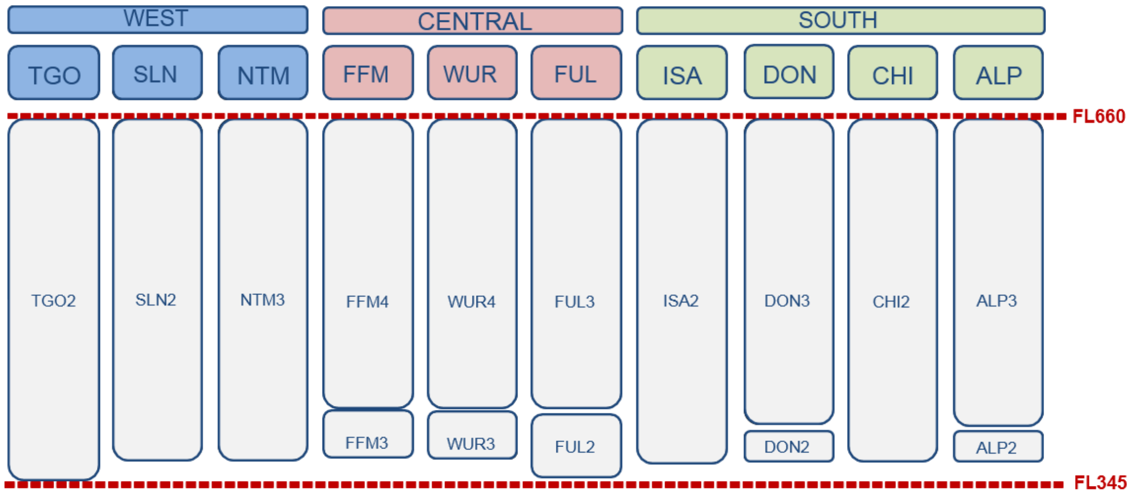


Figure 34: Split sector configuration for evaluation

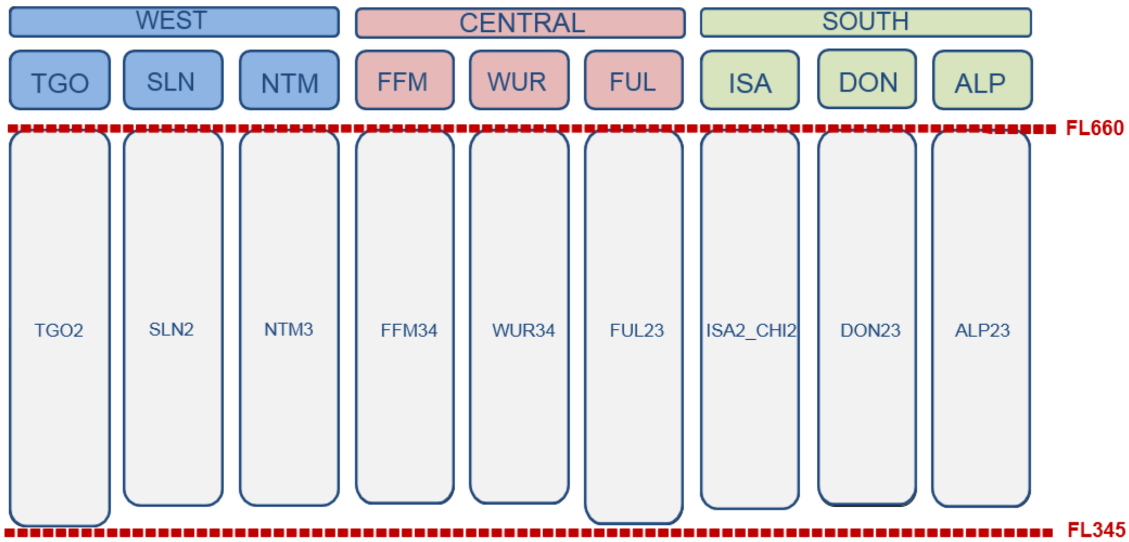


Figure 35: Combined sector configuration for evaluation

6.3.3 Exercise Results

6.3.3.1EBG West

Delivered detailed tables of Saturday (29 June) daytime workload and traffic counts for each simulated sector (single or combined) were used by Karlsruhe to select a useful time slot as traffic sample for the RTS (16:00-17:30 selected, also after checking the flight lists in detail).

Furthermore, anticipated results were achieved in avoiding further on-load in central sectors and ALP sector. Scenario 3a showed less critical impacts than scenario 1a.

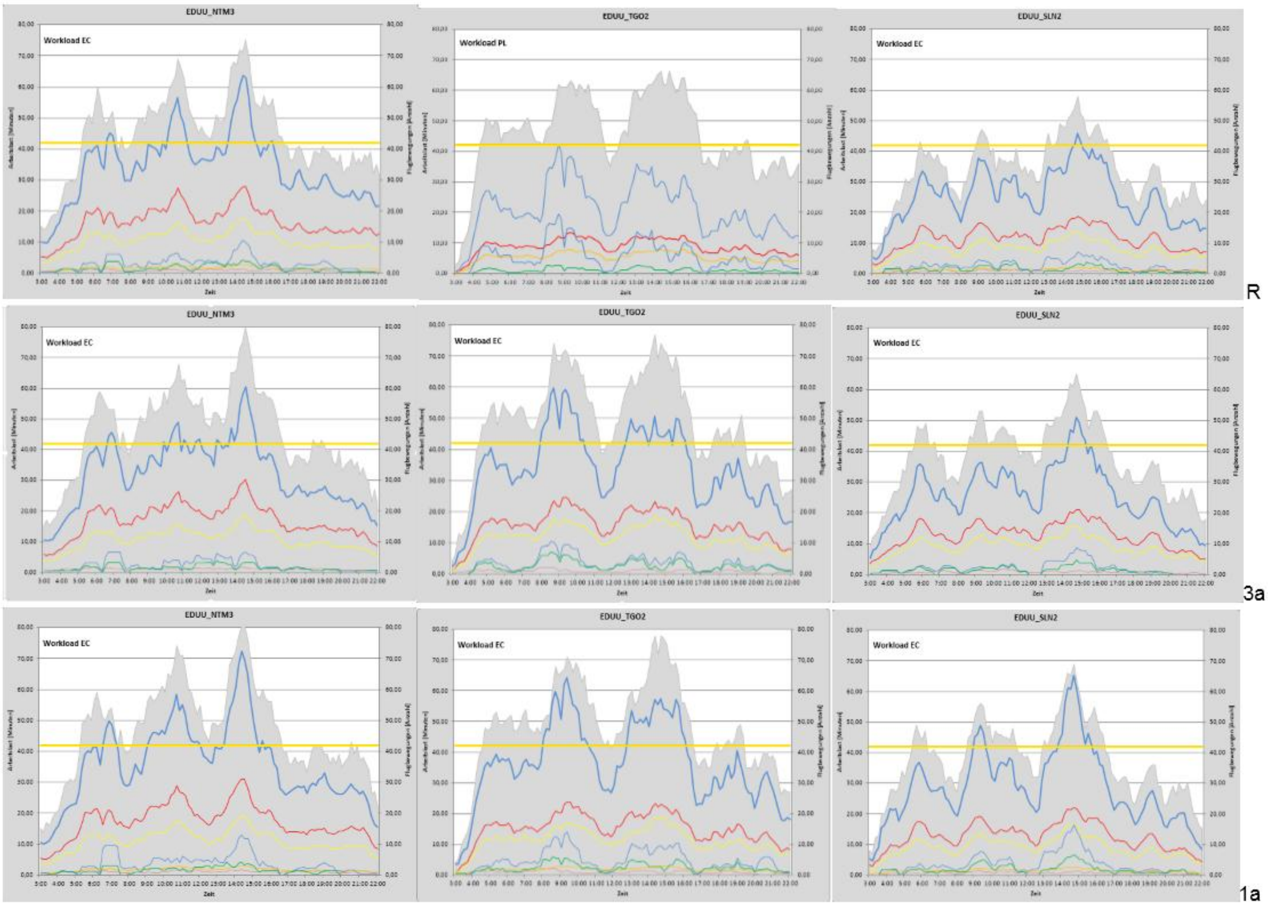


Figure 36: West Sectors (NTM3, TGO2, SLN2 as used for KASIM RTS)

Tables with traffic counts (grey) and workload (blue lines) for REF, SCEN 3a and SCEN1a

In sector NTM3 (FL355+,presently no further vertical split) already the REF scenario showed a significant over-load of traffic (2 peaks at around 75 movements/hour). With SCEN 3a the sector load reached 80 movements/hour, but the workload was slightly reduced. With SCEN 1a the traffic counts exceeded 80 movements/hour and the peak at 11:00 was also higher than in the REF. Furthermore the workload was slightly increased compared to the REF (and more compared to SCEN3a). Further detailed investigations are required regarding a possible change of DFL NTM2/3, a possible introduction of a NTM4 sector and/or an initial FL capping for departures (as used already in daily practice) e.g. for DEP EBBR to reduce those traffic peaks. Regulations in NATS Dover sectors or in EDYY Brussels sectors normally applied at this particular Saturday (beginning of holiday season) usually reduce the potential traffic peaks.

In TGO2 (FL345+) and similar in SLN2 (FL355+) the workload increased with scenario 1a, but also (only slightly less) with scenario 3a. Traffic counts increased slightly. The depicted (with SAAM calculated) overload as also partly shown in REF happened already with the real traffic in summer season 2013 (with implementation of SENEKA routes shortening the southeast bound flows and with FRAMaK weekend DCTs). To offer sufficient capacities, Karlsruhe UAC introduced TGO3 and SLN3 sectors with DFL375 in March 2014 (to be used mostly lateral combined).

6.3.3.2EBG Central

In the (vertical combined) sector FFM34 (FL355+) the scenarios reduce slightly the traffic peaks and workload. For WUR34 this effect is more distinctive (with SCEN3a the reduction in workload is even more significant). Splitted FFM4 (FL385+) and WUR4 (FL385+) are available (mostly used combined).

The analyses for FUL23 is little bit more complex, as with the scenario 3a also changes to the REF concerning traffic flows for FABEC CW package were applied. So the slightly reduction in workload (and slightly in traffic count) is more caused by the shifted traffic flows to GORLO via HMM in scenario 3a (slightly less traffic for this flow than on the more direct routing in REF and SCEN1a) than by the new DCTs.

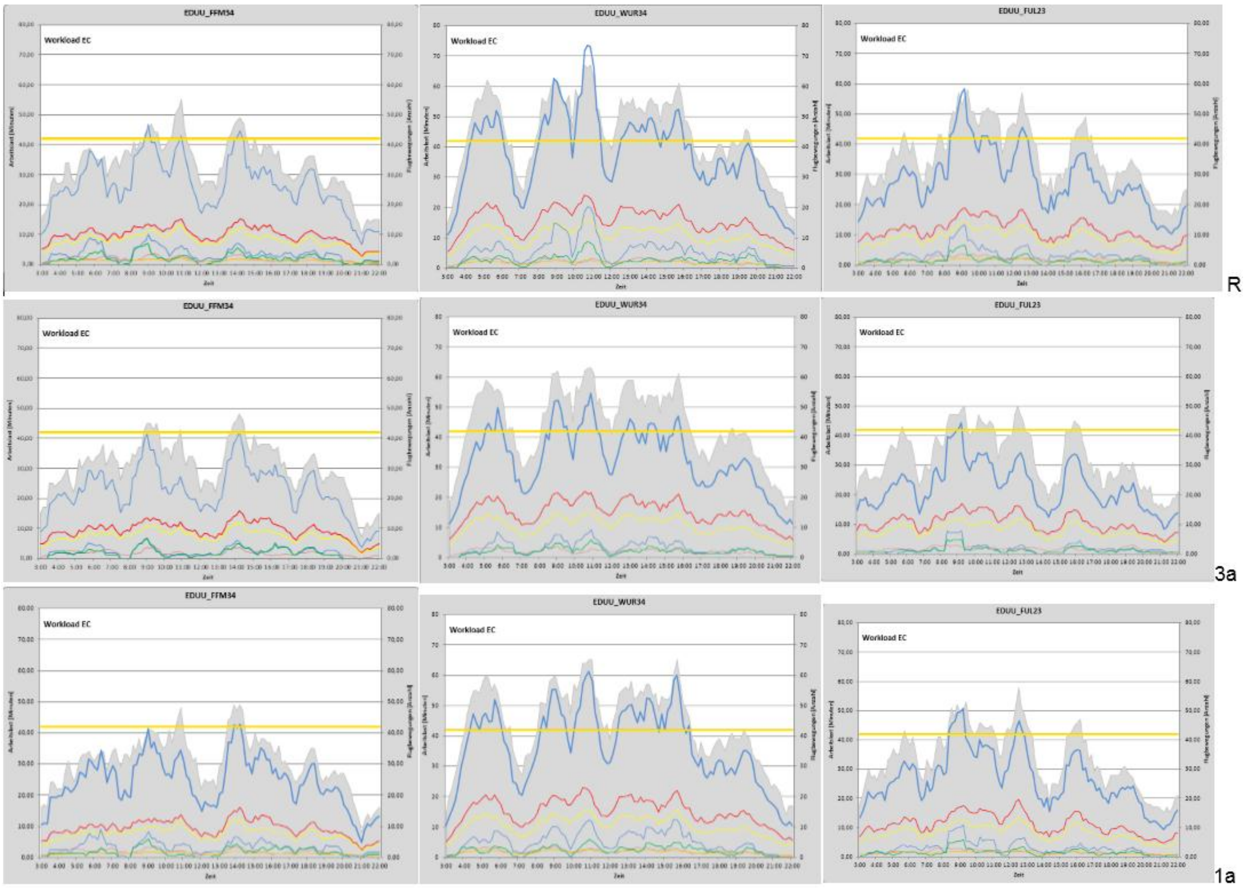


Figure 37: Central Sectors (FFM34, WUR34, FUL23 as used for KASIM RTS) – Tables with traffic counts (grey) and workload (blue lines) for REF, SCEN 3a and SCEN1a

6.3.3.3EBG South

The workload and traffic count in **ISA2CHI2** (combined top FL355+) sector is too high during afternoon peak in REF and scenarios and the sector need to be splitted (ISA2 and CHI2). During simulation for the SENEKA project is was still open, whether to use a combined ISA2CHI2 sector (reducing the number of ATCO) or to update the boundary ISA/ALP/CHI (enlarging CHI and reducing the size and workload of ALP sector). With potential shifted flows as simulated with SAAM for the REF a decision for changed sector boundaries seems to be more feasible (but some South-bound DCTs requires updates as they are aligned along the potential new boundary).

The high workload in ISA2CHI2 was reduced with scenario 3a and increased with scenario 1a (opposite Northwest bound DCTs).

For **ALP23** (FL355+) no negative impacts were measured as anticipated (after skipping new potential DCTs to BIRGI which significantly on-loaded ALP sector as shown with SAAM). With scenario 3a the workload is slightly reduced.

In **DON23** the traffic on-load is manageable by splitting the sector vertically. A second peak at afternoon requires longer opening times of splitted sector. Workload increased drastically in scenario 1a compared to scenario 3a.

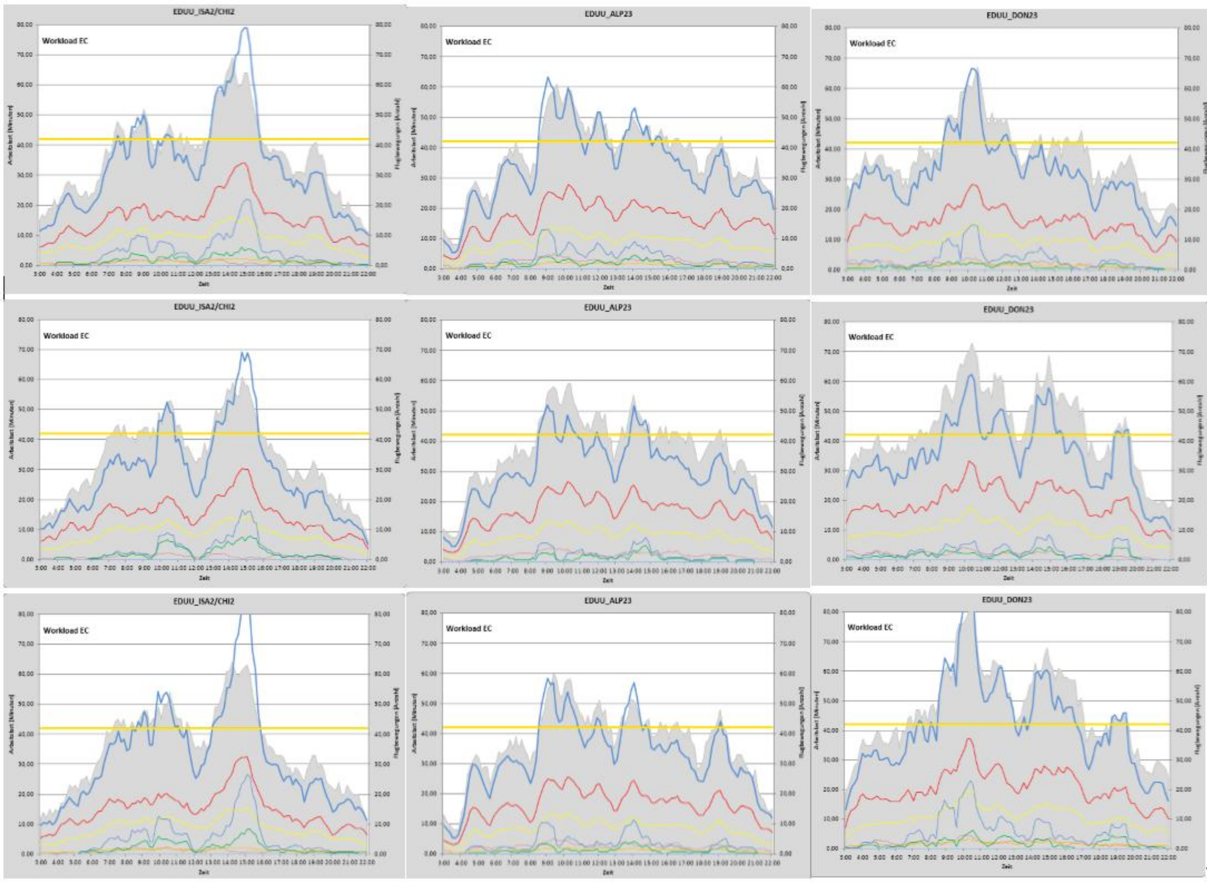


Figure 38: South Sectors (ISA2/CHI2, ALP23, DON23 as used for KASIM RTS) – Tables with traffic counts (grey) and workload (blue lines) for REF, SCEN 3a and SCEN1a:

6.3.3.4 Summary of Exercise Results

With AirTOp fast-time simulation a number of reference and evaluation scenarios, containing different packages of Cross-Border DCTs and different traffic samples – one representing H24-DCT-operations and one representing WE-DCT-operations – have been evaluated.

Different parameters referring to the below listed KPAs (Table 41) have been analysed.

As a conclusion it has to be stated, that the implementation of Cross-Border-DCTs does not negatively affect one of the analysed parameters. The results of the tested reference and evaluation scenarios are in total on a comparable level, depending on the degree of depicted DCT-operations.

The number of movements remains on a comparable level in each sector of the evaluation area. Moreover the maximum number of simultaneous aircraft in each sector (occupancy) is in general not affected negatively. From this results that a significant change of counted conflicts in the evaluation area, as a function of the number of published DCTs, does not take place. Covering all simulation scenarios acceptable average workload values were measured but predominantly too high peak values - particularly in WE-option – as a result of a very high traffic load in the traffic samples. A significant increase in controller's workload due to new implemented cross-border DCTs is not given as the basis in the shape of reference scenario also shows high movement and workload values

In the following Chapter 6.3.3.4.1 an overview of simulation results per KPA is given. Detailed results, containing charts and figures, is attached in [10].

6.3.3.4.1 Results per KPA

Table 41: Results per KPA EXE-0201-D003

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Efficiency (horizontal)	OBJ-0201-001	Reduction of FPL route length in Cross-Border DCT operations	SAAM/NEST: Reduction of route length per day: by 2,801 NM (5.56 NM per flight) for H24 DCTs ((Scen_1), by 4,294 NM (4.53 NM per flight) for WE DCTs (Scen_1a) by 4,430 NM (5.02 NM per flight)) for WE DCTs (Scen_3a) by 9,109 NM (6.77 NM per flight) for FRA 365+
Efficiency (horizontal)	OBJ-0201-001	Reduction of fuel burn in Cross-Border DCT operations	SAAM/NEST: Reduction of fuel burn per day: by 24,198 kg (48 kg per flight) for H24 DCTs (Scen_1), by 35,674 kg (46 kg per flight) for WE DCTs (Scen_1a) by 38,127 kg (43 kg per flight) for WE DCTs (Scen_3a) by 70,424 kg (52 kg per flight) for FRA 365+
Efficiency (horizontal)	OBJ-0201-001	Improvement of REDES in Cross-Border DCT operations	SAAM/NEST: Reduction of mean REDES by 0.01 to an average of 1.02.
Efficiency (horizontal)	OBJ-0201-001	Improvement of RESTR in Cross-Border DCT operations	SAAM/NEST: Reduction of mean RESTR by 0.01 to an average of 1.01.

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Environmental Sustainability	OBJ-0201-003	Reduction of CO_2 emission in Cross-Border DCT operations	SAAM/NEST: Reduction of CO_2 emission per day: by 76,433 kg (152 kg per flight) for H24 DCTs (Scen_1), by 112,730 kg (145 kg per flight) for WE DCTs (Scen_1a) by 120,482 kg (137 kg per flight) for WE DCTs (Scen_3a) by 222,570 kg (166 kg per flight) for FRA 365+
Environmental Sustainability	OBJ-0201-003	Reduction of NO_x emission in Cross-Border DCT operations	SAAM/NEST: Reduction of NO_x emission per day: by 336.2 kg (0.67 kg per flight) for H24 DCTs (Scen_1), by 524.5 kg (0.67 kg per flight) for WE DCTs (Scen_1a) by 571.3 kg (0.65 kg per flight) for WE DCTs (Scen_3a) by 831.9 kg (0.62 kg per flight) for FRA 365+
Safety	OBJ-0201-004	No increase of complexity in Cross-Border DCT operations	AirTOp: No significant rise of counted conflicts in evaluation area in consequence of cross-border DCTs, except in the sector group WEST of free route -scenario (FRA365+). See also workload depicted in Figure 36 - Figure 38.
Capacity	OBJ-0201-005 OBJ-0201-006	No adverse results regarding number of flights in Cross-Border DCT operations	AirTOp: Number of movements remains on a comparable level in cross-border DCT-operations. See also Figure 36 - Figure 38.

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Capacity	OBJ-0201-005 OBJ-0201-006	No adverse results regarding ENR Throughput in Cross-Border DCT operations	AirTOp: The occupancy of each sector (maximum number of simultaneously controlled aircraft) is not negatively affected generally. Only an indication of traffic-flow-shifts can be noted when comparing the different scenarios. See also Figure 36 - Figure 38.
Cost Effectiveness (Sectorization)	OBJ-0201-008	No adverse results regarding sector occupancy in Cross-Border DCT operations	AirTOp: The average flight times of aircraft in the evaluated sectors do not change significantly by implementing DCTs. Only differences in sector group South - especially in sectors ISA, CHI in scenario FRA365+ - are noticed.
Other - Workload	OBJ-0201-009	No increase in operator workload in Cross-Border DCT operations	AirTOp: The simulation provided acceptable average workload values but predominantly too high peak values, particularly in WE-option. A significant increase in operator workload due to cross-border DCT-operations is not given. See also Figure 36 - Figure 38.

6.3.3.4.1.1 OBJ-0201-001 EFFICIENCY and OBJ-0201-003 ENVIRONMENTAL SUSTAINABILITY

A performance assessment regarding Efficiency and Environmental Sustainability has been accomplished by means of SAAM using the scenarios described in Table 40; respective analyses were provided by EUROCONTROL NMD.

Table 42: Daily benefits regarding Efficiency and Environmental Sustainability

Date	Total impacted flights	Length (NM)	Flight duration (min)	Fuel burn (kg)	CO_2 (kg)	NO_x (kg)
Scen_1 (Potential gains/losses referring to REF)						
FRI 28JUN2013	504	-2,801.23	-413.45	-24,189.11	-76,432.54	-336.21
Scen_1a (Potential gains/losses referring to REF)						
SAT 29JUN2013	777	-4,294.45	-592.51	-35,674.08	-112,730.11	-524.51
Scen_3a (Potential gains/losses referring to REF)						
SAT 29JUN2013	882	-4,430.01	-622.81	-38,126.51	-120,481.78	-571.31
FRA365+ (Potential gains/losses referring to REF)						
SAT 29JUN2013	1,345	-9,108.70	-1,199.80	-70,424.19	-222,569.62	-831.89

The following conclusions can be made from the results listed in Table 42:

- Scenario 1a shows almost similar benefits as scenario 3a, but due to shift in flows for FABEC CW project it cannot be 100% compared
- FRA365 only doubles the benefits of the new DCTs (SCEN 1a/3a). With FRA365 all DCT combinations were possible, but only flights above FL365 were eligible. With SCEN 1a/3a only a limited number of new DCTs were tested. With more available new DCTs (also those shortcutting only 1-2 NM) and with eligible lower MIN FL it could be assumed that a much higher result for DCTs can be achieved coming closer to the result of FRA365. This should be subject to further studies as the operational impact for FRA365 seems to be more serious for ATC compared to the overall benefit for AO (in addition - the potential negative impact on vertical flight efficiency of FRA365 in the core area is not yet validated in detail).
- 5 (peak) FRI (weekdays) x 52 weeks would give ca 700,000 NM reduction per year versus 2 (peak) SAT (weekend) x 52 weeks would give ca. 450,000 NM reduction per year
- To compare: a potential reduction per year during weekend of 665,096 NM was simulated for the implemented DCTs during FRAMaK FR-CAP-01. This result comes indeed close to the estimated potential benefits of 950,000 NM per year during weekend for FRA 365 (9,108 NM x2x52) but calculated from the peak day. Of course the simulated area for FRA365 is only a part of the FRAMaK area, but it contains a major share in FRAMaK traffic.

Thus, the stepwise introduction of FRA DCTs seems to be a quite reasonable and similar efficient way for Free Route Operation.

Developed during the Route Design workshops of FRAMaK, several new cross-border route options could become available after ATM system updates in KUAC and MUAC (OLDI exchange).

Route efficiency indicators REDES and RESTR have been calculated for each flight. In Table 43 mean REDES and RESTR values are listed per scenario (ORG) referring to the respective REF.

Table 43: Route efficiency indicators REDES and RESTR

Date	REF			ORG		
	Total impacted flights	REDES	RESTR	Total impacted flights	REDES	RESTR
Scen_1						
FRI 28JUN2013	524	1.037	1.025	526	1.023	1.016
				Difference:	-0.014	-0.009
Scen_1a						
SAT 29JUN2013	781	1.033	1.023	788	1.019	1.013
				Difference:	-0.014	-0.010
Scen_3a						
SAT 29JUN2013	898	1.030	1.020	905	1.017	1.012
				Difference:	-0.013	-0.009
FRA365+						
SAT 29JUN2013	1,314	1.032	1.021	1,371	1.020	1.010
				Difference:	-0.011	-0.011

6.3.3.4.1.2 OBJ-0201-004 SAFETY

The parameter number of conflicts has been chosen to have an evaluation basis for the KPA Safety. The amount and the quality of counted conflicts are important factors to determine the complexity of an evaluated ATC-sector and thus the impact on safety. In the context of this fast-time simulation the parameter conflict is counted, when the measured lateral or vertical separation is equal to the prescribed lateral (5NM) or vertical separation minima (1000/2000ft).

6.3.3.4.1.2.1 WE-Traffic Option

In split and combined sector configuration no significant reduction of counted conflicts could be observed when comparing reference and the different evaluation scenarios. In contrast a rise of conflicts for several sectors in all sector groups has been detected, except sector ALP. In general a wide spread of conflict-figures is apparent when comparing scenarios and sectors.

6.3.3.4.1.2.2 H24-Traffic Option

Over all a comparable level of conflict-numbers in reference and evaluation scenarios is noted for both sector configurations. As in WE-option a wide spread of conflict-numbers was measured.

6.3.3.4.1.3 OBJ-0201-005 and OBJ-0201-006 CAPACITY

The parameter number of movements is the main criterion to measure the KPA Capacity. It includes every flight effectively crossing a specific sector, illustrated in 10-minute steps respectively for shifting hours. This method is more accurate in analysing traffic-peaks in comparison to an evaluation of static time-hours. The number of movements is evaluated as average and peak value within the evaluation period for each sector.

The criterion occupancy is the second parameter to analyse the KPA Capacity. It describes the maximum number of aircraft, which are controlled by a radar controller simultaneously and thus gives a good indication of maximum sector-load.

6.3.3.4.1.3.1 WE-Traffic Option

In general a medium to high traffic-load is measured in all sectors, except for top sectors of EBG Central with very low traffic. Some sectors possess a very high peak value for movements. The measured values show no significant gap between the sectors when comparing the different scenarios, only a trend of traffic shifts as average movement-numbers vary slightly.

As a result of high traffic load occupancy-values are much too high in some sectors, especially in combined sector configuration. In comparison to the reference scenario, the occupancy-values of evaluation scenarios are higher by trend.

6.3.3.4.1.3.2 H24-Traffic Option

A comparable picture as in WE-option for the parameter number of movements is depicted in the option with H24-traffic. As a result of high traffic load occupancy-values are very high in some sectors, especially in combined sector configuration. The threshold for controller´s workload is exceeded in nearly all sectors. Only in EBG Central a slight reduction of occupancy-values is detected when comparing reference and evaluation scenario.

6.3.3.4.1.4 OBJ-0201-008 COST EFFECTIVENESS

In general flight costs are proportional to the parameter flight time in the surrounding of air traffic. An indicator for the KPA Cost effectiveness is the average flight time an aircraft remains in a specific sector, subject to sector entry and exit times. A variation in average flight time of an ATC-sector due to a variation of routing options delivers conclusions to the cost effectiveness of the considered sector.

6.3.3.4.1.4.1 WE-Traffic Option

Only in EBG South changes in average flight time can be noticed from evaluation results. In sector ISA2 (resp. ISA2_CHI2) a significant reduction of average flight time is reported in the evaluation scenario FRA365+. In sectors DON and ALP the average flight time increases slightly with the implementation of WE-DCTs.

6.3.3.4.1.4.2 H24-Traffic Option

With H24-traffic-sample slight changes in average flight time are measured. The average flight duration in sectors ISA, CHI and ALP are slightly lower in evaluation than in the reference scenario. It is the other way round for sector DON.

6.3.3.4.1.5 OBJ-0201-009 OTHER - Workload

The parameter workload is measured with the DFS-workload model, based on the expenditure of time for different controller tasks (see Chapter 6.3.2.1.2). In this context the executive controller tasks are evaluated only.

The second parameter for analysing the KPA Other/Workload is the number of inter-sector coordination. The number of inter-sector-coordination is another parameter to describe the number of aircraft transfers from one sector to another. Thus conclusions about sector movements related to cross-border DCT-operations can be drawn.

For evaluation reasons it has been distinguished between internal and external inter-sector coordination. Internal coordination focusses on coordination procedures between sectors of Karlsruhe UAC but only inside evaluation area. In this context both coordination to lateral (e.g. WUR3-FFM3) and vertical adjacent sectors (e.g. FFM3-FFM4) were considered. External coordination describes coordination procedures between the sectors of evaluation area inside Karlsruhe UAC and adjacent sectors or upper area control center (e.g. FFM4-RUHR). This analysis was conducted for split sector configuration.

6.3.3.4.1.5.1 WE-Traffic Option

Moderate average workload values are counted in split sector configuration, except in top sectors of EBG Central, where the results are very low due to low traffic figures. Peak workload values are much too high in combined sector configuration, leading to overload situations in several sectors. In general the implementation of certain DCTs does not indicate a consistent picture on workload-results.

The number of internal and external coordination in evaluation area raises slightly with the implementation of WE-DCTs due to not adjusted sector boundaries. In this consideration especially the number of internal coordination inside the evaluation area grows when WE-DCTs are implemented.

6.3.3.4.1.5.2 H24-Traffic Option

Moderate average workload values are achieved in split sector configuration, except in top sectors of EBG Central and sectors of EBG South, where low average workload values are measured. In combined sector configuration peak workload values are partly too high, which cause overload situations. A slight increase of workload in EBG West and South and a slight decrease in EBG Central is observed when comparing the reference and evaluation scenario.

The number internal and external coordination in evaluation area raise slightly with the implementation of H24-DCTs. In total the number internal and external coordination in evaluation area raise slightly with the implementation of H24-DCTs.

6.3.3.4.2 Results impacting regulation and standardisation initiatives

n/a

6.3.3.4.3 Unexpected Behaviours/Results

The exchange, update and integration of traffic data was never executed before in that extensive way in DFS integrating two different FTS and one RTS (SAAM, AirTOp and KASIM). Already the data preparation in SAAM took much more resources as initially planned. SAAM itself is not yet the perfect tool for such detailed studies and it required huge resources for validating and correcting the data (e.g. implemented RAD restriction or PTR for correct trajectories). Therefore, some workload studies for sub-scenarios with AirTOp were skipped if a certain potential overload (in terms of traffic count on a routing) was already indicated by SAAM. Comparison between different DCTs for similar flows were just done with SAAM and the scenarios 1a and 3a were finally built according to the traffic shift onto each new DCT.

The data exchange to the subjacent simulators went as well not as perfect as planned as certain corrections in the traffic data (e.g. correction for odd / even segments or some flows e.g. ARR EBBR which were wrongly forced via ADKUK by SAAM) did not always reach the next simulator and had to be done once again.

The selection of a 90 minutes traffic sample for the RTS from a SAAM created H24 traffic sample was difficult as not all vertical sub-sectors could be simulated at the KASIM and hence the capacity was slightly reduced in the simulated area of central sectors. This subsequently reduced traffic in adjacent areas like West and South sectors. But ATCO insisted on high traffic to validate the new DCTs in a realistic environment and so certain conflicting traffic had to be added resulting in a very high traffic demand in the Central sectors. (Extra flights were just moved / copied from the H24 traffic sample.)

During adaption of delivered SAAM-scenarios for AirTOp-simulation it became apparent, that some routings had incorrect or missing even/odd information referring to the semi-circular-cruising-level rules.

The route structure used in AirTOp contains waypoints and ATS-Route segments. An ATS-route segment links two waypoints and contains information about start and end waypoint of the segment (linked waypoints), direction of usage and flight level allocation. The ATS-Route segments had been created by SAAM and delivered as ASE-File (see chapter 6.3.2.1.3.7).

The following table lists ATS-Route segments whose even/odd information had been emphasized as wrong. These ATS-Route segments had been changed in AirTOp-scenarios, missing ATS-Route-segments have been added manually to each scenario.

Table 44: ATS-Route segments with wrong even / odd information

Delivered ATS-ROUTE-segment	Wrong even /odd information	NEW ATS-ROUTE-segment	Correct even /odd information
ETAGO-LIRSU_1	odd	ETAGO-LIRSU_2	even
LIMGO-BIBAG_2	even	LIMGO-BIBAG_1	odd
BOMBI-UBENO_2	even	BOMBI-UBENO_1	odd
MASEK-KEMAD_1	odd	MASEK-KEMAD_2	even
KEMAD-TUGDU_1	odd	KEMAD-TUGDU_2	even
GALMA-AMOSA_2	even	GALMA-AMOSA_1	odd
KRH-PABLA_2	even	KRH-PABLA_1	odd
GIKOG-ABGUS_2	even	GIKOG-ABGUS_1	odd
DISKI-LIMGO_1	odd	DISKI-LIMGO_2	even
LAMSI-MAPOX_1	odd	LAMSI-MAPOX_2	even
KENIG-MAG_1	odd	KENIG-MAG_2	even
GRZ_TITIG_1	odd	GRZ_TITIG_2	even
KEMAD-MASEK_2	even	KEMAD-MASEK_1	odd
RIDSU-UBENO_2	even	RIDSU-UBENO_1	odd
SIMBA-ABABI_1	odd	SIMBA-ABABI_2	even
GUDOM-RASPU_1	odd	GUDOM-RASPU_2	even
BOMBI-MASEK_2	even	BOMBI-MASEK_1	odd
TUBLO-SUL_2	even	TUBLO-SUL_1	odd
NIKDI-RID_2	even	NIKDI-RID_1	odd

Additionally some routings had been calculated wrong by SAAM and were changed in AirTOp or the respected flights have been deactivated for simulation run.

- ARR EBBR via ADKUV: During night-time the correct routing has been changed to proceed via INBED-ADMUM
- The routing EDMM-LFPG has been changed to proceed via INBED-Y101-OSBIT
- Flightplan of TOM2FG has been deactivated in all weekend-scenarios
- Flightplans with routings HECA-EBBR, HECA-EBLG and HECA-EBOS have been deactivated in scenario FRA365+

All changes in scenarios have been agreed by Karlsruhe UAC in advance.

6.3.3.4.4 Quality of Demonstration Results

The achieved results of AirTOp fast-time simulation are directly linked with the output of SAAM-analyses. As described in chapter 6.3.3.4.3 several failures were found during preparation for AirTOp regarding ATS-route segments. By adapting the SAAM-scenarios it has only been possible to detect missing segments but it was not the task to analyse every single ATS-route segment for accuracy regarding start and end waypoint, flight level allocation and permitted direction of flight. Also an examination of the different evaluation scenarios regarding direct-distribution and -allocation in cross-border-DCT-operation has not been part of AirTOp fast-time simulation.

So far AirTOp fast-time simulation cannot guarantee for the accuracy and quality of data input as provided by SAAM.

6.3.3.4.5 Significance of Demonstration Results

A statistical significance of simulation results cannot be qualified. For each evaluated scenario only one simulation run has been conducted without changing conditions like wind or operators kind of route selection (e.g. cheapest route as most AO use or fastest route for hub operation). However, the tested scenarios are comparable as each simulation run has been carried out with same simulator settings.

The implemented traffic samples are synthetically as they deviate from todays real live traffic samples (the new route options shift traffic).

The traffic volume of the exported 90 Minute samples to the RTS (KASIM) has been afterwards increased artificially in order to generate a high traffic simulation environment. A reference simulation with a today's real live traffic sample has not been conducted as it would not be comparable and as it was not the aim (shifted traffic flows after all the planned changes in spring 2014). The changes initiated by new DCTs could only be compared with a "future REF" (in that case AIRAC 1404+) and not with "present REF" (autumn 2013 during preparation).

The operational significance in regard to realistic environment is given on a high degree in regard to airspace and air-traffic control procedures. The depicted sector structure represents the actual structure of Karlsruhe UAC. Only the sector reconfiguration of sectors FFM and FUL is not yet published. The major hubs are connected with actual departure and arrival route structure (SID/STAR). In contrast the SID- and STAR-structure of small airports has not been constructed, what has only a minor impact on flight profiles during departure resp. arrival phase. Nevertheless this has no impact on transition to the sectors of Karlsruhe UAC because of altitude of evaluation area above FL345 and because entry conditions to evaluation area are not affected.

The handover procedures for flights from one sector to another have been adapted from published Letter of Agreements and Operational Orders. To enhance accuracy of implemented handover procedures, Karlsruhe UAC has checked these sector rules for correctness in advance.

Finally an examination of simulated scenarios took place twice by Karlsruhe UAC. Last mistakes in handover procedure rules and route guidance have been detected and fixed.

6.3.4 Conclusions and recommendations

6.3.4.1 Conclusions

The AirTOp fast-time simulation has shown, that the evaluation scenarios 1a and 3a as delivered by SAAM do not significantly affect the evaluation parameters conflicts, number of movements per sector, occupancy, average flight time per sector and workload in comparison to the delivered reference scenarios for most sectors. Thus, a negative impact on analysed KPAs does not occur except partially for ISACHI, DON or TGO as described in 6.3.3. The detailed evaluation of the scenario FRA365 in detail is still in progress, as FRA365 was anyway not developed to be quickly implemented.

The main target of AirTOp fast-time simulation was to adapt SAAM scenarios for use in AirTOp and the further delivery to the KASIM. A suitable 90 Minutes traffic sample could be selected for the KASIM-RTS according to the SAAM results as shown in Figure 36 - Figure 38.

First conclusions from the SAAM benefit analyses of scenarios 1a, 3a and FRA365 (c.f. 6.3.3.4.1.1) show that further analyses especially cost-benefit analyses are required for FRA365, as the benefits seems to be not as significant higher as for scenario 1a/3a or those comparable benefits already achieved with implementation packages for FRAMaK FR-CAP-01.

While implementing new DCTs according to the scenarios 1a/3a and adding all those potential new DCTs shortcutting just 1-2 NM (which were not yet considered due to efforts required), similar benefits might be achieved as for FRA365. Certainly, a FRA with lower MIN FL will offer much more benefits, but as well more workload in certain sectors and potential negative results concerning vertical flight efficiency.

6.3.4.2 Recommendations

The iterative process of developing and expanding the DCT route options is a feasible way also for the core area.

Since SAAM Fast Time Simulations are considered more and more a standard step in airspace design projects the capabilities of SAAM should be enhanced with regard to

- Utilization of data available in the Enhanced Tactical Flow Management System (ETFMS), i.e. operational data comprising RAD constraints etc., for the generation of traffic examples,
- Optimisation of flights based on different criteria such as wind, route charges, airspace availability etc.

Correction when found e.g. in AirTOp or KASIM about wrong routings (mostly transitions to / from aerodromes) or wrong data (e.g. odd/even parity) should be seamless exported to the other (down- or upstream) simulators.

Even if not operationally accepted in the RTS, a scenario FRA365 in the core area could be further investigated in terms of eliminating certain hotspots by shifting boundaries (if not creating new hotspots) or adding extra rules for changing/limiting certain flows. The RTS made it more evident, that individually designed DCTs offer better results in terms of a compromise between optimum route length and minimizing negative operational impacts for ATC (capacity/safety) and AO (vertical flight efficiency).

New cross border direct route options from / to MUAC or from / to Austro Control up to certain anchor points (those points regular given to the neighbours for tactical shortcuts) within KUAC (but before the critical Central sectors in the middle) should be further investigated. Such cross border directs (after update of OLDI exchange) might bring further significant benefits as they avoid the zig-zag via COPs – if operational feasible as the present system with COPs in the core area segregates flows on purpose, therefor limiting the workload.

6.4 Demonstration Exercise EXE-0201-D004 "Simulation-based assessment of Cross-Border DCTs - KUAC Core Area Real Time Simulation" Report

Complementing EXE-0201-D001 and in addition to EXE-0201-D003 this exercise empirically evaluated effects of different setups of FRAMaK Cross-Border DCTs in Karlsruhe Core Area for a SAAM generated traffic sample ("cheapest routes") outside military activities (KUAC peak day 2013 – SAT 29JUN).

By means of a Real Time Simulation especially operational feasibility has been investigated for a "complete" Free Route Modell above FL365 and for 2 different sets of (cross-border and internal) RAD DCTs with different lower MIN FL (FL345 in the average). Possible "No-Go" items for a complete Free Route Airspace and actions to overcome such problems have been identified on one side and on the other side possible RAD DCTs which required simulations in the process of designing the route catalogue (WP2) were investigated for early implementation (target date - AIRAC DEC2014).

6.4.1 Exercise Scope

The geographical scope of EXE-0202-D004 was limited to the Karlsruhe UAC Core Area, comprising all top sectors of Karlsruhe UAC Central Sectors, West Sectors, South Sectors (until DEC2012 allocated at Munich ACC) and the East Sectors ERL and SAL. This area is one of the hotspots in Europe with a very high traffic density and complexity.

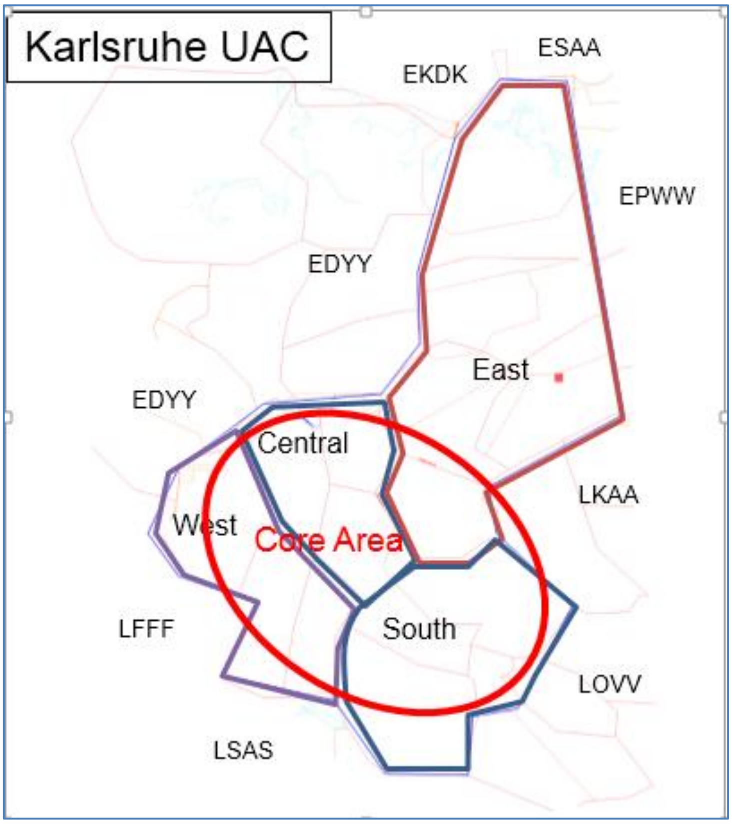


Figure 39: Geographical scope of EXE-0201-D004

6.4.1.1 Exercise Scenario

The underlying demonstration scenario is referred to as SCN-0201-001 "Cross-Border Entry-Exit DCTs" which in return refers to FR-CAP-01.

The determination of Cross-Border entry-exit DCTs has been accomplished in WP 2 Route Design. DCTs have been published in the Route Availability Document (RAD), Appendix 4 “En-route DCT limits – DCT limits” or were identified as subject to further investigation (“simulations required” as feedback from KUAC controllers board or after first safety analyses of the individual DCTs). FRAMaK entry and exit points have been defined as connecting points between the Cross-Border Direct routes developed in the project and the surrounding ATS Route System or Free Route airspaces both adjacent and subjacent to the FRAMaK airspace.

To minimize concerns of ATCOs regarding feasibility of certain DCTs, most of them were already implemented as RAD DCTs “only available during night” to ensure ATCOs awareness of certain traffic flows and conflict situation during the RTS. Therefore, the RTs could only be conducted at the end of this project.SCN-0201-001 is related to

- MUAC/KUAC overflights, i.e. transfers through the combined Maastricht & Karlsruhe airspace, and
- flights to and from hubs and major airports affected by airspace design activities in the FRAMaK airspace, i.e. flights
  - arriving from a destination outside the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace,
  - departing from a hub within/below the FRAMaK airspace directed towards a destination outside the FRAMaK airspace, and
  - between hubs within/below the FRAMaK airspace, i.e. departing from a hub within/below the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace.

6.4.1.1.1 Scenario Development in relation to other exercises

3 Sub-scenarios with 90 Minutes of Saturday traffic (29JUN2013) had to be created for the RTS to be simulated with different sector combinations (6 top sectors limited by available KASIM sectors [max.9] and pilot/ATCO resources). To achieve this goal an iterative process with SAAM, AirTOP and KASIM was established (Figure 40, Table 45).

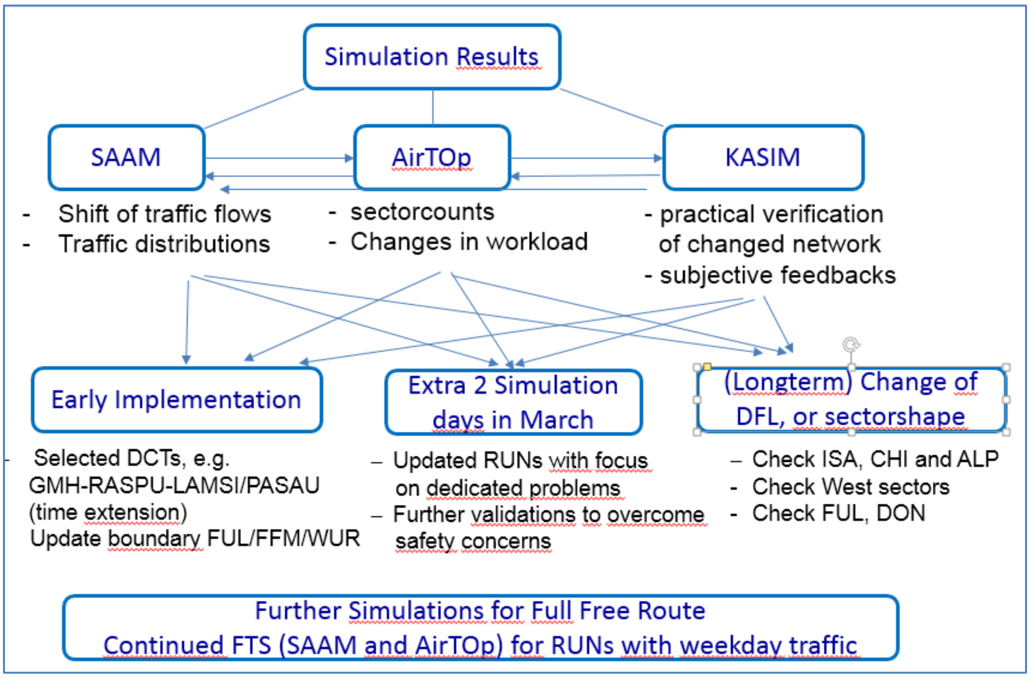


Figure 40: Scenario Development for Karlsruhe Core Area RTS

Table 45: Goals of Karlsruhe Core Area simulation elements

Simulation	Time Frame	Main Goals related to KASIM RTS (for more details see the respective chapters)
SAAM	AUG2013 -APR2014	Implement in SAAM several sub-scenarios (with different sets of new DCTs) and create new traffic examples “cheapest routing” using existing and planned new route options. The model “cheapest route” and the validation on the European network level was a new approach of conducting FTS and RTS for DFS, but without pre-validating flow changes an assessment of the new DCTs wouldn’t be correct enough (even it is still an assumption and ignoring daily shifting winds). Note, for the assessment of the KPIs Efficiency and Environmental Sustainability the model “shortest routes” was calculated to be comparable with other projects.. Validate the shifted traffic and changes of traffic loads Re-design scenarios if required (after results SAAM/AIRTOP/KASIM) KPI assessments on European network level for Efficiency and Environmental Sustainability and subjective support for assessing the KPI Safety and Capacity Assessments of new DCTs created for “Safety KASIM RUNs” 13/27MAR1014
AirTOP	AUG2013 -APR2014	Import the SAAM traffic samples (according to scenarios) and export the new created (updated and shortened) AirTOp traffic sample for 3 runs in KASIM Validate sector counts and workload for KUAC top sectors in order to select a 90 Minutes traffic sample out of it Assessment of KPI Safety and Capacity
KASIM	FEB/MAR 2014	Conduct (pre-validation) PRTS on selected 90 Minutes traffic samples (3 SCEN), add extra traffic if required (03/04FEB) and correct routing / FL Conduct RTS for updated 3 scenarios with different lateral sector combinations (max 6) Conduct FRAMaK KASIM Safety Runs in order to find mitigations for early implementation of selected DCTs (update of alignment, allowed flows, availability - but initially without SAAM network evaluation due to time constraints/resources) See also 6.4.1.2

6.4.1.1.2 Exercise Sub scenarios

The Karlsruhe Core Area RTS was based on an airspace design as of AIRAC 1404 (effective 03 APR 2014) including

- Kosovo airspace open
- H24 DCTs implemented in Vienna UIR and in South-East Europe
- corresponding updates of Karlsruhe UAC DCTs implemented

- latest routings resulting from SENEKA airspace design project.

The airspace design also took into account foreseen changes related to the FABEC Central West implementation affecting flows in the FUL sector (Note: For scenario 3a those flows were changed):

- ARR EG** via ROBEL GORLO
- ARR EHAM via SOPOD INDAM (new fix South-East of NORKU)

Future updates resulting from FABEC project SWAP / CBA 22 are not considered.

Table 46: Karlsruhe Core Area RTS Sub-scenarios

Sub-SCENARIO	TRAFFIC SAMPLE	DESCRIPTION
REF1	WE	Reference scenario representing the actual (AIRAC DEC2013) route structure (including published RAD DCTs) added by the known/planned changes for AIRAC MAR2014 (e.g. H24 DCTs LOVV and a FRAMaK RAD DCT implementation package) and AIRAC APR2014 (e.g. further FRA changes in Southeast Europe and the opening of new "KFOR sector"). The **REF** included also planned changes of FABEC project "Central West" with realignments of ARR EHAM (VEXIL-SOPOD-INDAM) and ARR EG** via ROBEL – GORLO (shift of traffic flows). REF was not used as scenario for RTS, but for validations within FTS.
SCEN1A	WE	Solution scenario containing **all** directs as delivered by Rhein UAC to the AirTOp-team according *RAD-APP4_FRAMaK_CoreFTS_scenario_selection.xlsx*. According this document SCEN1A contains all directs except those named aaaa and except the direct DITOM-DOMAL
SCEN3A	WE	Solution scenario containing **all** directs as delivered by Rhein UAC to the AirTOp-team SCEN3A contains all directs named xxxx, several directs named yyyy1 (MAMOR-VALAR-VIBOM-BETEX-TOLVU) and one direct from the aaaa-group (KORUP-NOSPA)
FRA365+	WE	Solution scenario for a "completely" free route airspace above FL365 without additional RAD DCTs except those RAD DCTs already published. The scenario contains entry and exit fixes, which have been linked by SAAM. Therefore the entire evaluation area has been divided into a northern part (FRAN) with lower level FL335 and a southern part (FRAS) with lower level FL365. The internal boundary between northern and southern part is located approximately along the line VARIK-WRB. Additionally departure and arrival fixes have been established to ensure vertical flows to airports, e.g. LSZH. To circumnavigate France an intermediate fix has been established at EDISA. An overview of used fixes is given in Figure 43.

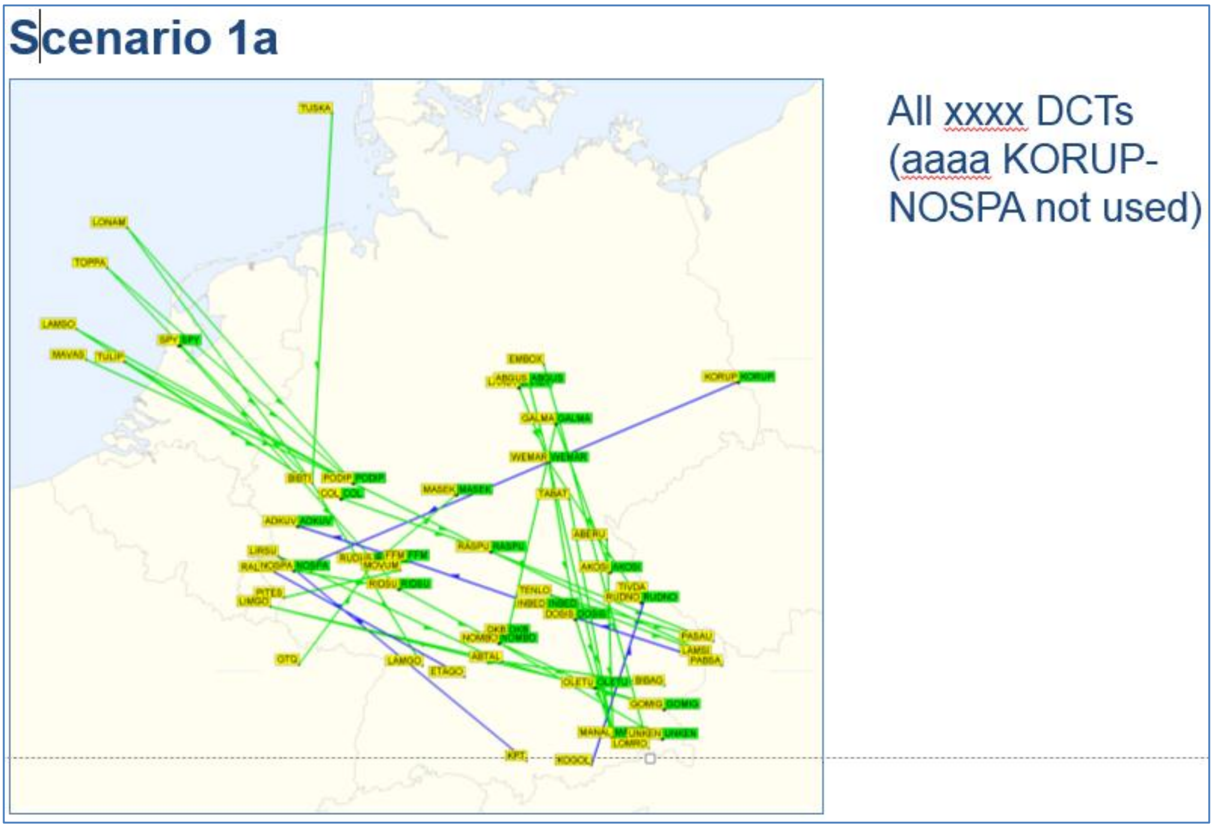


Figure 41: Karlsruhe Core Area RTS scenario 1a, "xxxx" DCTs

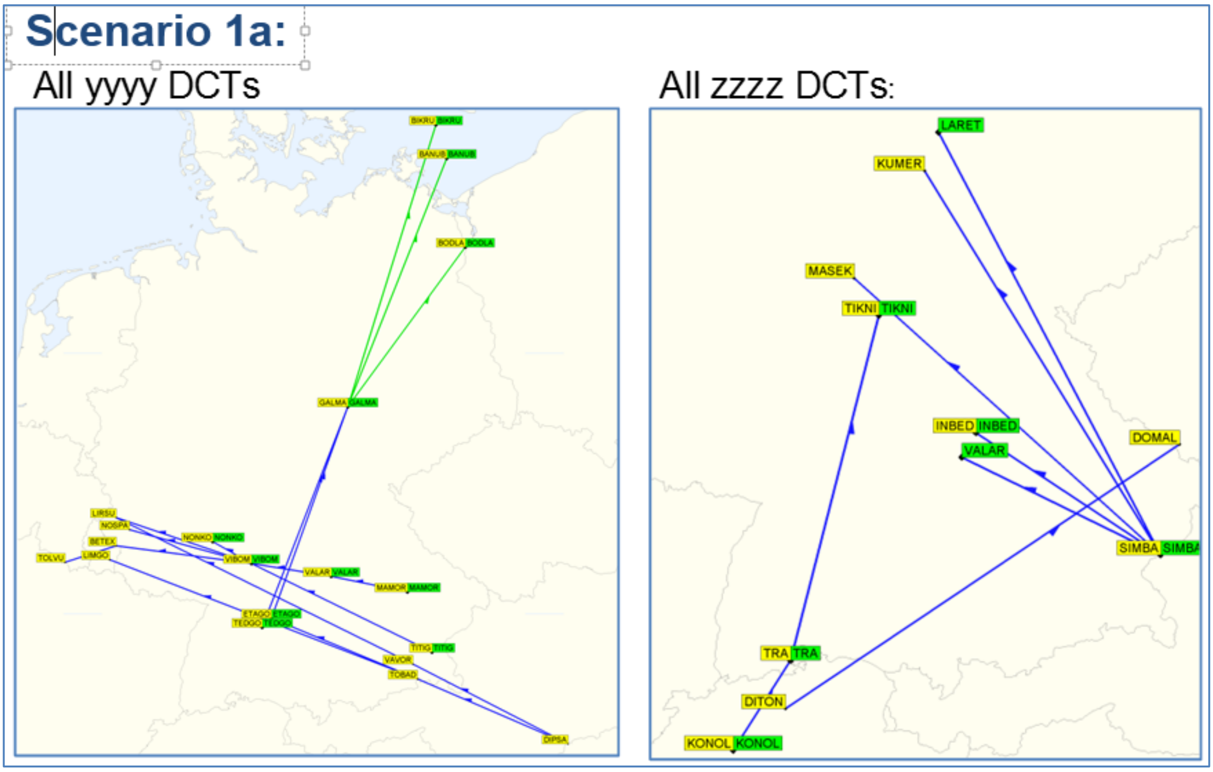


Figure 42: Karlsruhe Core Area RTS scenario 1a, "yyyy" and "zzzz" DCTs

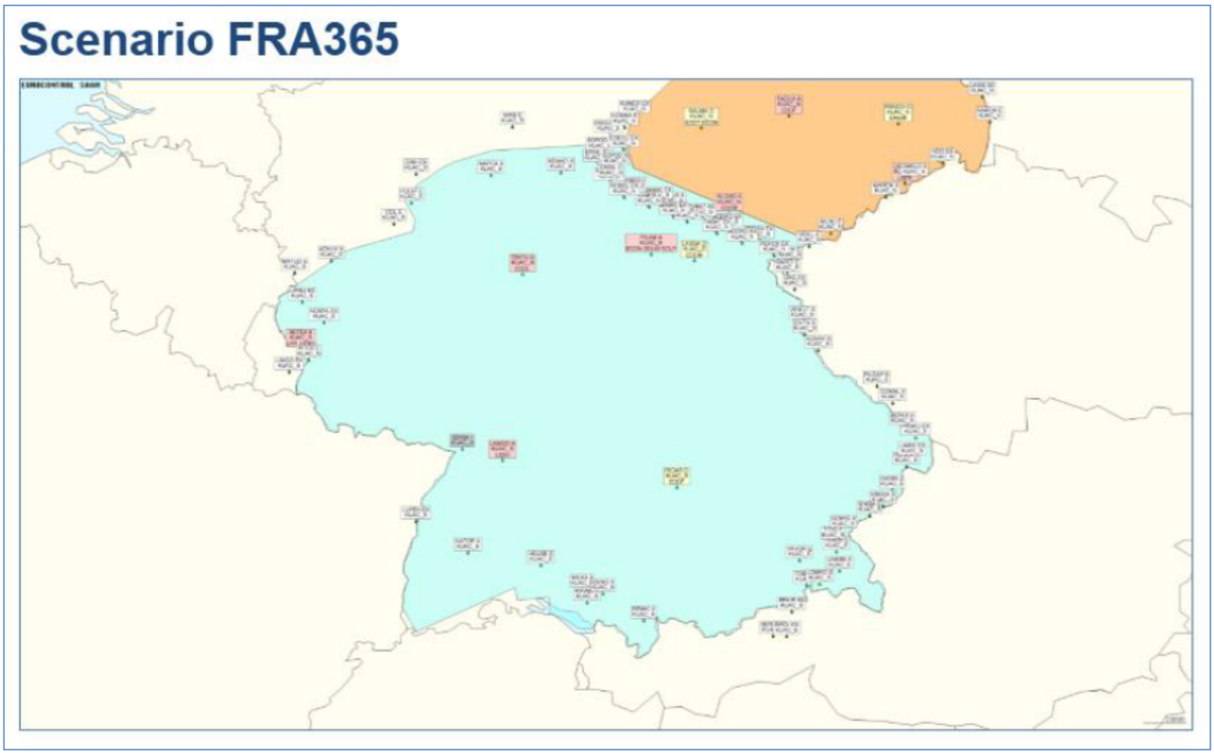


Figure 43: Karlsruhe Core Area RTS scenario "FRA 365"

6.4.1.2 Exercise Objectives

The exercise shall contribute to the investigation of objectives listed in Table 47.

Table 47: Demonstration Objectives EXE-0201-D004

Objective ID	Description	KPAs
OBJ-0201-004	Safety of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs do not negatively affect Safety.	Safety
OBJ-0201-005	Capacity related to Cross-Border DCTs It is to be demonstrated that based on a suitable route design the usage of Cross-Border Directs will not negatively affect capacity of the FRAMaK airspace.	Capacity
OBJ-0201-009	Operator Workload related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect operator workload and situational awareness of both ATCOs and crews. Contrariwise, based on a suitable route design a reduction of workload and an increase of situational awareness might be achievable.	Other
OBJ-0201-010	Operational Feasibility of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs provide a sufficient feasibility for operational usage.	Other

6.4.2 Conduct of Exercise

6.4.2.1 Exercise Preparation

6.4.2.1.1 ATCO Questionnaire

In order to collect feedback from ATCOs a questionnaire has been elaborated which covered the following items:

- Which steps / mitigations should be done in order to implement a “Full Free Route Airspace” above FL 365; are there any “no go”-items?
- Validation of dedicated new direct routings (or amended DCTs in terms of operational availability) offering quick and reasonable benefits to airlines and better traffic distribution within EDUU, but on-loading sectors like e.g. DON, NTM:
    - A further traffic split on main South-East bound flows via more exit points (GMH area – RASPU – LAMSI/PASAU and BOMBI-TENLO-LAMSI/PASAU – all weekend – in addition to exits via GOMIG, UNKEN, LOMRO KPT area)
    - New westbound connections ARR LF** via MAMOR-VALAR-VIBOM-BETEX-TOLVU (weekend) or via KORUP-NOSPA
    - New eastbound connections from LIMGO for DEP LFPG
    - Westbound flow INBED-FFM-ADKUV
- Validation of changed sector boundaries WUR / FUL / FFM (enabling GMH-RASPU clear of FUL) for a possible early implementation.

6.4.2.1.2 Simulation Runs

The following simulation runs were prepared for the Karlsruhe Core Area RTS.

6.4.2.1.2.1 Pre-Validation Runs

Prevalidation RUNs of the 3 scenarios (SCEN1a, SCEN 3a and SCEN FRA365) at KASIM - to check correct routing, flows and decide for extra traffic to be added.

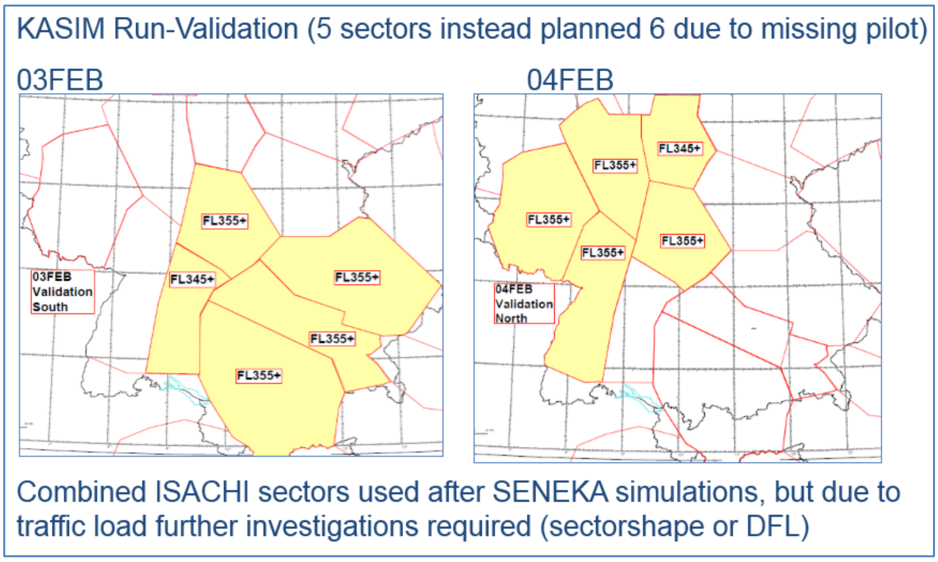


Figure 44: Sector Layout Pre-Validation

Resulting to an excel sheet with approximately 100 extra flights per scenario to be better able to analyse the scenarios.

6.4.2.1.3 Main Exercise Runs

3 (Main) Exercise RUNs with the updated SCEN1a, 3a and FRA365 from prevalidation. (those Main RUNs were also exported back to AirTOp for a future detailed assessment) For each RUN and sectorgroup different questionnaires were prepared.

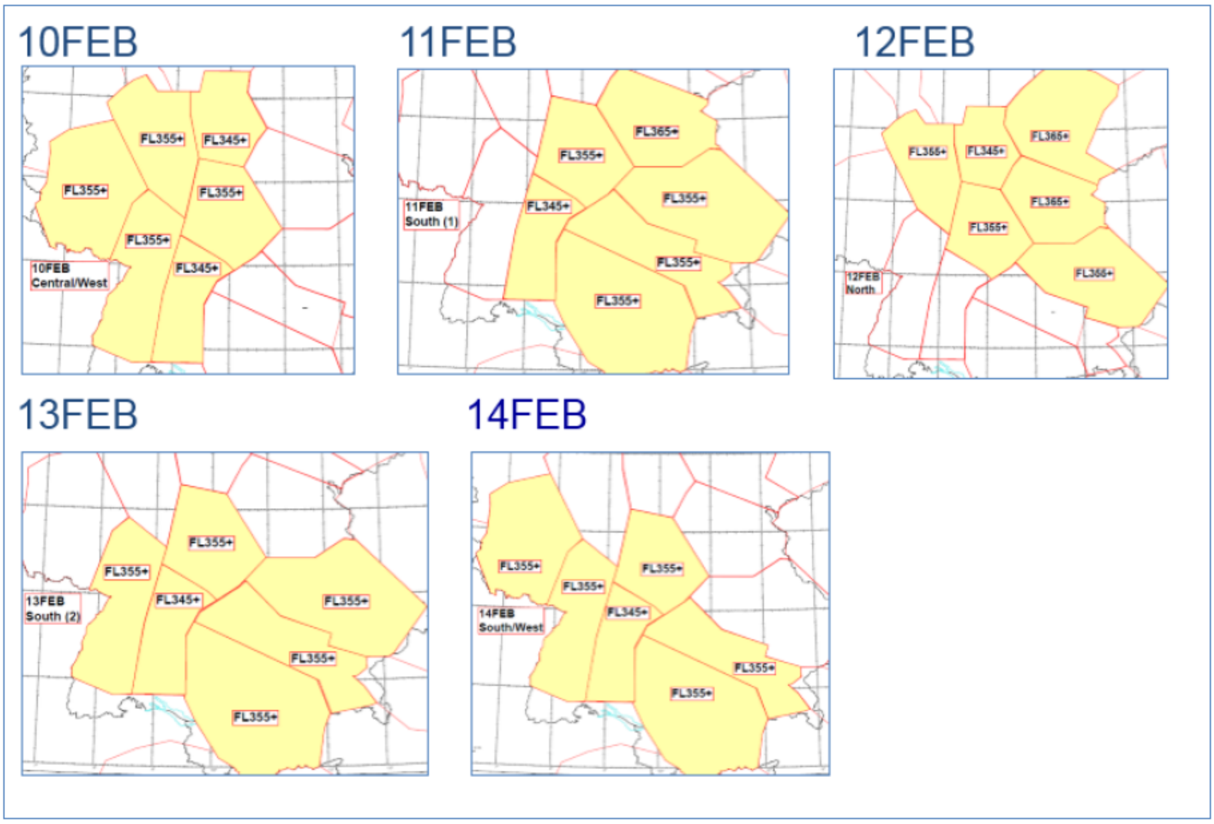


Figure 45: Sector Layout Main Exercise Runs

From the overall feedback as well from feedback and discussions after the runs including discussion in controllers board and negotiations with Praha ACC and MUAC) the run with SCEN3a was updated (corrected) in stepwise approach for safety RUNs conducted on 13MAR2014.

6.4.2.1.3.1 Safety RUNs 13MAR

Safety Runs accomplished on 13/03/2014 comprised 3 runs with the following characteristics:

Table 48: Characteristics of Safety Runs 13MAR

Run 1	▪ DCTs TEDGO / ETAGO – GALMA excluded ▪ DCT INBED – FFM – ADKUV added ▪ DCT MAMOR – VALAR – VIBOM – BETEX added ▪ ARR LFPG via KORUP – NOSPA now via KORUP – RASPU – NOSPA ▪ Overflights / DEP EHAM via GMH / COL are towards SE Europe via TESGA – OSBIT – KEMES – LAMSI / PASAU (map w/o KEMES) ▪ DEP LFP* to SE (LO**, LH**) via ISACHI

Run 2	▪ DCTs TEDGO / ETAGO – GALMA excluded ▪ DCT INBED – FFM – ADKUV added ▪ DCT MAMOR – VALAR – VIBOM – BETEX replaced by / realigned to INBED – FFM – RUDUS ▪ ARR LFPG via KORUP – NOSPA now via LKAA / OKG – NOSPA ▪ Overflights / DEP EHAM via GMH / COL are towards SE Europe via TESGA – OSBIT – KEMES – LAMSI / PASAU (map w/o KEMES) ▪ DEP LFP* to SE (LO**, LH**) via LUPEN
Run 3	▪ DCTs TEDGO / ETAGO – GALMA excluded ▪ DCT INBED – FFM – ADKUV added ▪ DCT MAMOR – VALAR – VIBOM – BETEX replaced by / realigned to INBED – FFM – RUDUS ▪ ARR LFPG via KORUP – NOSPA now via LKAA / OKG – NOSPA ▪ DEP EDDL to SE may use DCT to OSBIT and continue as above ▪ ARR LOWW / LHBP via OSBIT – ANELA – LULAR – ABUDO (except DEP ED**) ▪ DEP LFP* to SE (LO**, LH**) not via LUPEN

In Figure 46 DCTs under study in the Safety Runs 13MAR are shown for the WUR sector. The sector layout fo the Safety Runs 13MAR are shown in Figure 47.

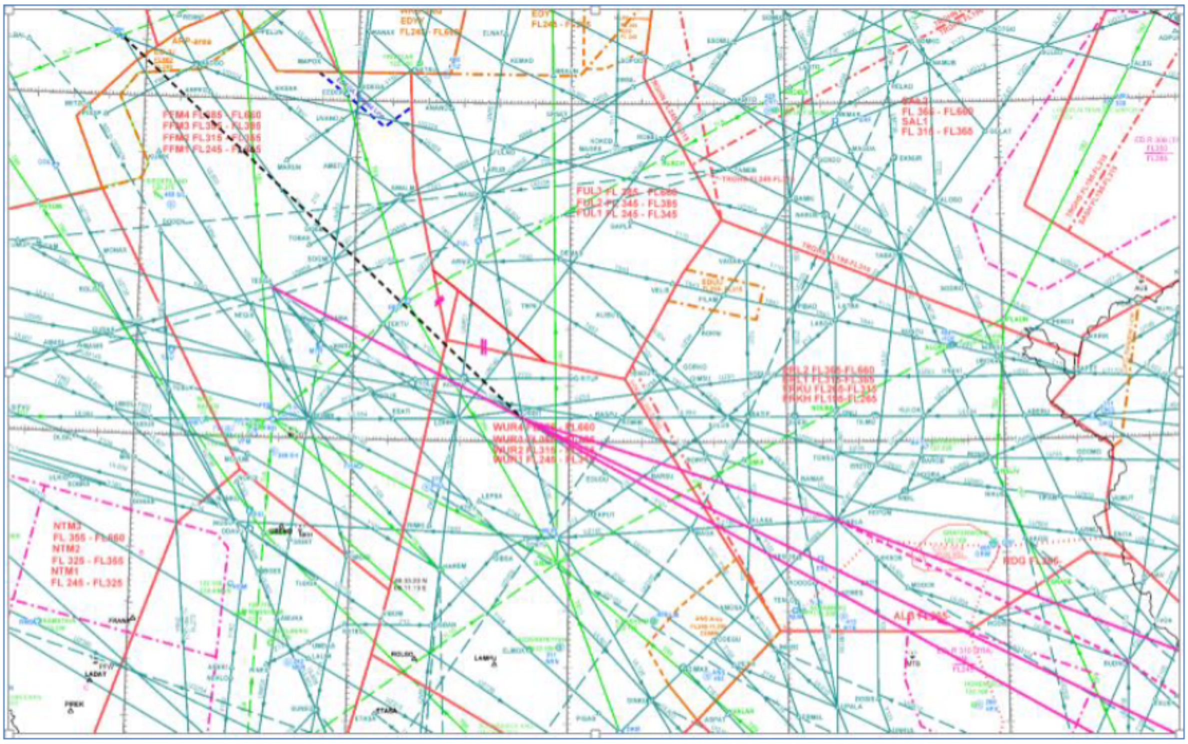


Figure 46: Draft DCTs WUR sector

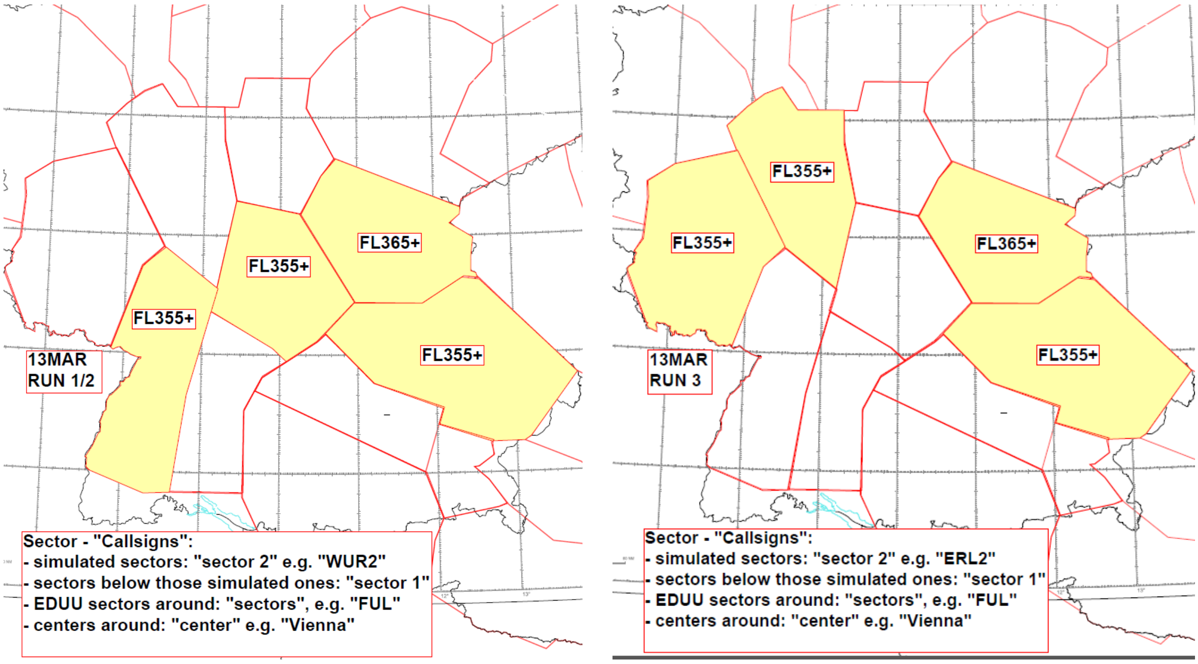


Figure 47: Sector Layout Safety Runs 13MAR

Note: Due to one missing KASIM pilot, the west sectors could not be simulated (NTM or SLN), but main focus anyhow was on the interface WUR/FFM with ERL and DON sector. (2 ATCOs were returned to ops room).

6.4.2.1.3.2 Safety RUNs 27MAR

In Safety Runs 27MAR the same scenario was simulated three times.

After confirmation of negotiation results of a meeting KUAC and Praha ACC (including Munich ACC) end of February 2014 a proposed routing for ARR LOWW/LHBP and LZIB was added in the RUNs 27MAR (as in the last for 13MAR). This clarified options and flows within KUAC DON sector (AO would mainly use cheaper LKAA airspace for a routing from the west).

ATCO proposed during FEB simulations a westbound flow split towards ADKUV and as an initial idea 2 (overhead BATTY) converging route options were included in the 27MAR runs. Parallel routings would lengthen the route. Simulation is an ideal basis for trying tactical directs on one of the converging flows to obtain separation into MUAC airspace.

Table 49: Characteristics of Safety Runs 27MAR

- DCTs TEDGO / ETAGO – GALMA excluded
- DCT INBED – FFM – ADKUV replaced by INBED – FFM – RASVO – BATTY – BUB
- UK routing via OSBIT – LOHRE – ADKUV replaced by OSBIT – GEBSO – BUB
- DEP LKPR via DIMSU – LOHRE – ADKUV replaced by DIMSU – KONAP – GEBSO – BATTY – BUB
- DCT MAMOR – VALAR – VIBOM – BETEX – TOLVU added
- ARR LFPG via KORUP – NOSPA now via KORUP – RASPU – NOSPA
- Overflights / DEP EHAM via GMH / COL area towards SE Europe via TESGA – OSBIT – KEMES – LAMSI / PASAU (map w/o KEMES)
- DEP LFP* to SE (LO**, LH**) not via ISACHI but via LIMGO – RUDUS – BOMBI – OSBIT – ANELA – LULAR – ABUDO – BUDEX (continued VENEN for LOWW or GIMBO – LADAG – STO for LZIB / LHBP)
- Other ARR LOWW 7 LHBP / LZIB via OSBIT or RASPU same routing (or part of) as above)

The above scenario (Safety RUNs 27MAR) was validated with 3 different sector layouts: (actually is planned to…)

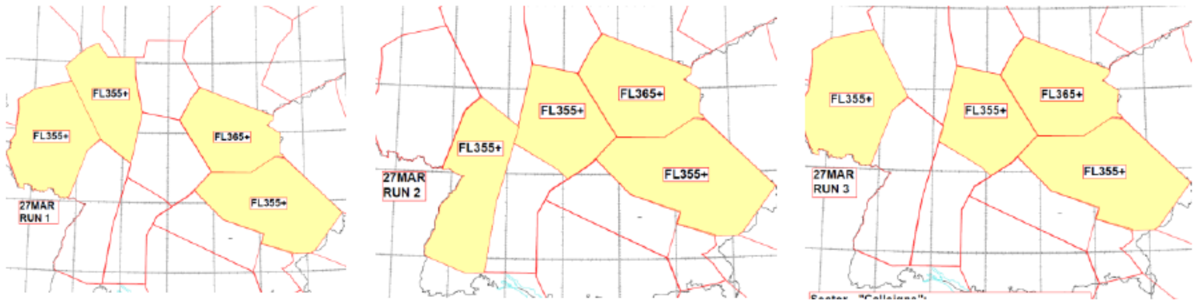


Figure 48: Sector Layout Safety Runs 27MAR

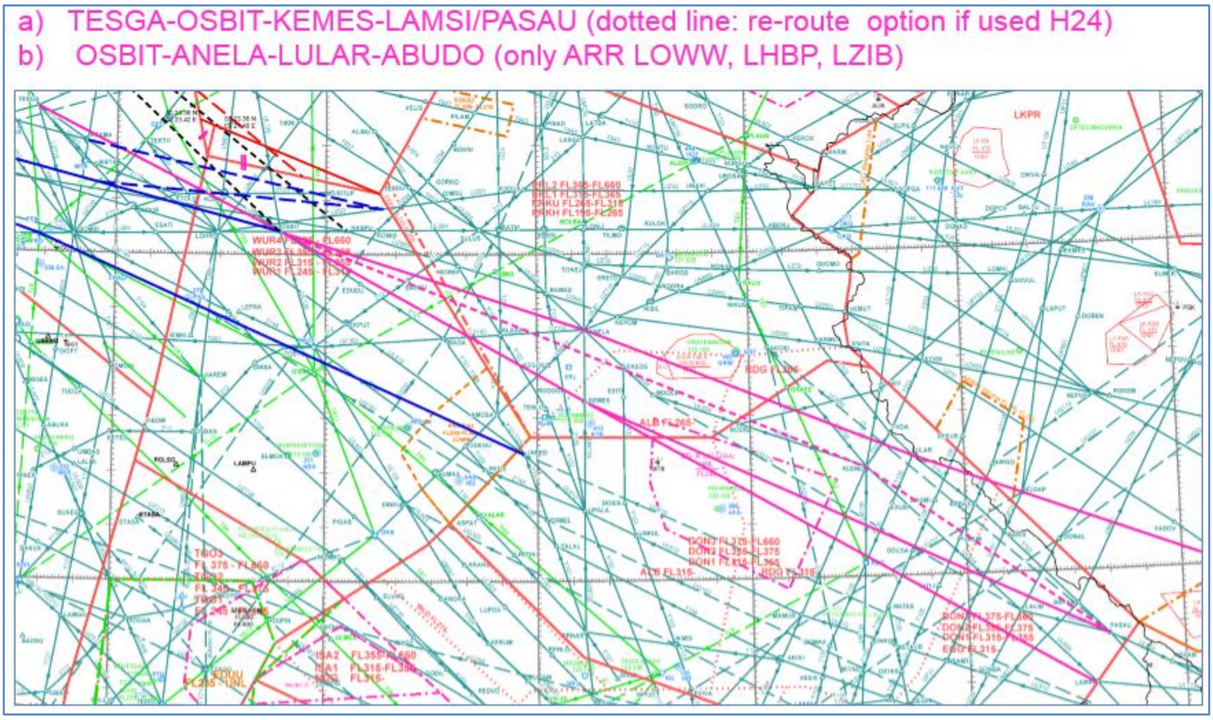


Figure 49: Updated DCTs via DON sector

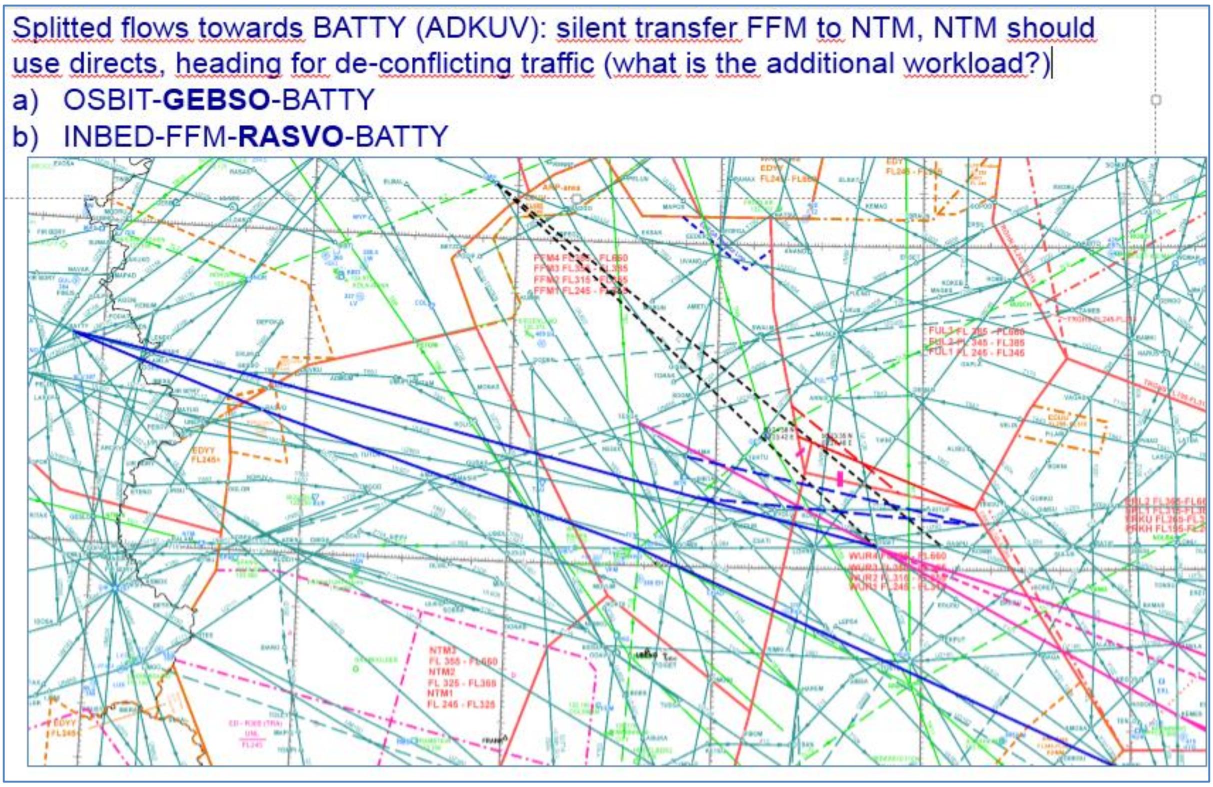


Figure 50: Updated westbound DCTs

6.4.2.2 Exercise execution

The simulation was conducted (sector layout, scenarios etc.) as described in 6.4.1.1 and 6.4.2.1.

The following daily schedule was used (sometimes with different order of the scenarios):

Figure 51: Daily schedule of KUAC RTS

Every simulation day briefing presentation was given, see attachment.

After each Run questionnaires had to be filled and returned. (Sometimes it was allowed to start prior the end of the run to get more time for feedback discussions).

During Safety KASIM Runs in March no questionnaires were prepared, as the focus was on feedback discussions.

6.4.2.3 Deviation from the planned activities

One sector was not simulated during pre-validation and Safety RUN 13MAR (one pilot less – no impact).

Assessments of KPI in exercise plan was described not totally according operational needs. The common package of FTS SAAM and AirTOp and KASIM RTS was not clearly communicated beforehand, even it was intended as such. KPI e.g. flight efficiency should only be assessed on European network level, as flow changes just within 90 Minutes of a RTS cannot deliver correct results.

Initially it was also planned to simulate one weekday traffic sample, but due to complications with the SAAM tool results were initially not promising (wrong FPLs). Anyway it was the better approach just to simulate weekend traffic as impacts of military areas would have changed simulation results and it would have been difficult to allocate the correct corresponding problems, issues. (Weekday traffic was still subject to SAAM and AirTOp valuation.)

6.4.3 Exercise Results

6.4.3.1 Main Exercise – Scenario FRA365:

Low acceptance in central sector group (sectors with very high traffic density and complexity requiring vertical traffic to be kept on segregated transition routes to avoid multiple coordination between the vertically splitted sectors e.g for vectoring avoiding traffic on DCTs).

In comparison – selected and published RAD DCTs (not random DCTs like in FRA365) could avoid certain sector boundaries and conflict areas, lengthen the route maybe by only 0.5 NM.

Opposite flows in ISACHI Area (South sectors) increased workload and complexity (FL changes to solve conflicts of converging/crossing major Southeast bound flows towards Austria not always possible or they need to be done well in advance).

Multiple conflicts sometimes were very difficult to solve. With the new random DCT options possibilities for multiple conflict situations increased (e.g. 3 separated flights from Southeast – sometimes from different sectors- could conflict with 2-3 as well individual separated flights from Northeast making conflict solutions for overflights were complicated). With old structure (ATS routes and DCTs such multiple conflict situation could be avoided/limited by network design with FRA365 a metaplanning position could help to avoid

Very complex conflict situations in areas at common boundaries of 3 sectors e.g. in SULUS or AMOSA area made conflict solutions (e.g. responsibilities) difficult, coordination of vectoring became sometimes complicated (system inputs such as requests and acknowledgments from all 3 sectors involved in short time were required – otherwise system calculation continued on not updated trajectory with safety issue)

More frequent vectoring was required for solving conflict situations due to random and less segregated direct routings leading to **a) safety issues** as MTCD works less correct (trajectories cannot be updated as accurate as the system does it with the FPL routing) and to **b) capacity issues** as higher workload for system inputs requires capacity reduction like for thunderstorm.

Vertical flight efficiency for certain flows was negatively impacted (e.g. DEP LSZH via ETAGO would stay quite often at lower FL, ARR EDDL via TETKU or ARR LSZH via DKB would have to descent early)

(from subjective feedback) **The number of conflicts has increased** compared with present route network or dedicated DCTs (but after adding extra traffic in simulation runs). **Conflict areas** have increased as conflicts occur more randomly (also at sector boundaries as described above).

Intermediate anchor points (segmented DCT or direct routing) were requested/ preferred to avoid trouble with sector sequence (sector snapper) and to ease system inputs

FRA405 in the core area instead the simulated FRA365 seems to be feasible, but experiences out of the higher FRA for further expansion to a FRA365 seems to be rather limited (ATCO feedback).

One main concern for FRA365 was FL adherence, as pilots would not always stick to filed MIN FL 365 (or ATCO need to clear at lower FL due to traffic) creating very complex situation also in the mixed mode DCTs and other network. Feedback of ATCO about FRA365 considered a reasonable part of traffic below FL365 on the possible DCTs for FRA365.

Another major concern in central sector group was the (ICAO) **requirement to keep distance of 2.5 NM to sector boundaries.** This was with FRA365 randomly not possible (as DCTs crossed to close to boundaries and changes of sector shapes seems to be not feasible). ATCOs from central sectors still requested the unchanged working method (very small sectors, reluctant to give away potential “silent vector space”) – this would be indeed a “**No Go item**” for Full FRA with random crossings. ATCOs were open to further trials and investigation for this subject.

6.4.3.2 Main Exercise – SCEN 1a and 3a

6.4.3.2.1 Results for proposed DCTs subject to early implementation

The proposed DCT routing **GMH RASPU LAMSI/PASAU** was successful updated and tested as **TESGA OSBIT KEMES LAMSI/PASAU** (safety run) and considered as feasible even optimized with connection from Maastricht UAC via new COP(s) between COL and GMH (subject to final negotiation with MUAC and FABEC CW project). Also it was recommended to allow (or even force) all traffic from Northwest on the route segment TESGA OSBIT (with routing to South east) to avoid mixed and crossing traffic.

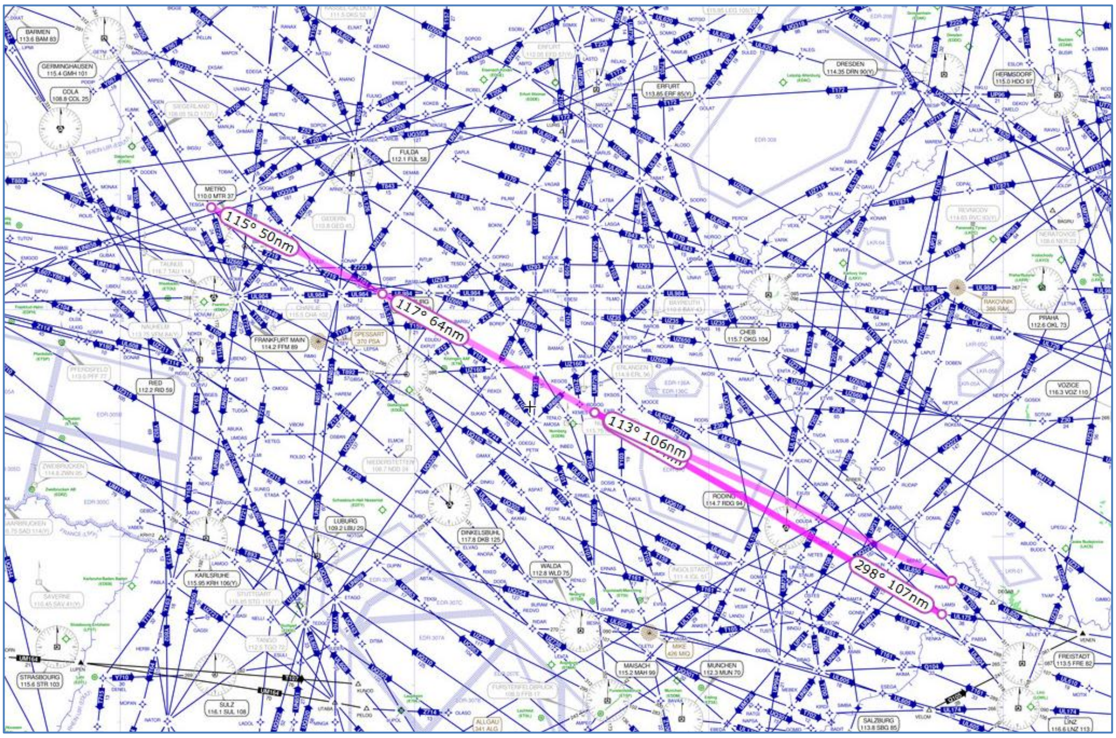


Figure 52: Direct routing TESGA OSBIT KEMES LAMSI/PASAU

With the recommendation above initial flow limitations (e.g. only DEP EHAM) are not suitable – so live test during winter season should be done first.

The (existing) direct routing from England (BOMBI TENLO LAMSI PASAU) should be initially kept at night time only. At daytime the routing via OSBIT KEMES LAMSI/PASAU is recommended instead of TENLO (if used by AO due to slightly longer routing and therefore more expensive than a routing via LKAA). To limit additional traffic in the DON sector the KEMES LAMSI/PASAU routing will be made available initially for traffic from Northwest (COL GMH area).

At the third safety run on 27MAR tactical re-routings for traffic planned on DCT OSBIT KEMES LAMSI/PASAU around activated TRA ED-R310 were tested by ERL sector. As ATCO from east sectors are used to tactical re-routing with ED-R 308 or MVPA the re-routing for the rare case of TRA310 activation seems to be feasible and the DCT KEMES LAMSI/PASAU could be in a future step timely extended to H24 DCTs (if activation of ED-R310 remains at the present low level).

The additional new DCT routing (MIN FL330) for ARR LOWW/LHBP/LZIB **OSBIT ANELA LULAR (COP to LKAA) ABUDO BUDEX** was successfully tested at safety run 27MAR but a slightly update was recommended with alignment **OSBIT <u>EKSOS</u> LULAR** (giving better separation to traffic on UZ660).

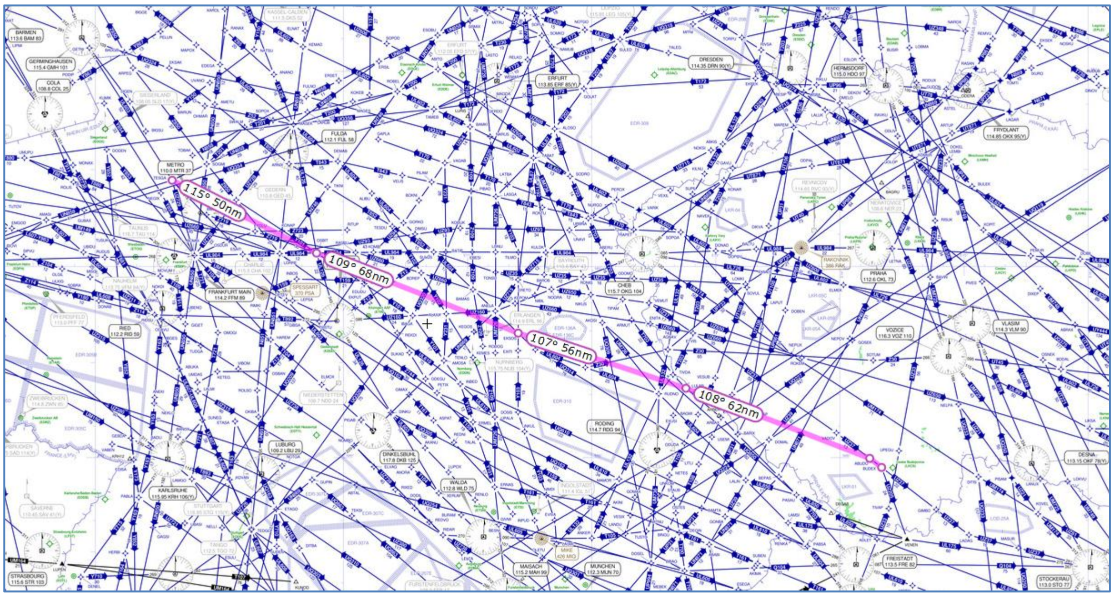


Figure 53: Direct routing OSBIT EKSOS LULAR

The mentioned ARR LOWW/LHBP/LZIB should consequently be restricted from the proposed OSBIT KEMES PASAU routing above (reducing complexity in DON sector and keeping traffic flows more simple).

The proposed routing **MAMOR VALAR VIBOM BETEX TOLVU** (ARR LF**) was finally recommended for a live trial in winter season with MIN FL360. During the simulation runs in February some ATCOs expressed concerns about increased complexity in WUR (multiple crossing points) and during the safety runs some ATCOs from DON were afraid about increased coordination workload (to obtain lower FL than FL360 for ARR EDDF on transfer DON2 to DON1 due to potential conflict with traffic on the new MAMOR VALAR routing).

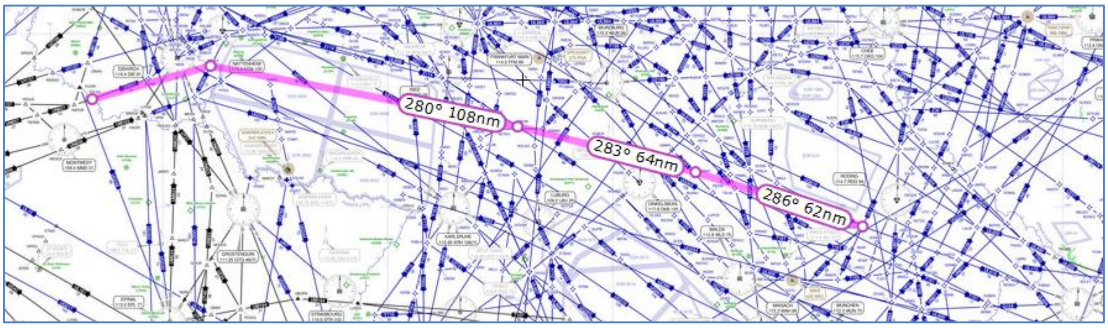


Figure 54: Direct routing MAMOR VALAR VIBOM BETEX TOLVU

The connection BETEX TOLVU at Maastricht side is still subject to negotiation with Maastricht UAC and from first operational feedback reasonable, but the change itself might be conflicting (in timing and resources) with planned changes for FABEC projects like SWAP or CW.

The proposed direct routing **INBED FFM ADKUV** was rated rather critical due to possible impacts on other flows in WUR sector and only low benefits (shortcut not so huge). It was suggested to split flows towards ADKUV / BATTY to enable silent transfer FFM to NTM sector on (temporary) separated routes.

For Safety Run 27 MAR this was successful tested with routes OSBIT GEBSO BATTY and INBED FFM RASVO BATTY with possible silent transfer FFM to NTM sector and coordination NTM with Maastricht UAC (or further general tactical directs to de-conflict traffic). Both routings are subject to negotiation with Maastricht UAC.

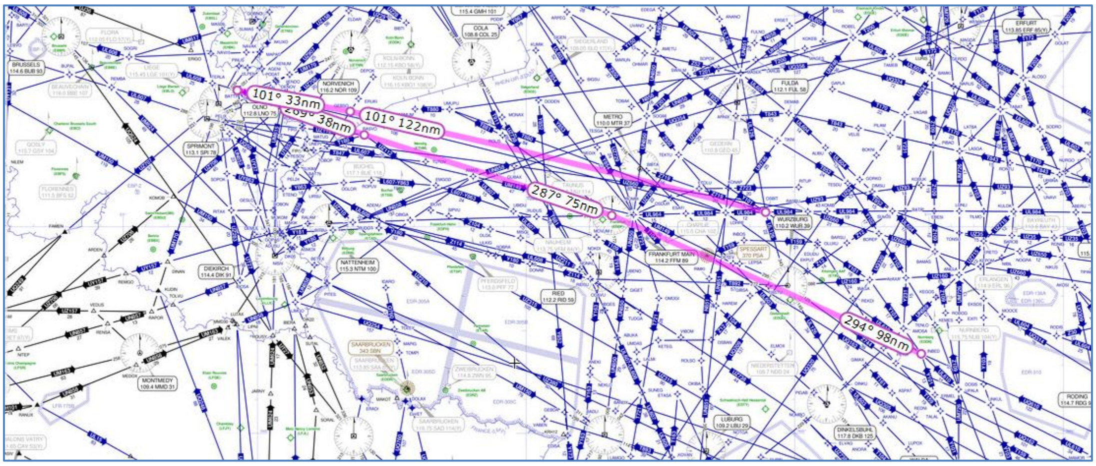


Figure 55: Direct routings OSBIT GEBSO BATTY and INBED FFM RASVO BATTY

Proposed southbound DCTs to MANAL are accepted for implementation DEC2014 (but due to possible re-shaping of sector boundaries ISA/CHI/ALP in 2015 it has to be verified again).

6.4.3.2.2 Results not specified for dedicated DCTs

Iteration process for each single DCTs is still required. The used process of implementing night DCTs initially and then extending opening times after gaining first real experiences is appreciated – simulation runs can help for decision making but cannot completely replace daily practical live tests (with random conditions). The final proposal for early implementation of selected DCTs after the Safety Run 27MAR and ongoing discussion at Karlsruhe UAC controllers board and with Maastricht UAC about alignment and implementation slot is forseen in early summer 2014 (first implementation slot AIRAC 11DEC2014). Approval and acceptence to new DCTs cannot be given for all DCTs in the complete package according to scenario 1a or 3a, but for selected single new DCTs considering also the dedicated validation in the Safety Runs.

Segmented DCTs or new “Multiple Highways” in the core area complemented by DCT route options on each side seems to be favourable.

Even the sectors at the periphery are able and willing to handle a bunch of new DCTs, limiting factor remains the central sector group (with reasons).

Central sectors require still more time to get used to daily variations of routings (as already usual in East Sectors). Very volatile sector loads (due to various numbers of new route options) might impact capacity in KUAC. Flexible sector boundaries or a cross sector ATCO training/license program could help to react to this trend.

With limited numbers of new DCTs KUAC could remain an actor adding the best new route options assigning a good compromise between flight efficiency and capacity.

field trials during (or even implementations) for less complex and loaded winter season are accepted (subject to extra seasonal briefings like it used to be done for Ski traffic in Munich sectors) – this is a quite important way to make new route options in certain sectors available (“**winter routings**” in addition to night and weekend routings).

6.4.3.3 Summary of Exercise Results

6.4.3.3.1 Results per KPA

Table 50: Results per KPA EXE-0201-D004

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Safety	OBJ-0201-004	No increase of complexity in Cross-Border DCT operations	ATCO feedback showed increased complexity in certain sectors. More route options increased the number of multiple conflicts thus complexity in certain sectors.
Safety	OBJ-0201-004	No degradation of the perceived level of safety in Cross-Border DCT operations	Reduction of number of flights within the sector were recommended by ATCOs to keep safety level (similar to thunderstorms). Safety impacts were mentioned concerning less precise MTCD on manual updated trajectories for traffic on radar vectors.
Safety	OBJ-0201-004	No degradation of the perceived level of situation awareness in Cross-Border DCT operations	In certain sectors situation awareness decreased significantly due to new and multiple crossing / conflicts. (this can be overcome by staggered introduction of new DCTs, but maybe not with a "full FRA365")
Capacity	OBJ-0201-005	No adverse results regarding number of flights in Cross-Border DCT operations	Subjective feedback from ATCO was to require a capacity reduction like done for thunderstorms in certain sectors.
Cost Effectiveness (Sectorization)	OBJ-0201-008	No adverse results regarding sector occupancy in Cross-Border DCT operations	No change to current situation reported.
Other - Workload	OBJ-0201-009	No increase in operator workload in Cross-Border DCT operations	Problems for coordination concerning directs crossing 3 sectors (sector snapper) were reported. Increased workload for updating trajectories (vectoring more often required due to missing intermediate points)

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Other – Operational Feasibility	OBJ-0201-010	No adverse operator feedback regarding Cross-Border DCT operations	Intermediate points on direct routings were recommended for the core area to keep sector sequence and responsibilities for separation between dedicated major flows. With FRA365 this becomes more randomly and for certain sectors difficult.

6.4.3.3.2 Results impacting regulation and standardisation initiatives

(ICAO) requirement to keep distance of 2.5 NM to sector boundaries should be verified. With new systems (including MTCD) at least in some sectors (e.g. Karlsruhe East sectors - large and with less complex and less traffic) this could be skipped. For Central sectors it was a no-go item for Full FRA365.

6.4.3.3.3 Unexpected Behaviours/Results

The selection of a 90 Minutes traffic sample for the RTS from a SAAM created H24 traffic sample was difficult as not all vertical sub sectors could be simulated at the KASIM and hence the capacity was slightly reduced in the simulated area of central sectors. This subsequently reduced traffic in adjacent areas like West and South sectors. But ATCO insisted on high traffic to validate the new DCTs in a realistic environment and so certain conflicting traffic had to be added resulting in a very high traffic demand in the Central sectors. (Extra flights were just moved / copied from the H24 traffic sample.)

6.4.3.3.4 Quality of Demonstration Results

The constraints deriving from the traffic sample selection within the simulation process are already described in 6.3.3.4.

A 90 minutes traffic sample cannot include all possible variation in changed traffic flows influenced by e.g. wind; AO's selected cost index or the random traffic / conflict constellation.

By adding extra conflicting traffic, the scenarios were considered by ATCOs as realistic for evaluation of the potential problems caused by the new DCTs.

Feedbacks for FRA365 (but also similar for the DCTs in SCEN 1a, 3a) were always considering that a certain part (20-30%) of the traffic filed above FL365 e.g. at FL370 could actually use one lower FL such as FL350 (pilots requests, initial climb performance, traffic situation). If the FL adherence could be guaranteed in future, results (subjective feedback) would differ.

The selection of ATCOs for the RTS was randomly done by the appropriate planning office in Karlsruhe. Especially in the sector group Central it became evident, that the older and experienced ATCOs (they were in the majority) validated more conservatively and were reluctant to certain changes as they grew up with structure changes in the central sectors caused by huge traffic growths. Those ATCOs focused more on high capacity and segregated vertical flows for their (normally 3-4 vertically layered) sector structure than younger colleagues or those from the other sector groups. Choosing only younger colleagues could have given different feedbacks but potentially results might have been not ready for implementation (as they would be not accepted by a significant part of KUAC ATCOs).

6.4.3.3.5 Significance of Demonstration Results

The RTS of scenarios 1a, 3a (including safety runs) showed the operational feasibility of selected DCTs tested with scenario 1a and 3a (it was not intended to bring one of the scenarios completely to an implementation). The RTS was the pre-requisite to overcome initial safety concerns and uncertainty mentioned by the ATCOs during development of selected new route options. (Specific DCTs of CAP01 were subject to simulation while others could be implemented without.) An implementation during the winter season (and/or reduced flows on the new DCTs) will further help to verify the simulation results in daily practice but with less traffic.

FRA365 is not an option for implementation in the near future in the core area KUAC.

6.4.4 Conclusions and recommendations

6.4.4.1 Conclusions

A set of new DCTs (developed from simulated scenario 1a/3a) can be made available for early implementation e.g. in DEC2014 (still final agreement with MUAC for certain new route options required). A new route option South East bound via KUAC DON sector towards Austro Control Vienna (connected to H24 FRA DCTs) can be offered initially during weekend and H24 in a future step (subject to appropriate FUA procedures or optional radar vectors when ED-R310 becomes active). A new route option towards LKAA airspace for ARR LOWW, LHBP and LZIB could be finally developed, coordinated and tested in the frame of the RTS.

FRA365 in the core area of KUAC is not an option for a mid-term implementation, as many mitigations for mentioned safety concerns are required. The results for FRA365 showed that some very high dense and complex areas /sectors are bottlenecks for implementation what need to be respected (otherwise, capacity and vertical flight efficiency is reduced). It should be more feasible to initially develop a FRA above a certain MIN FL within the less complex and dense KUAC East sectors not dealing with operational issues (complexity and much more new conflicts as in the core area) and procedural issues (such as distance to boundaries) at the same time. Cross-border FRA in same less complex and less dense airspaces in Northern Europe seems to be more promising for mid-term implementation.

For the time being the development of individually designed (tailor made) new (cross-border) DCT route options in the core area represents a cost beneficial way to optimize horizontal flight efficiency while avoiding negative operational impacts (capacity or vertical flight efficiency) and offering the safe opportunity for stepwise introduction.

6.4.4.2 Recommendations

Selected tested direct route options (finally updated and tested during safety runs in March) should be implemented after final coordination and agreements with Maastricht UAC.

In the core area segmented DCTs (instead of long entry-exit DCTs) are preferred to have anchor points for vectoring thus keeping sector sequence and avoiding extra coordination. It has to be further discussed, if a direct routing containing 3 or 4 DCT segments (even if connectable with other segments like a spider net) couldn't be better implemented as an ATS route. Especially those route options for major flows are considered as "multiple highways" in Karlsruhe and they offer not only shortcuts but also certain flow segregation and define clearly certain conflict areas. With a segmented and slightly curved routing in some cases a better flow segregation or conflict situation could be achieved, but it makes this "direct routing" questionable as actually it might be better labelled as an ATS route. On the other hand, the advantages of DCT routings are still available as the number of DCT segments is more or less unlimited, but not the number of ATS routes (designators).

Field trials for certain flows on certain new potential DCTs or "Seasonal DCTs" are recommended to overcome safety concerns (which often do not apply for the winter season) and to further give daily practice to ATCOs.

Previous stepwise introduction of (initially night) DCTs and timely expansion (extended by morning and/or evening hours) gives ATCO the chance to gain experiences and to accept a daytime DCT during simulation.

Further developments for "Full FRA" above a certain MIN FL should be initially focused within the less complex and dense KUAC East sectors and furthermore within Northern Europe.

For FRA in the core area more SAAM validation and cost benefit analyses are required as the further development of DCT segments seems to be better tailor made for the customer avoiding negative impacts on vertical flight efficiency and capacity.

6.5 Demonstration Exercise EXE-0201-D005 "Simulation-based assessment of Cross-Border DCTs - MUAC Core Area Real Time Simulation" Report

Complementing EXE-0201-D001 and exercise empirically evaluated effects of different setups of FRAMaK Cross-Border DCTs in the Maastricht UAC Core Area.

By means of a Real Time Simulation especially operational feasibility has been investigated with a focus on sector clipping issues and methods to address negative effects.

The overall objective of the simulation was to create sector layouts for improved workload balancing and better adoption between demand and airspace, typically for scenarios with many direct flows like with increased direct routes, weekend traffic and MIL-off situations. The specific objective of this real time simulation was:

- To validate the so called "Just Small Improvements to the Current Sectorisation" (J6) which contains numerous straightened boundaries which are better adapted to direct flows emanating from the FRAMaK project;
- To validate airblock delegation for some airspaces, targeting a toggling of the whole HANN sector group, and small boundaries shifts in BRUS as well as between DECO and HANN.

The simulation ran all three MUAC sector groups (up to 11 positions) with many positions having multiple pilots. The conduct of the simulation was hugely successful; proactive controller relationships resulted in refinements, rejections and validation of the sector layouts:

- Most of the streamlining of sector bounds is validated, including the striking change of bounds between DELTA and RHR and MNS sectors. Those changes are accepted and wanted, and are valid for weekends and weekdays.
- Reshapes of sectors within the Hannover sector group is rejected, however.
- Trialling a North/South split in the Brussels sector group is very successful, and might also lead to higher capacity.
- Dynamic airspace delegation on the level of smaller airblocks was further validated, confirming the same hazards as variable division flight levels and hence requiring the same mitigations. Nonetheless, all but one airblock under investigation failed the test for usefulness as an airspace layout.

Qualitative cost-benefit statements on all the simulation themes have been developed, with recommendations for the follow-up: smaller yet useful parts could be implemented by briefings for AIRAC cycles, other spin-offs could become stand-alone projects (BRUS N/S), and yet other are proposed for implementation in the MARS-2 project (J6.1 with DELTA Cut & HOL bound).

For a full description of the RTS please refer to [11].

6.5.1 Exercise Scope

The geographical scope of EXE-0201-D005 covered the Maastricht UAC Area.

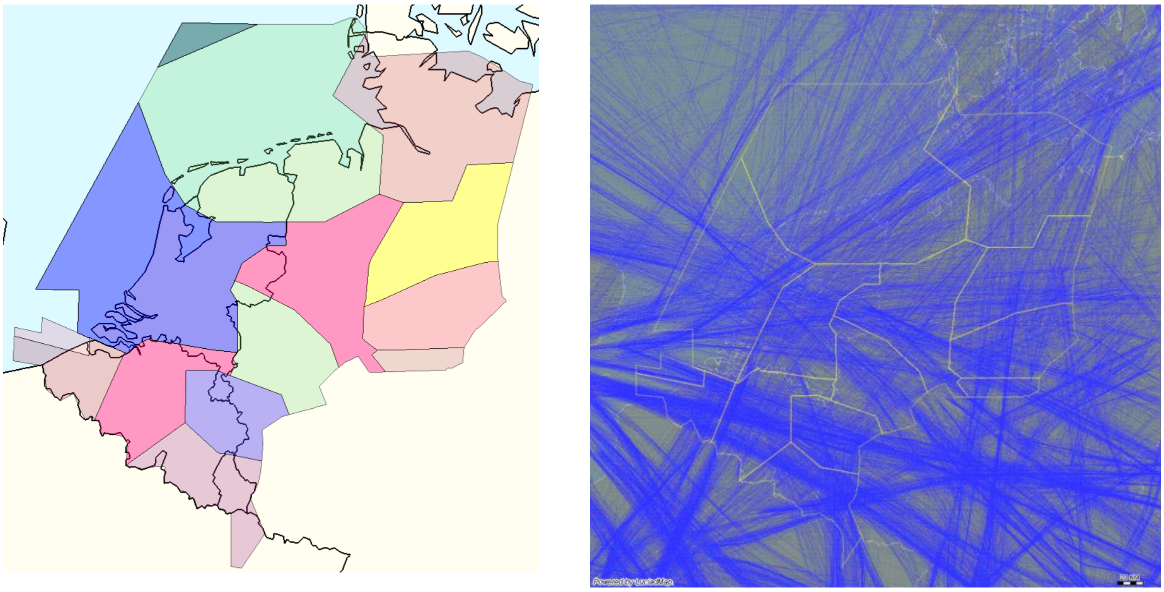


Figure 56: Current MUAC Airspace Layout (left) depicted with radar traffic > 245 from Sunday, 2013-06-23 (right).

Weekend traffic is a synonym for DCT traffic which also emanates from additional DCTs as from the FRAMaK project.

6.5.1.1 Exercise Scenario

The underlying demonstration scenario is referred to as SCN-0201-001 “Cross-Border Entry-Exit DCTs“ which in return refers to FR-CAP-01.

The determination of Cross-Border entry-exit DCTs has been accomplished in WP 2 Route Design. DCTs have been published in the Route Availability Document (RAD), Appendix 4 “En-route DCT limits – DCT limits”. FRAMaK entry and exit points have been defined as connecting points between the Cross-Border Direct routes developed in the project and the surrounding ATS Route System or Free Route airspaces both adjacent and subjacent to the FRAMaK airspace.

SCN-0201-001 is related to

- MUAC/KUAC overflights, i.e. transfers through the combined Maastricht & Karlsruhe airspace, and
- flights to and from hubs and major airports affected by airspace design activities in the FRAMaK airspace, i.e. flights
  - arriving from a destination outside the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace,
  - departing from a hub within/below the FRAMaK airspace directed towards a destination outside the FRAMaK airspace, and
  - between hubs within/below the FRAMaK airspace, i.e. departing from a hub within/below the FRAMaK airspace directed towards a hub within/below the FRAMaK airspace.

6.5.1.1.1 Exercise Sub scenarios

The MUAC RTS was based on an airspace design focused on adaptation to traffic flows emanating from (Cross-Border) DCT flightplan filing.

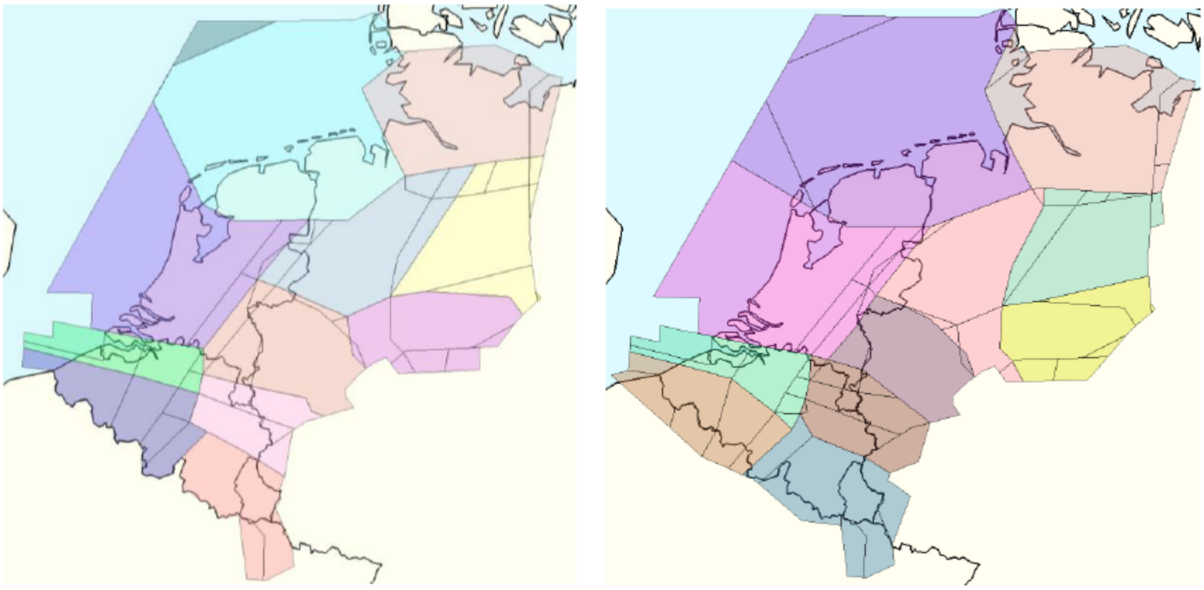


Figure 57: Airspace Layout as designed before (left) and during (right) the RTS.

Part of the design included Airspace Blocks that could be swapped between sectors:

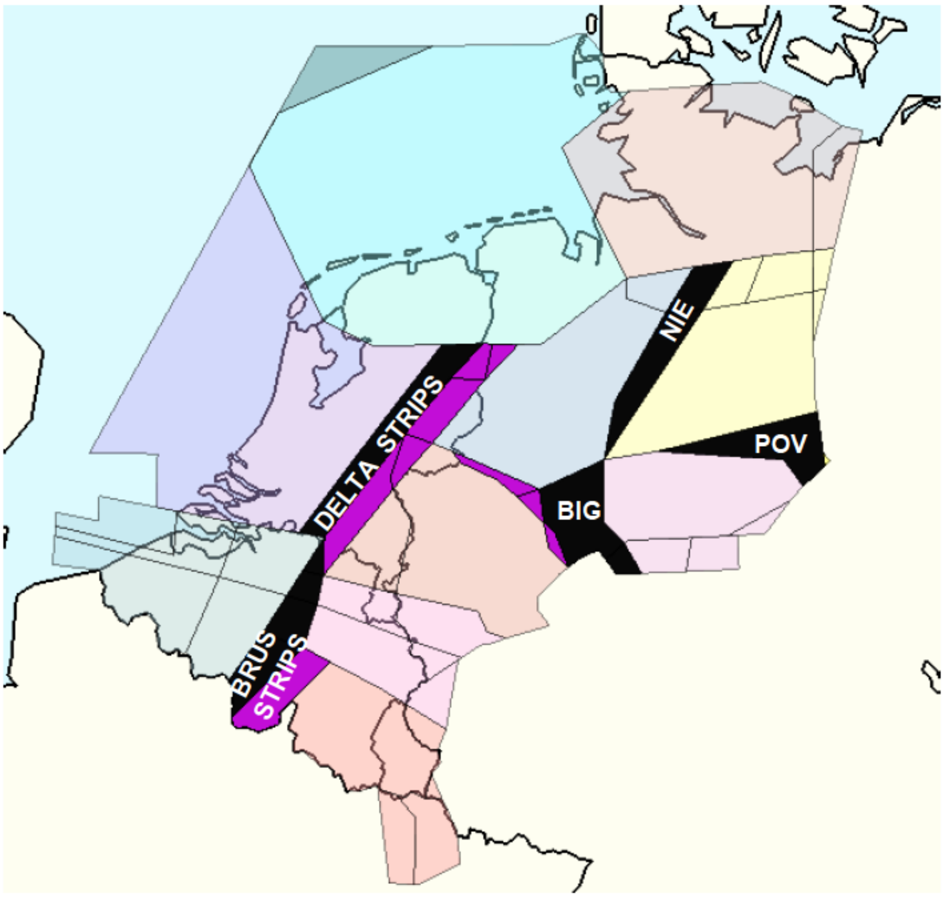


Figure 58: Illustration of dynamic airblock delegation.

BRUS Strips move small volumes between West and East sectors. DELTA Strips move small volumes between DEL and MNS-RHR sectors. SOLLING Drift makes a rotation between current and new sector layouts using bigger airblocks encapsulating own function: BIG and POV; NIE is a strip. POV is also evaluated as stand-alone airblock between CEL and SOL. BIG is also evaluated as stand-alone airblock between SOL and MNS (BIG Valve).

6.5.1.2 Exercise Objectives

The exercise shall contribute to the investigation of objectives listed in Table 51.

Table 51: Demonstration Objectives EXE-0201-D005

Objective ID	Description	KPAs
OBJ-0201-004	Safety of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs do not negatively affect Safety.	Safety
OBJ-0201-005	Capacity related to Cross-Border DCTs It is to be demonstrated that based on a suitable route design the usage of Cross-Border Directs will not negatively affect capacity of the FRAMaK airspace.	Capacity
OBJ-0201-009	Operator Workload related to Cross-Border DCTs It is to be demonstrated that the usage of Cross-Border Directs will not negatively affect operator workload and situational awareness of both ATCOs and crews. Contrariwise, based on a suitable route design a reduction of workload and an increase of situational awareness might be achievable.	Other
OBJ-0201-010	Operational Feasibility of Cross-Border DCTs It is to be demonstrated that Cross-Border Directs provide a sufficient feasibility for operational usage.	Other

6.5.2 Conduct of Exercise

The RTS was conducted from January 14-17, 2014. The planning of the simulation as defined in [3] prepared 5 scenarios that should be repeated each, summing to 10 scenarios spread over 4 days. During the execution, the first 5 scenarios were simulated as planned. Then, the second set of 5 scenarios was completely changed in order to use the new sector layout that resulted from the feedback of the first two days. The last five scenarios applied 2 airspace and 1 traffic iteration.

Table 52: RTS 1 Schedule

Scenarios 1 to 5 were executed as planned, further scenarios were adapted. (* - first airspace iteration, **-second airspace iteration, "-traffic iteration)

	14 Jan 2014	15 Jan 2014	16 Jan 2014	17 Jan 2014
0900 – 1030	Briefing	Sc3	Sc1*	Sc2**"
1045 – 1215	Sc1	Sc4	Sc4*	Sc3**"
1315 – 1445	Sc2	Sc5	Sc5*	De-Briefing

6.5.2.1 Exercise Preparation

Sector shapes and airblocks for the airspace under study was the result of a first high-level design validated by initial Fast Time Simulation, focused on measured sector clipping values. Where deemed feasible, airblocks were designed as possible candidates for swapping between adjacent operational sectors.

Refinement of sector design was introduced from experience with the first runs in Real Time Simulation.

Traffic sample was historical track based trajectories, containing opportunity flights including latest FRAMaK cross-border DCT usage.

RTS participants were duly briefed about the objectives of the simulation, in particular on the process of swapping airblocks between operational sectors.

6.5.2.2 Exercise execution

RTS exercises were executed in traditional sense of quasi, high-fidelity type of sector operations, including all standard ATC system features such as Trajectory Prediction, STCA, ATCO system inputs etc.

Airblock swapping between operational sectors were executed by modified Supervisory functionality available through the Sector Configuration Management HMI.

6.5.2.3 Deviation from the planned activities

No deviation.

6.5.3 Exercise Results

6.5.3.1 Themes Ranking

The following table summarises the findings in qualitative cost-benefit statements, the more stars the better i.e. many blue stars means <u>low</u> investment. The benefit is an absolute comparative and qualitative statement, i.e. DELTA Cut and BRUS COA-CIV have both high impact and therefore higher benefit than the smaller boundary changes.

Table 53: Cost-Benefit, conclusions and recommendations per validation theme.

Airspace	Benefit	Invest	Conclusion	Recommendation
DELTA CUT	★★★★★	★★★☆☆	★★★★★	Implement with J6.1 in 2015-03-05
BRUS CIV-COA	★★★★★	★★☆☆☆	★★★★★	Spin-off own AOM project.
DELTA-BRUS Bound	★★★☆☆	★★★★★	★★★★☆	Airac briefing, conducted in AOM.
JEV Bounds	★★★☆☆	★★★★★	★★★★☆	Airac briefing, conducted in AOM.
BRUS Cosmetics	★★★☆☆	★★★★★	★★★★☆	Airac briefing, conducted in AOM.
RHR-OLN Bound	★★★☆☆	★★☆☆☆	★★★☆☆	Needs fine tuning, merge with CBA/CW efforts.
POV Airblock	★★☆☆☆	★★☆☆☆	★★★☆☆	Postponed, could have capacity benefits.
HOL-MNS/CEL Bound	★★☆☆☆	★★★☆☆	★★☆☆☆	Needs fine tuning, eventual safety hazard. Implement with DELTA CUT.

Airspace	Benefit	Invest	Conclusion	Recommendation
BIG Airblock	★☆☆☆☆	★☆☆☆☆	★☆☆☆☆	Dead, rework area with CBA/CW project.
BRUS Strips	☆☆☆☆☆	★★☆☆☆	☆☆☆☆☆	Dead.
SOL Drift	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	Dead.

6.5.3.2 Weekend or Weekday

Feedback from the de-briefings is that all valid bounds are independent of weekend and are as valid for weekday and MIL-on operations. Only the COA-CIV is an exception because of its narrow corridors, which would not work under certain MIL-on scenarios.

6.5.3.3 Dynamic Airspace

Dynamic airspace applying airblock delegation was trialled in several configurations and locations. Only for the POV airblock some benefit could be evaluated, the other sector layouts had no benefit and hence dynamic airblocks were useless in these cases.

Nonetheless, the concept of dynamic airblock delegation was not rejected, and would lead to the same safety hazards that are already identified for the VDFL projects, and will hence require the same mitigations – maybe to a smaller extend because this concept resembles very much today's sector collapsing and de-collapsing with smaller sized airspaces.

If dynamic airblock delegation is continued, then it requires strong improvements to the Supervisor HMI.

6.5.3.4 Summary of Exercise Results

6.5.3.4.1 Results per KPA

Table 54: Results per KPA EXE-0201-D005

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Safety	OBJ-0201-004	No increase of complexity in Cross-Border DCT operations	No exercise was rejected due to excessive complexity. Design improvements introduced during the RTS improved handling of traffic.
Safety	OBJ-0201-004	No degradation of the perceived level of safety in Cross-Border DCT operations	No exercise was rejected due to perceived loss of safety. Design improvements introduced during the RTS improved safe handling of traffic.
Other - Workload	OBJ-0201-009	No increase in operator workload in Cross-Border DCT operations	No exercise was rejected due to excessive operator workload. Design improvements introduced during the RTS improved workload.

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Other – Operational Feasibility	OBJ-0201-010	No adverse operator feedback regarding Cross-Border DCT operations	No exercise was rejected by ATCOs.

6.5.3.4.2 Results impacting regulation and standardisation initiatives

Airblock swapping between operational sectors affect external interfaces, system-wise such as OLDI and operational such as telephone connection.

In addition, ATC frequency usage becomes non-trivial, and must be managed in a way that ensures that ATCO-Pilot voice communications are never impaired.

6.5.3.4.3 Unexpected Behaviours/Results

Nothing to report; this RTS has been a first exploration of mitigation possibilities against sector clipping issues, which is an expected effect coming from Direct Routing.

The mitigation strategy can be static (reshaping of operational sectors) or dynamic (airblock swapping). Further study is required to achieve at the most effective solutions.

6.5.3.4.4 Quality of Demonstration Results

Limiting the quality of sector design in the preparation phase, and then allowing fine-tuning from experience in the first sets of RTS exercises appeared feasible and valuable; obviously, with RTS being limited in number of variances in traffic samples, reversion to design activity under full FTS support is a required next step.

Airblock swapping was included for initial operational feasibility investigation, as this next step towards dynamic sectorisation was a first encounter without prior proof of concept. The result being that such operational concept is 'workable' is not sufficient for on-line introduction. Clearly, solid business logic was not yet available to also demonstrate the added value of this concept; the supervisory decision to invoke an airblock swap was not yet based on traffic and sector load reasons.

6.5.3.4.5 Significance of Demonstration Results

The RTS has confirmed and further revealed that sector clipping issues are correlated to the level of customer-oriented (cross-border) Direct Routing; where such issues impose unwanted effects or cause unwanted ATCO workload, mitigation can be sought in sector design or dynamic sectorisation concepts.

6.5.4 Conclusions and recommendations

6.5.4.1 Conclusions

The RTS was a first investigation about strategies to mitigate unwanted effects from sector clipping related to (cross-border) Direct Routing.

Sector design and dynamic sectorisation concepts appear promising and feasible strategies, once fully validated and on-line implemented, allowing to focus Free Route design on maximum benefits for Airspace Users without high need to compromise for ATC performance.

6.5.4.2 Recommendations

Sector Clipping effects from (cross-border) DCT and other Free Route applications, should be duly investigated as they may cause operational issues and negatively affect controller workload and thus capacity.

Sector Design and dynamic sectorisation concepts should be investigated as mitigation means.

6.6 Demonstration Exercise EXE-0201-D006 “Cross-Border User Preferred Routes Flight Trial” Report

EXE-0201-D-006 had a focus on the Airline Operator’s option of filing User Preferred Routes within the FRAMaK airspace (FR-CAP-02).

In accordance with the FRAMaK Operational Procedure for Cross-Border User Preferred Routes Demonstrations [4] and the FRAMaK - Cross-Border User Preferred Routes Demonstrations Test Plan [2] Deutsche Lufthansa accomplished 62 UPR Test Flights on six citypairs Frankfurt – Stockholm, Frankfurt – Los Angeles, Frankfurt – Vancouver, and Munich – Manchester, Munich – Oslo, Munich – San Francisco.

The flight trials started in September 2013 and were completed in March 2014. From Dec 2013 an extended UPR Test Area, comprising parts of UK airspace as well as Danish, Norwegian and Swedish airspace could be used for the planning of User Preferred Routes.

For a further detailed description of the exercise please refer to [13].

6.6.1 Exercise Scope

Regarding the geographical scope of this exercise please refer to section 4.1.4.1

6.6.1.1 Exercise Scenario

The underlying demonstration scenario is referred to as SCN-0201-003 “Mixed Mode Operation“ which in return refers to FR-CAP-02 (in coexistence of FR_CAP-01 operations).

Scenario SCN-0201-003 refers to the simultaneous application of both of the aforementioned scenarios, i.e. allowing concurrent filing of FPLs containing Cross-Border DCTs and User Preferred Routes.

For the UPR Flight Plans rules and constraints have been determined in the UPR Test Plan [2] which contains inter alia the following regulations:

Arriving and departing aircrafts should make use of the proposed UPR transition points and transition routes for traffic to/from EDDF and EDDM (see Appendix A, Part I and Part II).

For entering the UPR Test Area from adjacent or subjacent airspace a Test Area entry point listed in Appendix B must be filed in the UPR routing. At the Test Area entry point the aircraft’s altitude must be equal or greater than the minimum flight level applicable in the respective AoR.

For leaving the UPR Test Area towards adjacent or subjacent airspace a Test Area exit point listed in Appendix B must be filed in the UPR routing. At the Test Area exit point towards a subjacent ACC the aircraft’s altitude must be equal or greater than the minimum flight level applicable in the respective AoR.

UPR FPLs may comprise any number of intermediate points which are significant points (c.f. AIP publications ENR 4.4 of EB, ED, EG, EH, EK, EN, ES) or radio navigation aids (c.f. AIP publications ENR 4.1 of EB, ED, EG, EH, EK, EN, ES) in the UPR Test Area (see Appendix C). Flight segments between the Test Area entry point, the intermediate point(s) and the Test Area exit point must be filed as Directs (DCT).

Within the UPR Test Area UPR routings must not affect activated AMC manageable areas.

Outside the UPR Test Area routings shall be compliant to the respective AIP regulations (c.f. AIP publications ENR 1.10).

Flight level changes can be filed at the Test Area entry point and/or the Test Area exit point and/or – if so – any other intermediate point.

In general, the airspace users should apply the Flight Level Orientation System applicable within the UPR Test Area.

If due to this regulation for flights around heading 360° or 180° the required Flight Level would vary frequently between odd and even, the RFL the AO files should be even for northbound flights and odd for southbound flights.

A Flight Plan related to an UPR Flight Trial shall be identified by means of the information "RMK/FRAMAK UPR" in item 18 "Other information" of the FPL.

The following steps were envisaged prior the demonstration activities:

Table 55: UPR Flight Preparation

Step	Content	Time	Owner	Remarks
1.1	Briefing of COS / Supervisors / ATCOs	pre shift	all ANSPs affected	Staff affected by the particular flight (both in UACs and ACCs) is briefed regarding the execution of a flight as an UPR flight trial. ACCs/UACs affected by the UPR Flight Trial: ATCOs are advised not to deviate from the FPL routeing unless necessary for safety or operational (e.g. mil. activity) reasons. Adjacent UACs and ACCs: ATCOs are advised not to deviate from the FPL regarding the routeing beyond the Test Area entry point unless necessary for safety or operational (e.g. mil. activity) reasons.
1.2	Briefing of flight crews are briefed regarding the execution of a flight as an UPR Flight Trial	flight briefing	DLH	Flight crews are briefed regarding the execution of a flight as an UPR Flight Trial. Flight crews are advised not to deviate from the FPL routeing unless necessary for safety reasons.
2	Flight is executed according to FPL	n/a	DLH all ANSPs affected	Flight shall be tactically rerouted and/or vectored for safety or capacity reasons only. During/after flight execution data assessment is accomplished (DLH A/C system data, feedback from dispatch personnel, flight crews, ATCOs).

Coordination between ANSPs affected by an UPR Flight Trial will be accomplished verbally

6.6.1.2 Exercise Objectives

The exercise shall contribute to the investigation of objectives listed in Table 56.

Table 56: Demonstration Objectives EXE-0201-D006

Objective ID	Description	KPAs
OBJ-0201-011	Flight Efficiency of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes making best usage of e.g. wind effects positively affect flight duration and fuel burn	Efficiency
OBJ-0201-012	Environmental Sustainability of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes positively affect CO_2 emission.	Environmental Sustainability
OBJ-0201-013	Safety of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes do not negatively affect Safety.	Safety
OBJ-0201-014	Capacity related to Cross-Border User Preferred Routes It is to be demonstrated that the usage of Cross-Border User Preferred Routes will not negatively affect capacity of the FRAMaK airspace.	Capacity
OBJ-0201-015	Network effects related to Cross-Border User Preferred Routes It is to be demonstrated that the usage of Cross-Border User Preferred Routes will not negatively affect capacity demand in the adjacent centres/sectors serving the connecting ATS routes.	Capacity
OBJ-0201-016	Operator Workload related to Cross-Border User Preferred Routes It is to be demonstrated that the usage of Cross-Border User Preferred Routes will not negatively affect operator workload and situational awareness of both ATCOs and crews.	Other
OBJ-0201-017	Operational Feasibility of Cross-Border User Preferred Routes It is to be demonstrated that Cross-Border User Preferred Routes provide a sufficient feasibility for operational usage.	Other
OBJ-0201-018	Interference of simultaneous FRA operations It is to be demonstrated that simultaneous execution of FPLs comprising of Cross-Border DCTs and User Preferred Routes (dual mode operations) does not jeopardize positive effects demonstrated in single mode operation and has no negative impact on Capacity.	Efficiency Environmental Sustainability Capacity Other

6.6.2 Conduct of Exercise

6.6.2.1 Exercise Preparation

6.6.2.1.1 Date and time of Flight Trials

Initially, UPR Flight Trials took place on weekends only.

The usage of the NATS Scottish UIR airspace for UPR Flight Trials on transatlantic routes was limited to weekend only.

In general, UPR Flight Trials within Europe and departing to USA and Canada, have comprised flights with STD not before 0900 UTC.

The UPR Flight Trials within a month has been announced at least 7 days prior to each month by means of a monthly schedule. The schedule was sent by DLH to all affected parties.

6.6.2.1.2 Number of flights

In general, a maximum of 3 flights (legs) per day were foreseen to be accomplished. In August and September there was a maximum of one flight per day.

6.6.2.1.3 FPL Planning and Verification

For the planning and verification of FPLs for UPR Flight Trials an operational procedure agreed between the FRAMaK project partners (Deutsche Lufthansa, DFS Deutsche Flugsicherung, and Eurocontrol Maastricht UAC), the associated partners Avinor, Luftfartsverket (LFV), National Air Traffic Services (NATS), and Naviair, and Eurocontrol IFPS [4] was effective.

For Flight Plans related to UPR Flight Trials foreseen in the context of the FRAMaK project the following regulations were effective:

I. FPLs submitted by Deutsche Lufthansa which are identified by the information “RMK/FRAMAK UPR” in item 18 of the FPL are to be considered as FPLs for UPR Flight Trials according to this operational procedure.

II. By notifying the AO about the acceptance of the draft FPL the ANSP affected by the UPR Flight Trial accepts the responsibility that within the AoR of the respective ANSP and with regard to coordination with adjacent/subjacent ACCs/UACs the FPL submitted by the AO is in accordance with the regulations described in FRAMaK - Cross-Border User Preferred Routes Demonstrations - Test Plan [2], section 3.

III. For FPLs which have been accepted by the ANSP affected by the UPR Flight Trial IFPS will ignore error messages arising from route errors associated to those route segments within the AoRs of the respective ANSP and with regard to the connections from/towards adjacent/subjacent ACCs/UACs.

Based on the FRAMaK WP6 FR-CAP-02 Test Plan [2], Appendices A-C, the Deutsche Lufthansa dispatch support created User Preferred Routes and stored them as Lufthansa Company Routes in Lido/Flight to facilitate the calculation of the UPRs for the test flights. Most of the NAT entry/exit points have been connected to EDDF and EDDM via UPRs, some of them with 2 or 3 UPR. The intention was to offer a broad optimization area for the test flights to/from KLAX, KSFO and CYVR. For the flights to/from ENGM, ESSA and EGCC have been created between 1 and 4 UPRs for each city pair. In total Lufthansa created 103 UPRs. NOTAMs and Restricted Airspaces have been considered. Reason why Company Routes were developed was that the LIDO Free Flight module could not optimize the routes just using waypoints (cost optimization). LIDO Free Flight module was also unable to handle the restrictions which apply to the FRAMaK FR-CAP-02 demonstrations (flight planning in accordance with compulsory transition routes etc.).

Dispatcher started to create the flightplans of FRAMaK flights as usual. Fuel- and time optimization of a certain routing taking notams and restrictions into account was the base to create a legal flightplan.

The entry waypoints into upper airspace of participating FIRs would lead to a first try to adjoin one of the UPR-Routings. For some entry points there were sometimes more than one UPR-Predictions offered in the flightplanning tool. A flight plan was created accordingly with UPRs. If it turned out that a routing with UPRs was best – means the fastest and the lowest costs, following the FRAMaK Operational Procedure for Cross-Border UPR Demonstrations the dispatcher sent the ATC flight plan to all concerned ANSPs. Afterwards dispatcher calls all supervisors of the ANSPs in charge and asks for acknowledgement of the flight plan. After a while it wouldn't be necessary to call anymore, all involved supervisors would send an acknowledgement via email right away – of course only if they accepted the flight plan. In case a routing would not go through any participating airspaces an email to all ANSP would be send to de-register the flight(s).

6.6.2.1.4 ATCO Questionnaires

For the assessment of operator feedback regarding safety, workload and operational feasibility a questionnaire has been developed which was provided to all ATCOs affected by an UPR Flight prior to its execution (see [13]).

6.6.2.2 Exercise execution

Since 14 SEP 2013 Lufthansa accomplished UPR Flight Trials. In initial eight flights the focus has been on testing of procedures with regard to FPL planning, approval and official filing.

From 26 OCT 2013 until 23 MAR 2014 the following 62 UPR flights have been successfully executed and – despite of 1 case with missing information - data have been collected and analysed (Table 57). For some transatlantic routings corresponding charts have been added to provide a better overview.

Table 57: List of UPR Flight demonstrations

Date	Citypair	LH Flight No	Callsign	User Preferred Routing
26 OKT 2013	EDDM-ENGM	LH2454	DLH6CN	EDDM INPUD1S INPUD Y102 UPALA UM726 LASGA FF_DCT KUMER FF_DCT TUGDU FF_DCT AMSEV P602 PIPEX M609 RIPAM ENGM
27 OKT 2013	EDDM-ENGM	LH2454	DLH6CN	EDDM INPUD1S INPUD Y102 UPALA UM726 LASGA FF_DCT UNGEM UZ711 BAMOR FF_DCT SABAK L997 LUNIP ENGM
02 NOV 2013	ENGM-EDDM	LH2451	DLH5PF	ENGM TOR P615 ARTOR FF_DCT LOMPU T504 MIC FF_DCT ALOSO T703 LULAR T105 EXUSI EXUSI1A EDDM
02 NOV 2013	EDDM-ENGM	LH2454	DLH6CN	EDDM INPUD1S INPUD Y102 UPALA UM726 LASGA FF_DCT UNGEM UZ711 BAMOR FF_DCT SABAK L997 LUNIP ENGM
03 NOV 2013	ENGM-EDDM	LH2451	DLH5PF	ENGM TOR P615 ALASA UM852 BIBNU DCT ABGUS FF_DCT ALOSO T703 LULAR T105 EXUSI EXUSI1A EDDM
03 NOV 2013	EDDM-ENGM	LH2454	DLH6CN	EDDM INPUD1S INPUD Y102 UPALA UM726 LASGA FF_DCT UNGEM UZ711 BAMOR FF_DCT SABAK L997 LUNIP ENGM
09 NOV 2013	ESSA-EDDF	LH803	DLH803	ESSA NOSLI N850 BAGOS UN850 MIC T155 ALOSI T157 KERAX KERAX1L EDDF
16 NOV 2013	ENGM-EDDM	LH2455	DLH5XY	ENGM OKSAT L996 KELIN FF_DCT SALLO DCT MAREM UT106 VESUB T106 BAGMI BAGMI2A EDDM
16 NOV 2013	EDDM-ENGM	LH2456	DLH9TX	EDDM INPUD1S INPUD Y102 UPALA UM726 LASGA FF_DCT LARET FF_DCT TUGDU UM852 ALASA FF_DCT NERDO T600 PIPEX M609 RIPAM ENGM

Date	Citypair	LH Flight No	Callsign	User Preferred Routing
21 NOV 2013	EDDM-KSFO	LH458	DLH458	EDDM/08L N0471F280 INPUD1Q INPUD Y102 UPALA Z109 BAMKI DCT KUMER DCT KUGAL/N0479F300 DCT KARLI/N0480F320 DCT GUNPA/M083F360
23 NOV 2013	KSFO-EDDM	LH459	DLH459	GUNPA/F370 DCT KARLI DCT AMADA DCT ARTER DCT BOMBI T104 ANORA ANORA1A EDDM/08L
23 NOV 2013	EDDM-ENGM	LH2456	DLH9TX	EDDM INPUD1S INPUD Y102 UPALA UM726 LASGA FF_DCT UNGEM UZ711 BAMOR FF_DCT SABAK L997 LUNIP ENGM
23 NOV 2013	ENGM-EDDM	LH2455	DLH5XY	ENGM TOR P615 ARTOR FF_DCT LOMPU T504 MIC FF_DCT ALOSO T703 LULAR T105 EXUSI EXUSI1A EDDM
14 DEZ 2013	EGCC-EDDM	LH2503	DLH6KA	EGCC DESIG1Z DESIG UL603 MAMUL FF_DCT SOMVA FF_DCT TINIK FF_DCT BOMBI T104 ANORA ANORA1A EDDM
19 DEZ 2013	ESSA-EDDF	LH803	DLH803	ESSA NOSLI N850 ABAMA FF_DCT KOSEB FF_DCT HLZ T157 KERAX KERAX1L EDDF
22 DEZ 2013	EDDM-EGCC	LH2502	DLH8FW	EDDM GIVMI5W GIVMI Y101 OSBIT UL984 LOHRE FF_DCT AKUXO FF_DCT SASKI FF_DCT LESTA DAYNE1B EGCC
23 DEZ 2013	ENGM-EDDM	LH2451	DLH5PF	ENGM TOR P615 ARTOR FF_DCT LOMPU T504 MIC FF_DCT ALOSO T703 LULAR T105 EXUSI EXUSI1A EDDM
23 DEZ 2013	EDDM-ENGM	LH2454	DLH6CN	EDDM INPUD1S INPUD Y102 UPALA UM726 LASGA FF_DCT UNGEM UZ711 BAMOR FF_DCT SABAK L997 LUNIP ENGM
04 JAN 2014	EDDF-KLAX	LH456	DLH456	EDDF/25C F240 MARUN2M MARUN Y152 ARPEG/F320 Z850 ABILU DCT MAXUN/F310 DCT INBOB/F320 DCT KLONN DCT GUNPA/F320
11 JAN 2014	EDDF-KLAX	LH456	DLH456	EDDF/25C F240 MARUN2M MARUN Y152 ARPEG/F340 Z850 ABILU DCT MAXUN DCT INBOB DCT KLONN DCT GUNPA/F360
11 JAN 2014	CYVR-EDDF	LH493	DLH493	GONUT/F350 DCT CUTEL UL7 LONAM DCT DIXAT T149 LIPMI T150 ROLIS ROLIS1L EDDF/25R
16 JAN 2014	EDDF-ESSA	LH802	DLH1VV	EDDF MARUN3F MARUN Y150 TOLGI FF_DCT SONAL FF_DCT IDPAL FF_DCT MIKNA N851 PELUP Z226 NILUG NILUG1P ESSA
16 JAN 2014	ESSA-EDDF	LH803	DLH803	ESSA NOSLI N850 ABAMA FF_DCT KOSEB FF_DCT HLZ T157 KERAX KERAX1L EDDF
16 JAN 2014	EDDM-ENGM	LH2454	DLH6CN	EDDM INPUD1S INPUD Y102 UPALA UM726 LASGA FF_DCT GITER FF_DCT SABAK L997 LUNIP ENGM
18 JAN 2014	EDDF-CYVR	LH 492	DLH 492	EDDF/25C F240 MARUN2M MARUN Y152 ARPEG/F340 Z850 ABILU DCT MAXUN DCT INBOB DCT KLONN DCT GUNPA/F360
18 JAN 2014	EDDM-EGCC	LH2502	DLH8FW	EDDM GIVMI5W GIVMI Y101 OSBIT UL984 LOHRE FF_DCT AKUXO FF_DCT SASKI FF_DCT LESTA DAYNE1B EGCC
19 JAN 2014	EGCC-EDDM	LH2503	DLH6KA	EGCC DESIG1Z DESIG UL603 MAMUL FF_DCT SOMVA FF_DCT TINIK FF_DCT BOMBI T104 ANORA ANORA1A EDDM
19 JAN 2014	EDDM-EGCC	LH2504	DLH8VC	EDDM GIVMI5W GIVMI Y101 OSBIT UL984 LOHRE FF_DCT AKUXO FF_DCT SASKI FF_DCT LESTA DAYNE1B EGCC

Date	Citypair	LH Flight No	Callsign	User Preferred Routing
20 JAN 2014	ENGM-EDDM	LH2455	DLH5XY	ENGM TOR P615 ARTOR FF_DCT GITER FF_DCT MIC FF_DCT ALOSO T703 LULAR T105 EXUSI EXUSI1A EDDM
21 JAN 2014	ENGM-EDDM	LH2455	DLH5XY	ENGM TOR P615 ARTOR FF_DCT GITER FF_DCT MIC FF_DCT ALOSO T703 LULAR T105 EXUSI EXUSI1A EDDM
26 JAN 2014	EDDF-CYVR	LH492	DLH492	EDDF/25C F260 BIBTI2M BIBTI UZ28 DIBIR/F360 DCT LONAM DCT GIGUL DCT GONUT/F360
26 JAN 2014	EDDM-KSFO	LH458	DLH458	EDDM INPUD1N INPUD Y102 UPALA Z109 BAMAS UL604 ALIBU DCT KEMAD DCT SUTEB DCT LESRA DCT GONUT
08 FEB 2014	EDDF-CYVR	LH492	DLH492	EDDF MARUN Y152 ARPEG Z850 ABILU DCT MAXUN DCT INBOB DCT KLONN DCT GUNPA
08 FEB 2014	CYVR-EDDF	LH493	DLH493	BALIX DCT MADAD DCT TOPPA DCT DIXAT T149 LIPMI T150 ROLIS ROLIS1M EDDF
11 FEB 2014	EDDF-ESSA	LH802	DLH1VV	EDDF MARUN2M MARUN Y150 TOLGI DCT KOSEB DCT INPAL DCT MIKNA N851 PELUP Z226 NILUG NILUG1N ESSA
11 FEB 2014	ESSA-EDDF	LH803	DLH803	ESSA NOSLI N850 ABAMA FF_DCT KOSEB FF_DCT HLZ T157 KERAX KERAX1L EDDF
12 FEB 2014	EDDM-ENGM	LH2454	DLH6CN	EDDM/26R F380 INPUD1N INPUD Y102 UPALA UM726 LASGA/F390 DCT UNGEM/F380 UZ711 BAMOR DCT SABAK L997 LUNIP ENGM/19L
13 FEB 2014	EDDM-ENGM	LH2454	DLH6CN	EDDM/08L F380 INPUD1Q INPUD Y102 UPALA UM726 LASGA/F390 DCT BERIM DCT PIXID/F370 DCT SABAK/F380 L997 LUNIP ENGM/19L
15 FEB 2014	KSFO-EDDM	LH459	DLH459	60N015W DCT BALIX/F390 DCT MADAD DCT TOPPA DCT NYKER DCT BOMBI T104 ANORA ANORA2A EDDM/26R
15 FEB 2014	EDDF-CYVR	LH492	DLH492	EDDF/25C F240 MARUN2M MARUN Y152 ARPEG/F340 Z850 ABILU DCT MAXUN DCT INBOB DCT KLONN DCT GUNPA/F340
16 FEB 2014	KSFO-EDDM	LH459	DLH459	BALIX/F390 DCT MADAD DCT TOPPA DCT NYKER DCT BOMBI T104 ANORA ANORA2A EDDM/26R
17 FEB 2014	EDDF-ESSA	LH802	DLH1VV	MARUN Y150 TOLGI DCT SALLO DCT VIBAR Z227 NILUG
17 FEB 2014	ESSA-EDDF	LH803	DLH803	ESSA NOSLI N850 ABAMA FF_DCT KOSEB FF_DCT HLZ T157 KERAX KERAX1L EDDF
18 FEB 2014	ESSA-EDDF	LH803	DLH803	ESSA NOSLI N850 ABAMA FF_DCT KOSEB FF_DCT HLZ T157 KERAX KERAX1L EDDF
22 FEB 2014	CYVR-EDDF	LH 493	DLH493	GUNPA/F370 DCT KARLI DCT GREFI DCT COL T150 ROLIS ROLIS1B EDDF/25L
22 FEB 2014	EDDF-CYVR	LH 492	DLH492	EDDF/25C F240 MARUN2M MARUN Y152 ARPEG/F300 Z850 ABILU DCT MAXUN/F310 DCT INBOB/F320 DCT KLONN DCT GUNPA/F340
28 FEB 2014	ESSA-EDDF	LH803	DLH803	ESSA NOSLI N850 ABAMA FF_DCT KOSEB FF_DCT HLZ T157 KERAX KERAX1L EDDF
01 MAR 2014	EDDF.KLAX	LH 456	DLH 456	EDDF MARUN Y152 ARPEG Z850 ABILU DCT MAXUN DCT INBOB DCT KLONN DCT GUNPA

Date	Citypair	LH Flight No	Callsign	User Preferred Routing
02 MAR 2014	EDDM-EGCC	LH 2502	DLH8FW	EDDM/26R F360 GIVMI5W GIVMI Y101 OSBIT UL984 LOHRE DCT AKUXO DCT SASKI DCT LESTA DAYNE1B EGCC/23R
03 MAR 2014	ENGM-EDDM	LH2455	DLH5XY	ENGM/01L F380 TOR P615 ARTOR/F390 DCT GITER DCT MIC DCT ALOSO T703 LULAR/F380 T105 EXUSI EXUSI2A EDDM/26R
03 MAR 2014	ESSA-EDDF	LH 805	DLH805	ESSA NOSLI N850 ABAMA FF_DCT KOSEB FF_DCT HLZ T157 KERAX KERAX1L EDDF
04 MAR 2014	ESSA-EDDF	LH 805	DLH805	ESSA NOSLI N850 ABAMA FF_DCT KOSEB FF_DCT HLZ T157 KERAX KERAX1L EDDF
07 MAR 2014	CYVR-EDDF	LH 493	DLH493	GUNPA/F390 DCT LAMRO DCT VALBO DCT DIXAT T149 LIPMI T150 ROLIS ROLIS1M EDDF/07L
08 MAR 2014	EDDF-KLAX	LH 456	DLH456	EDDF BIBTI UZ28 DIBIR DCT GODOS DCT MADAD DCT BALIX
11 MAR 2014	EDDM-ENGM	LH 2454	DLH6CN	EDDM/08L F360 INPUD1Q INPUD Y102 UPALA UM726 LASGA/F370 DCT BERIM DCT PIXID DCT SABAK/F360 L997 LUNIP ENGM/01R
14 MAR 2014	CYVR-EDDF	LH 493	DLH493	OLKER DCT AKAM DCT VALAM DCT DIXAT T149 LIPMI T150 ROLIS
21 MAR 2014	CYVR-EDDF	LH 493	DLH493	ERAKA DCT NEPSO DCT GODOS DCT DIXAT T149 LIPMI T150 ROLIS
22 MAR 2014	CYVR-EDDF	LH 493	DLH493	GUNPA/F370 DCT KARLI DCT GREFI DCT COL T150 ROLIS ROLIS1B EDDF/25L
22 MAR 2014	EGCC-EDDM	LH2501	DLH3NC	EGCC/23R F390 DESIG1R DESIG UL603 MAMUL DCT SOMVA DCT TINIK DCT BOMBI T104 ANORA ANORA2A EDDM/26R
22 MAR 2014	EDDM-EGCC	LH 2502	DLH8FW	EDDM GIVMI5W GIVMI Y101 OSBIT UL984 LOHRE FF_DCT AKUXO FF_DCT SASKI FF_DCT LESTA DAYNE1B EGCC
23 MAR 2014	EGCC-EDDM	LH2501	DLH3NC	EGCC/23R F390 DESIG1R DESIG UL603 MAMUL DCT SOMVA DCT TINIK DCT BOMBI T104 ANORA ANORA2A EDDM/26R
23 MAR 2014	EDDM-EGCC	LH 2502	DLH8FW	EDDM INPUD1N INPUD Y102 ALIBU FF_DCT TORNU FF_DCT SASKI FF_DCT LESTA DAYNE1B EGCC

6.6.2.2.1 Deviation from the planned activities

Deviation 12: Incompatibility of UPR Routing with the North Atlantic Track System

As the long range flights were dependent on the North Atlantic Track System on several occasions with southerly routings, flights which have been planned in the monthly schedule could not participate in the Trial as they did not cross the reserved airspace anymore.

Deviation 13: Technical Limitations regarding automatic Flight Planning

As UPR flights could not be planned by the LIDO system automatically some flights had to be cancelled due to the lack of manpower within DLH dispatch. This was for example the case during days of industrial action in European countries.

6.6.3 Exercise Results

6.6.3.1 UPR Routings

In the following User Preferred Routings are depicted which have been elaborated by Lufthansa and executed in UPR Flight Trials.

Red lines do represent the last filed FPL while green lines represent the actual flown track. Usually – as flight crews and ATCOs were advised not to deviate from the FPL routing if not necessary e.g. for safety reasons – red and green lines are almost identical. Deviations – if any – were observed mainly near the departure and/or destination airports.

RAD-conform FPL routings for the respective citypair are depicted in the figures below with blue lines. Depending on runways-in-use for some relations multiple RAD-conform FPL routings have been identified.

Note: Radar tracks outside ECAC area are not valid. Therefore, deviation between FPL route and tracks, e.g. as shown at BALIX and GUNPA (north of UK) in Figure 59, are not to be considered outside ECAC.

6.6.3.1.1 Citypair Frankfurt - Los Angeles

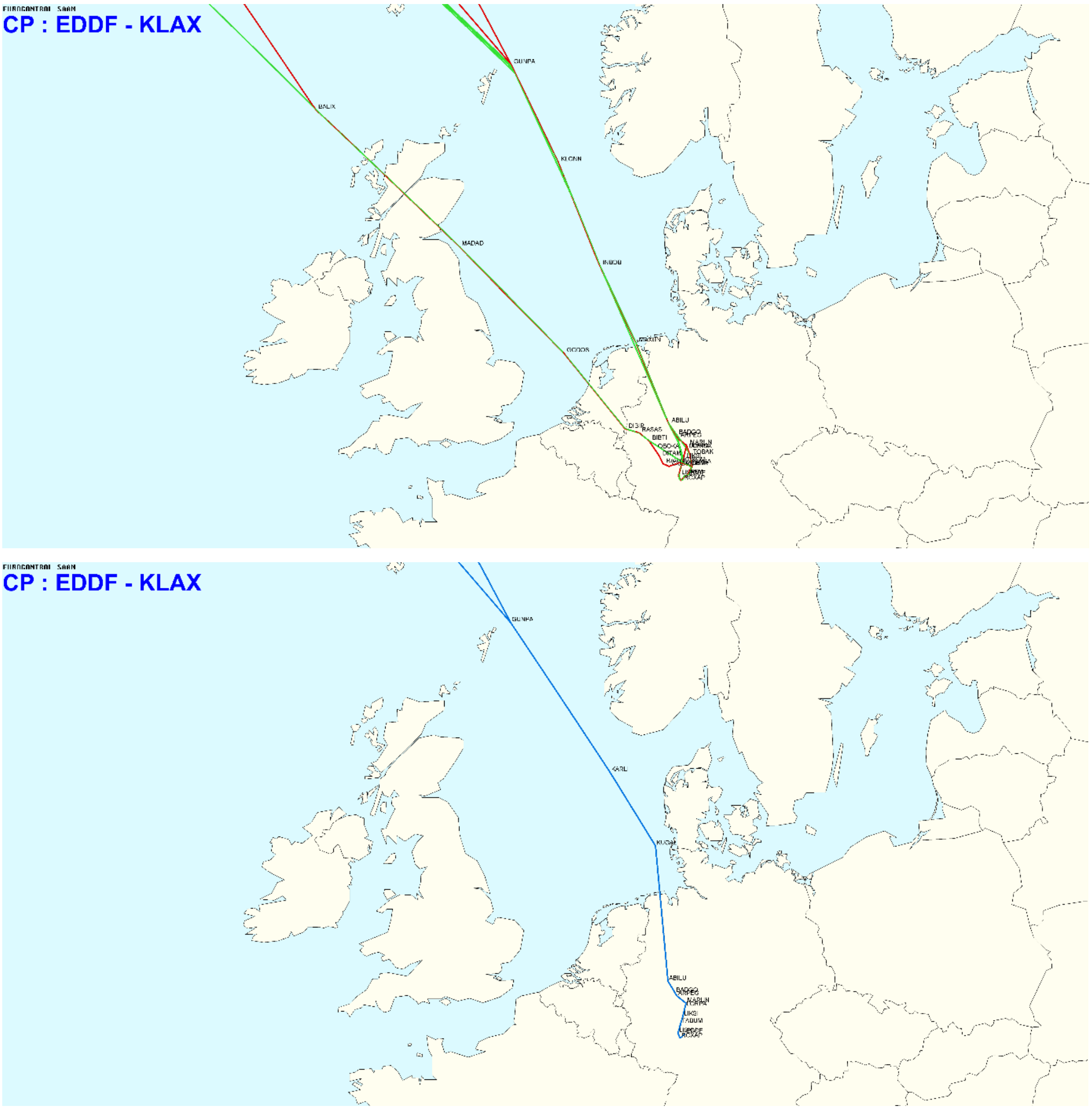


Figure 59: User Preferred Routings EDDF – KLAX (top) and respective RAD-conform routings (below)

Note: Return flights KLAX – EDDF made use of westerly routings not affecting the FRAMaK UPR Test Area.

6.6.3.1.2 Citypair Frankfurt - Stockholm

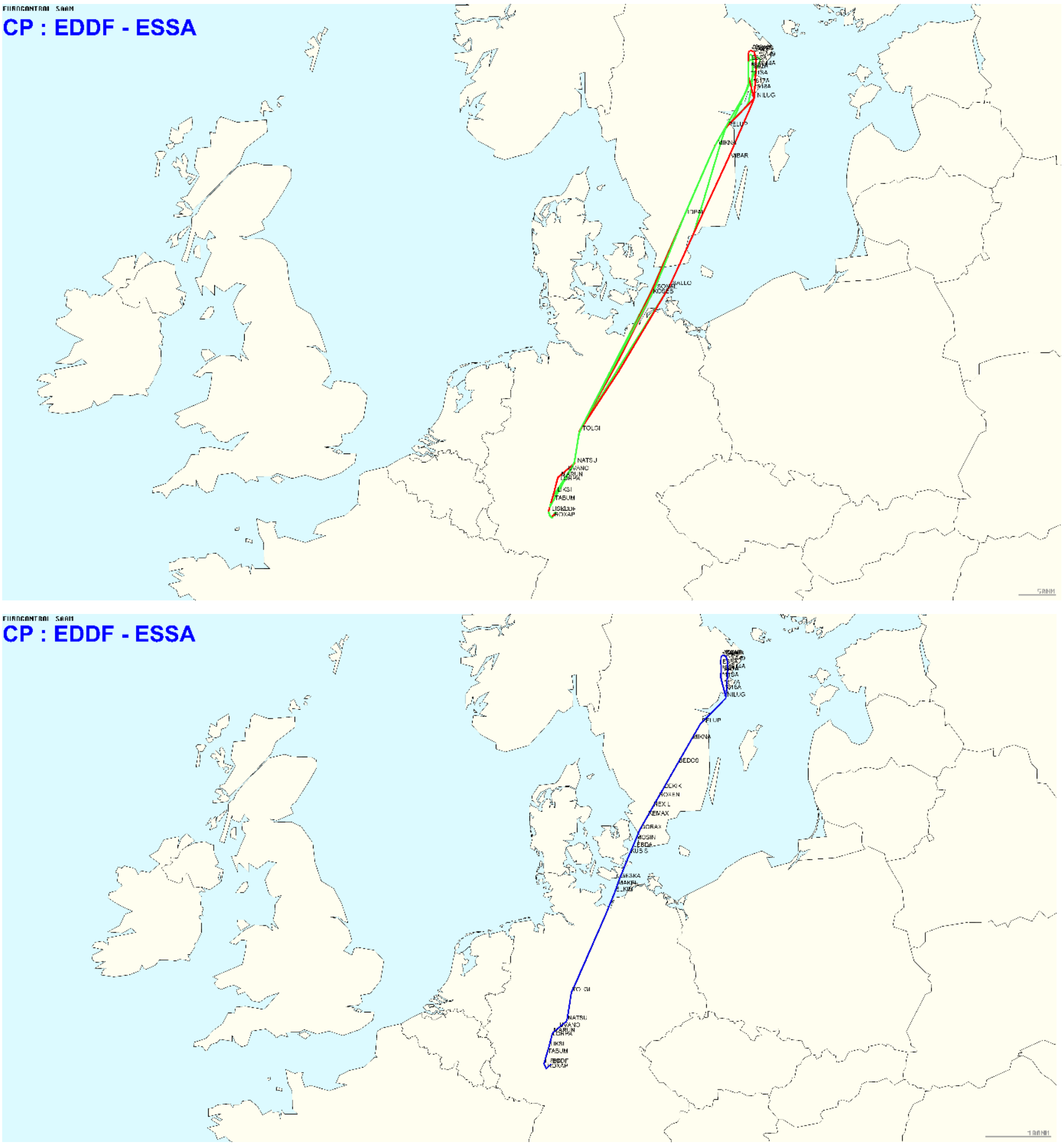


Figure 60: User Preferred Routings EDDF – ESSA (top) and respective RAD-conform routings (below)

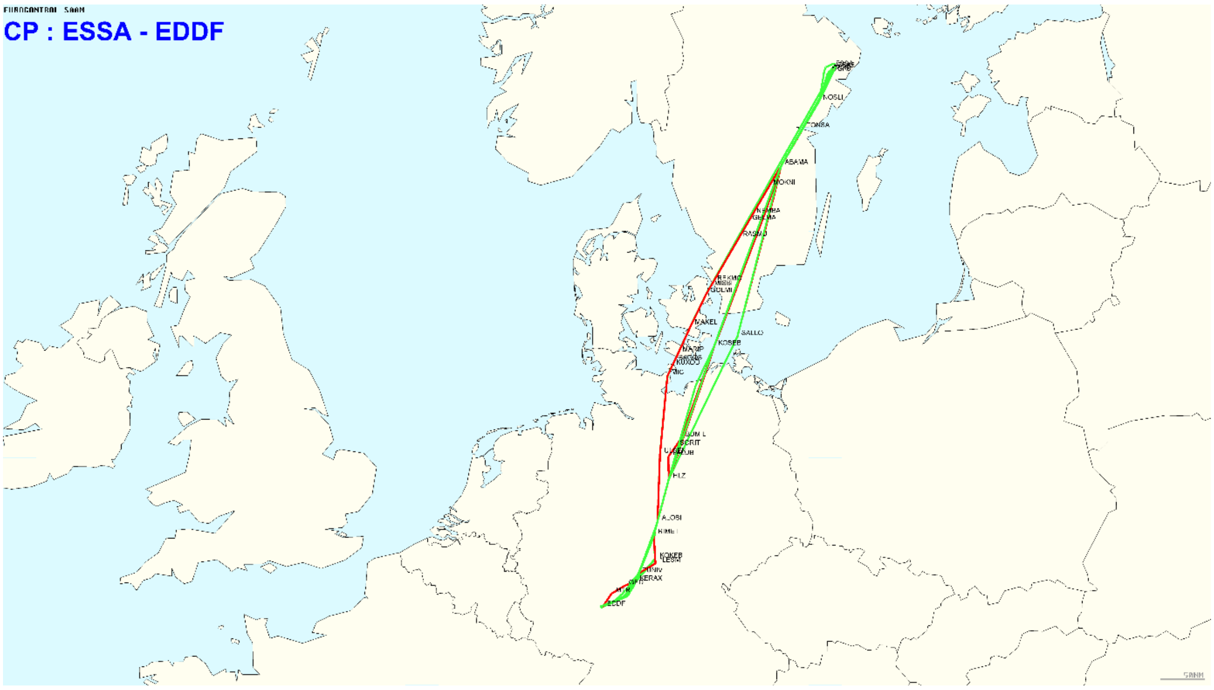


Figure 61: User Preferred Routings ESSA – EDDF (top) and respective RAD-conform routings (below)

6.6.3.1.3 Citypair Frankfurt - Vancouver

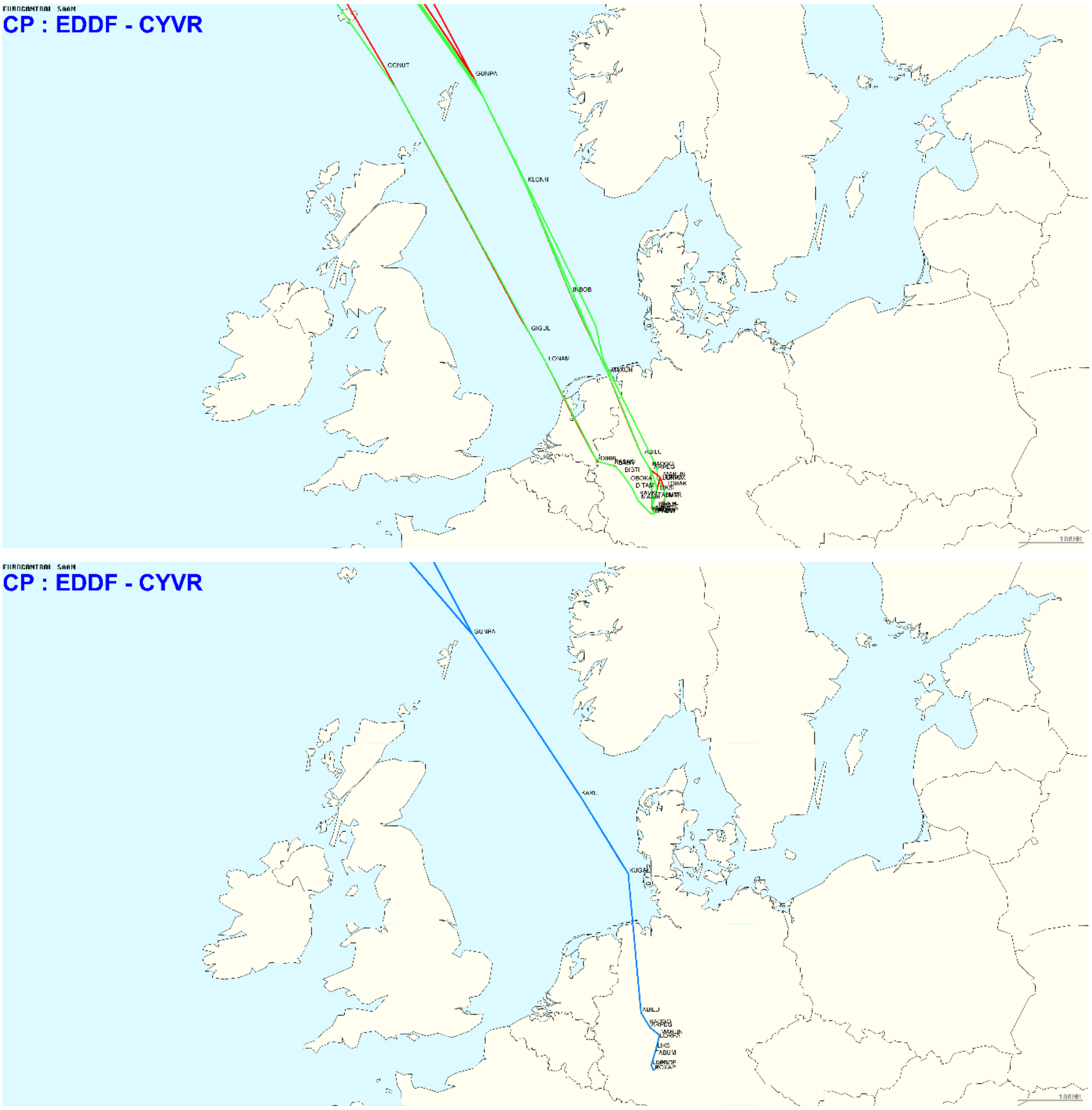


Figure 62: User Preferred Routings EDDF - CYVR (top) and respective RAD-conform routings (below)

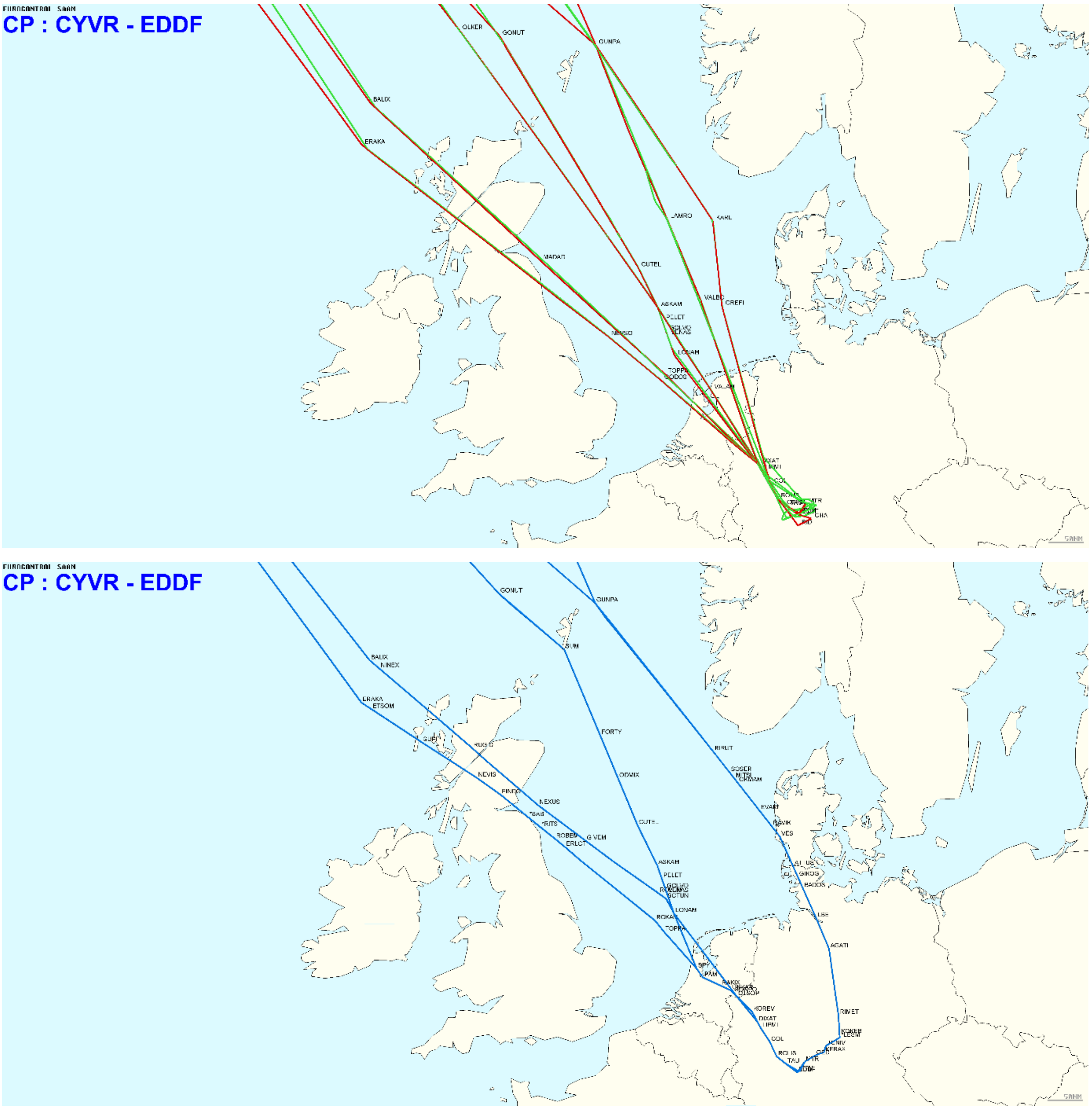


Figure 63: User Preferred Routings CYVR – EDDF (top) and respective RAD-conform routings (below)

6.6.3.1.4 Citypair Munich - Manchester

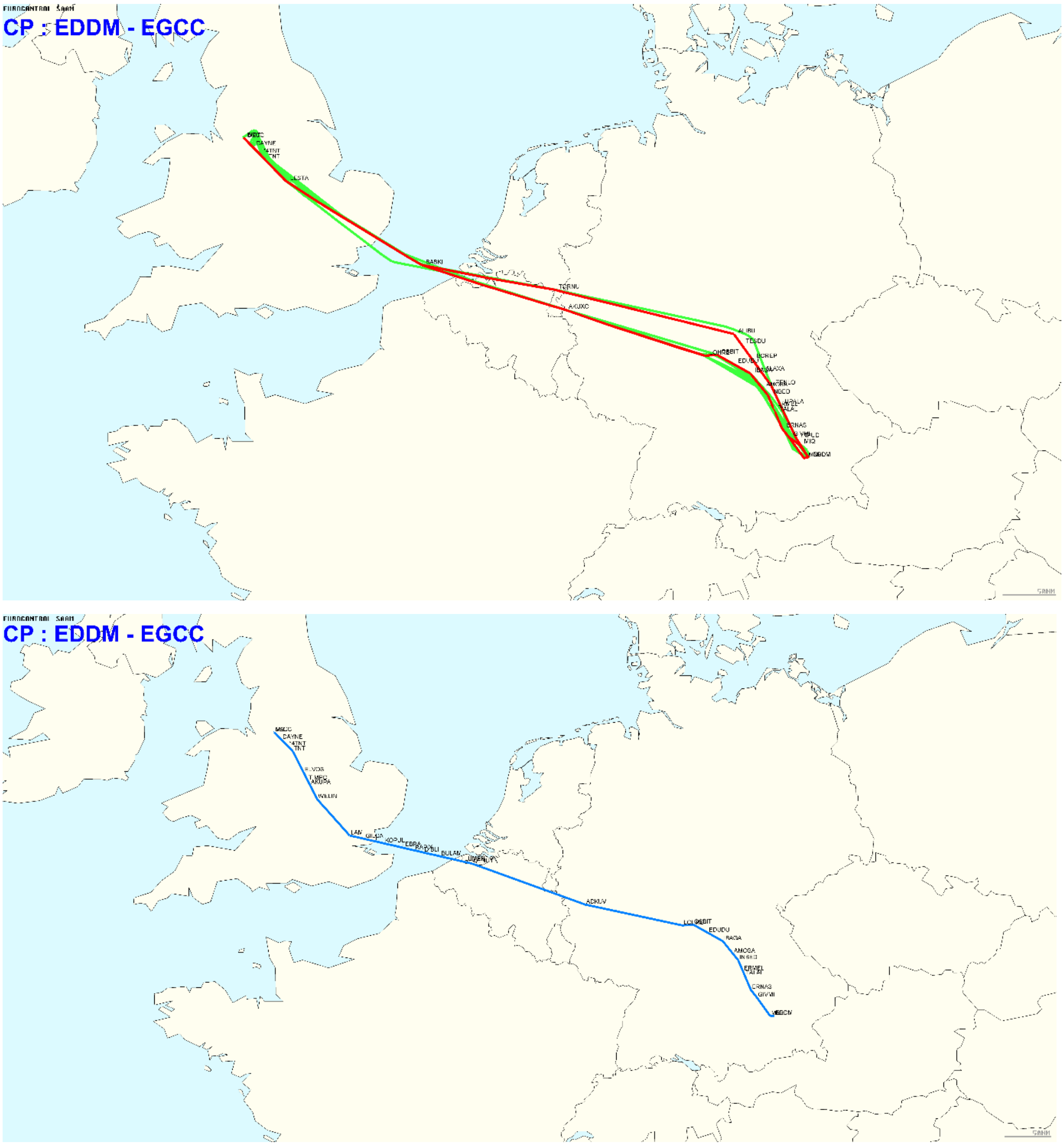


Figure 64: User Preferred Routings EDDM – EGCC (top) and respective RAD-conform routings (below)

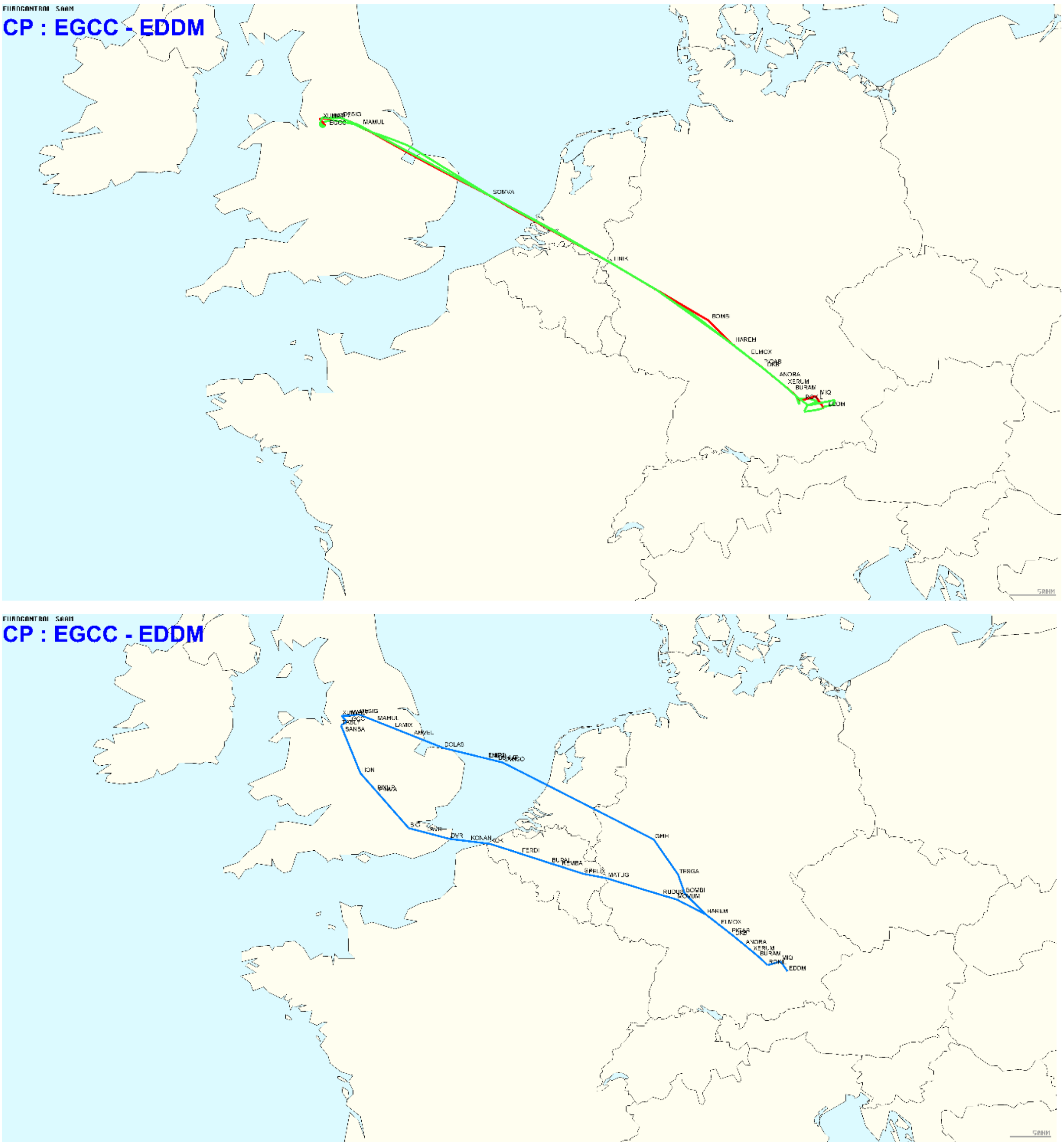
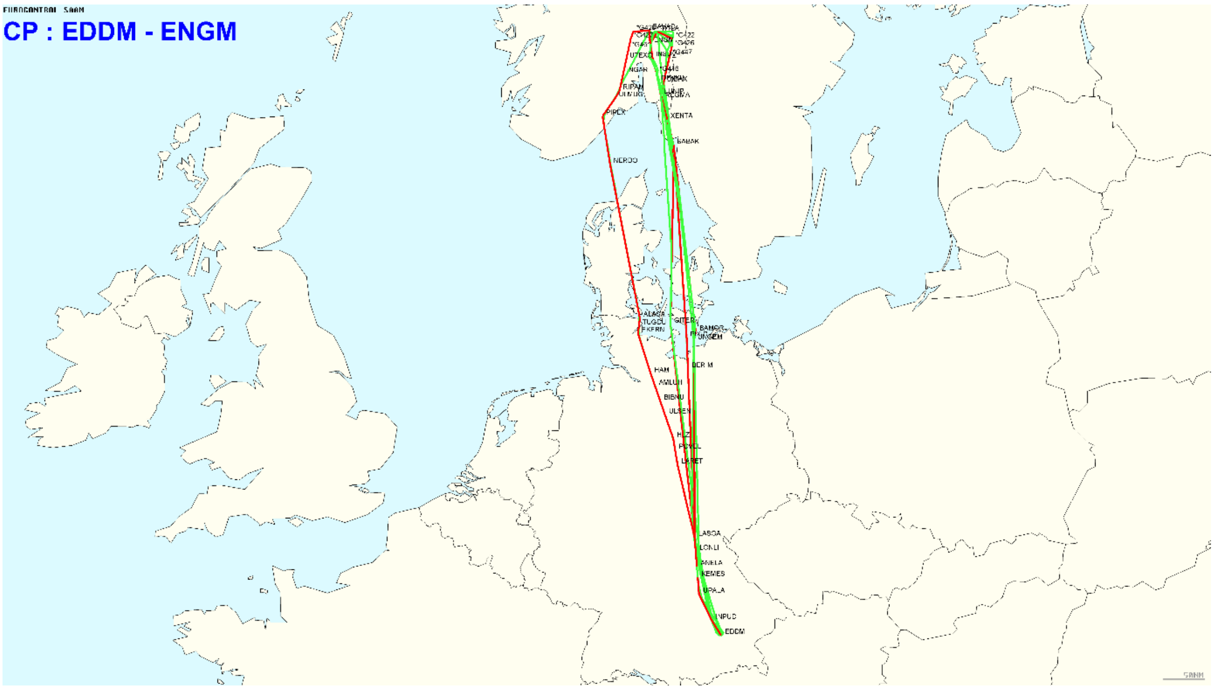


Figure 65: User Preferred Routings EGCC – EDDM (top) and respective RAD-conform routings (below)

6.6.3.1.5 Citypair Munich - Oslo



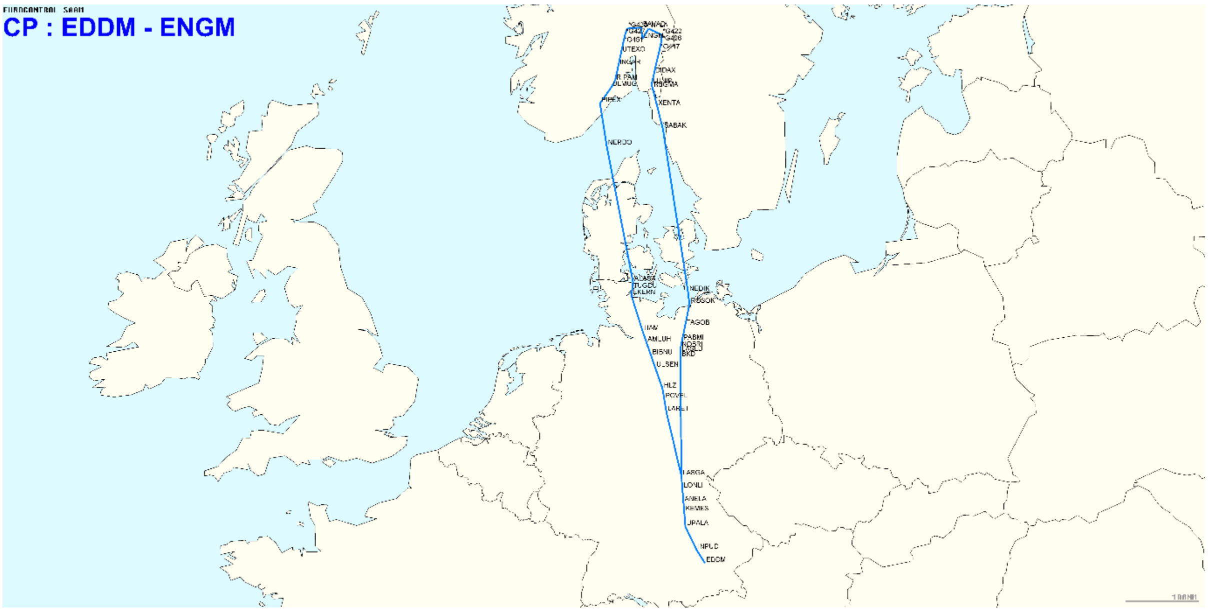


Figure 66: User Preferred Routings EDDM – ENGM (top) and respective RAD-conform routings (below)

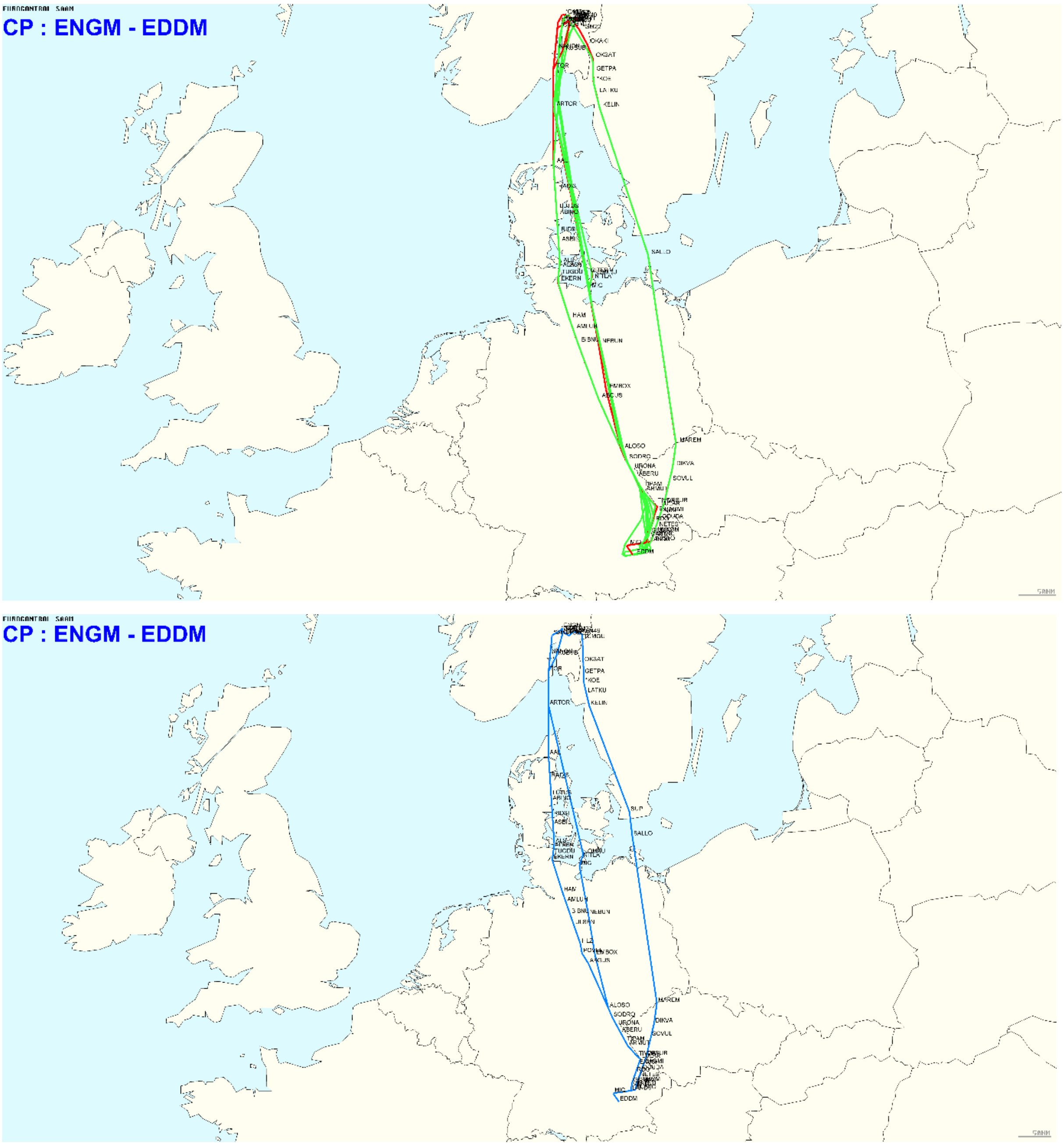


Figure 67: User Preferred Routings ENGM – EDDM (top) and respective RAD-conform routings (below)

6.6.3.1.6 Citypair Munich - San Francisco

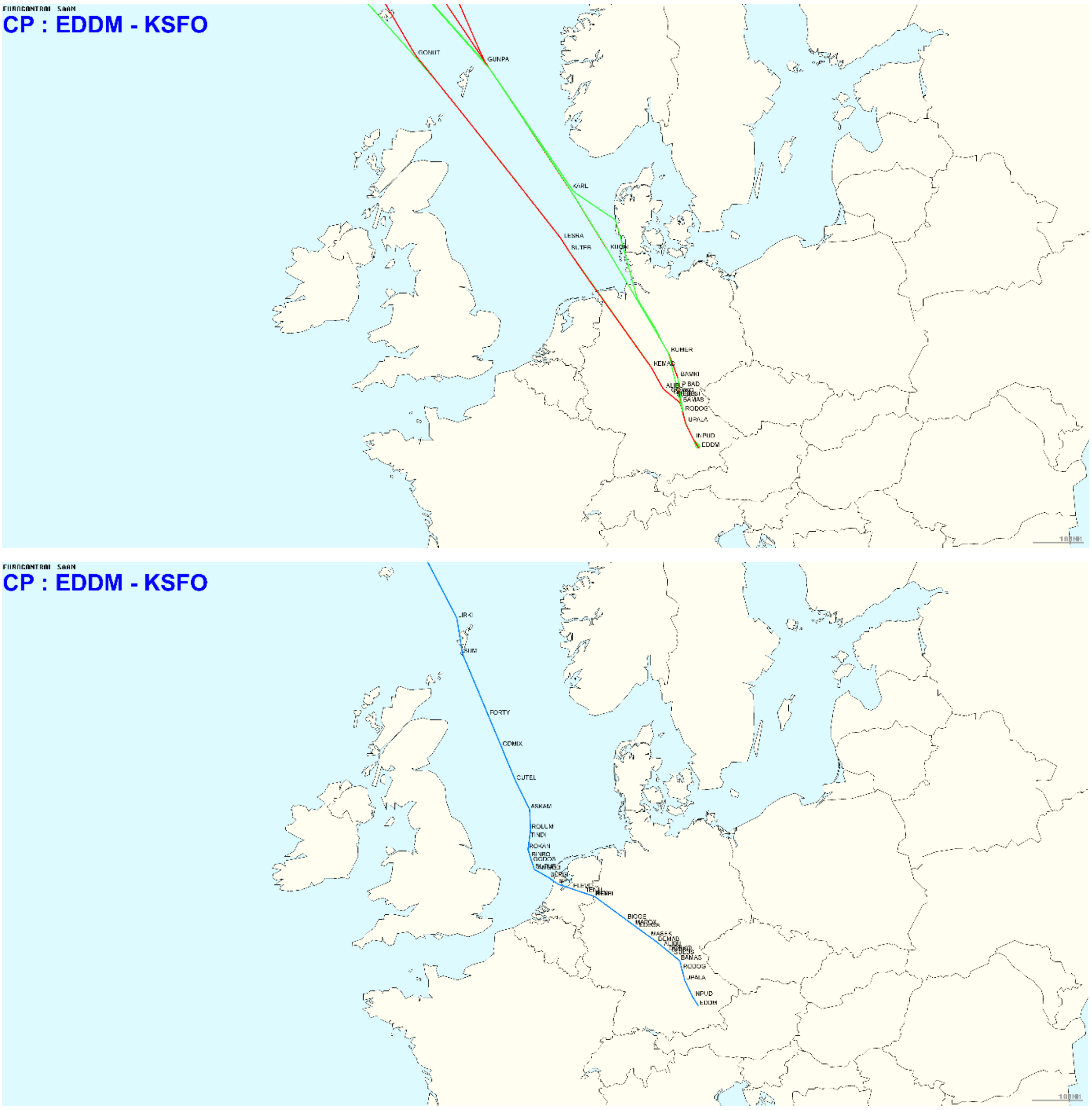


Figure 68: User Preferred Routings EDDM - KSFO (top) and respective RAD-conform routings (below)

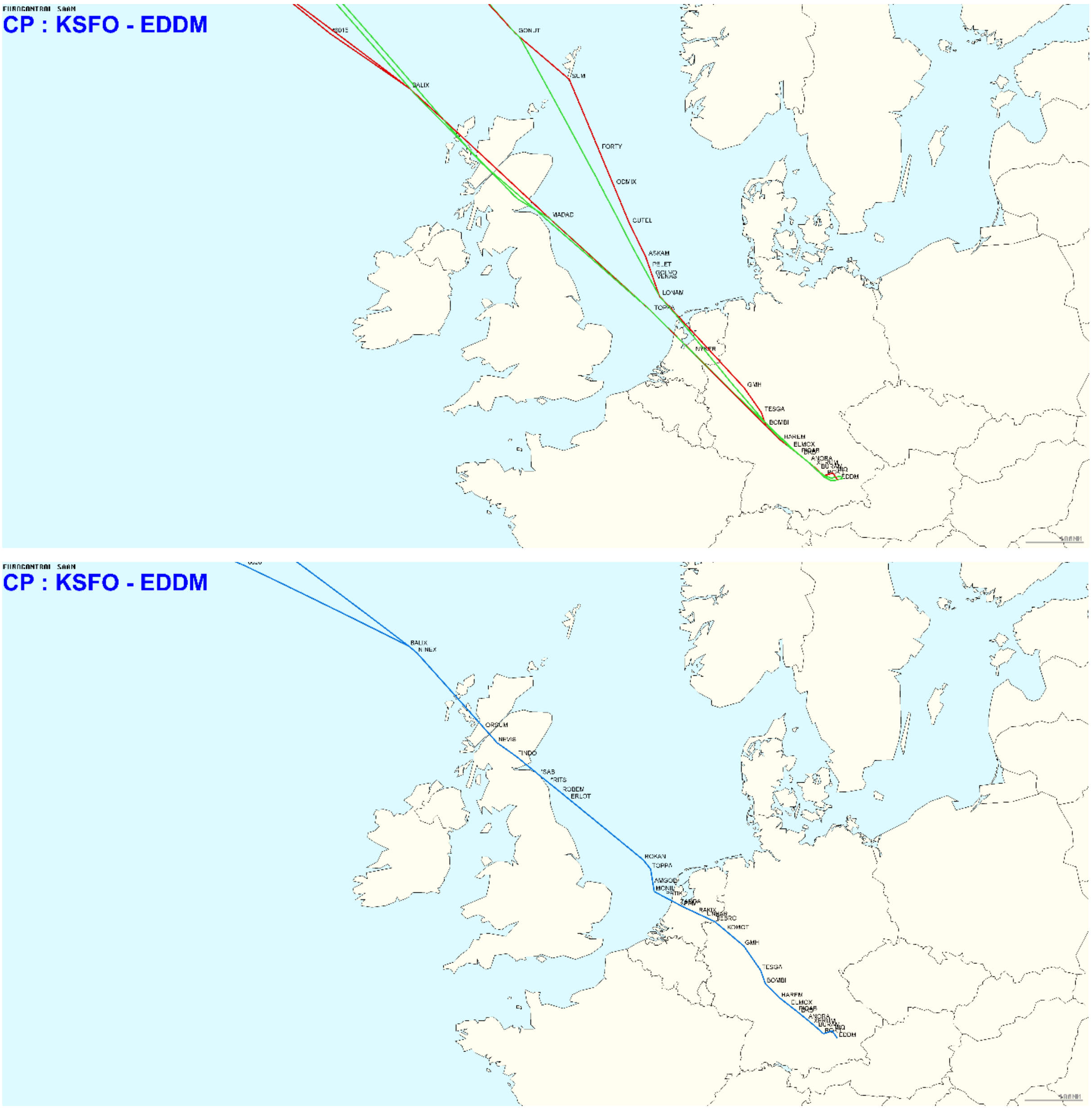


Figure 69: User Preferred Routings KSFO – EDDM (top) and respective RAD-conform routings (below)

6.6.3.2 Summary of Exercise Results

6.6.3.2.1 Results per KPA

Table 58: Results per KPA EXE-0201-D006

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Efficiency (horizontal)	OBJ-0201-011 OBJ-0201-018	Reduction of FPL route length in Cross-Border UPR operations[15]	Short-haul: 1 NM … 16 NM Long-haul: 12-25 NM
Efficiency (horizontal)	OBJ-0201-011 OBJ-0201-018	Reduction of actual route length in Cross-Border UPR operations	Short-haul: 1 NM … 16 NM Long-haul: 12-25 NM
Efficiency (horizontal)	OBJ-0201-011 OBJ-0201-018	Reduction of fuel burn in Cross-Border UPR operations	Short-haul: 5.6 kg per NM saved Long-haul: 23.6 kg per NM saved
Efficiency (horizontal)	OBJ-0201-011 OBJ-0201-018	Improvement of REDES in Cross-Border UPR operations	Actual flown UPR tracks: 1.015 (improvement vs. FR-CAP-01)
Efficiency (horizontal)	OBJ-0201-011 OBJ-0201-018	Improvement of RESTR in Cross-Border UPR operations	Actual flown UPR tracks: 1.007 (no improvement vs. FR-CAP-01)
Environmental Sustainability	OBJ-0201-012 OBJ-0201-018	Reduction of CO_2 emission in Cross-Border UPR operations	Not measured but due to route length reduction a reduction of CO_2 emission is to be assumed.
Safety	OBJ-0201-013	No increase of complexity in Cross-Border UPR operations	ATCOs reported higher complexity of work, especially for continental flights.
Safety	OBJ-0201-013	No degradation of the perceived level of safety in Cross-Border UPR operations	Crews and Dispatchers reported no safety issues. 14% of ATCOs reported safety hazards linked to UPR flights.

[15] Here and following the reference is formed by the usage of ATS routes

KPA	Objective Identifier	Success Criterion	Result of the demonstration
Safety	OBJ-0201-013	No degradation of the perceived level of situation awareness in Cross-Border UPR operations	UPR routings had to be checked and monitored continuously in order to maintain situation awareness. A clear labelling of UPR flights would be required.
Capacity	OBJ-0201-014 OBJ-0201-015 OBJ-0201-018	No adverse results regarding number of flights in Cross-Border UPR operations	On a case-by-case basis no capacity degradations were demonstrated. ATCOs stated that a high number of UPR flights would reduce capacity.
Other - Workload	OBJ-0201-016	No increase in operator workload in Cross-Border UPR operations	Dispatchers reported an increase in workload, especially in route construction, manual flight planning and filing. ATCOs reported an increase in workload due to the need for continuous checks of routings and the instruction not to deviate the flight from the FPL route.
Other – Operational Feasibility	OBJ-0201-017	No adverse operator feedback regarding Cross-Border UPR operations respectively	Approx. 77% of flight crews reported no irregularities. The major irregularity was ATCO not informed (offered DCT's).

6.6.3.2.2 Results impacting regulation and standardisation initiatives

According to ICAO DOC 4444, the change of cruise flight level can be initiated and indicated at published waypoints or by stating the Latitude / Longitude position in field 15 of the ICAO flight plan. As flight level changes at coordinates cannot be processed by all ATM systems, flight planning systems are currently designed to initiate a change of cruise flight level at a published waypoint only. If segments within a Free Route environment are very long, it can occur that the descent due to flight profile restrictions has to be initiated way too early in the flight plan compared to the actual ATC clearance (e.g. the distance between two waypoints is 500 nm and a profile restriction is applicable at the end of this segment, the descent is initiated about 500nm too early). This has negative implications on the planned fuel consumption and requires general solution for long segments (published or within Free Route areas) which has to be coordinated on Eurocontrol / ICAO level. This limitation of ATC systems can be solved by allowing intermediate waypoints with less distance to a waypoint with profile constraints so that an appropriate Top of Descent point can be determined.

ICAO requirement to keep distance of 2.5 NM to sector boundaries should be verified. With new systems (including MTCD) at least in some sectors (e.g. Karlsruhe East sectors - large and with less complex and less traffic) this regulation could be adapted. For Central sectors Karlsruhe it would be a no-go item for full use of UPR.

6.6.3.2.3 Unexpected Behaviours/Results

As the long range flights were dependent on the North Atlantic Track System on several occasions with southerly routings, flights which have been planned in the monthly schedule could not participate in the Trial as they did not cross the reserved airspace anymore.

As UPR flights could not be planned by the LIDO system automatically some flights had to be cancelled due to the lack of manpower within DLH dispatch. This was for example the case during days of industrial action in European countries. It was not possible to plan random UPR while respecting constraints like transition points, entry/ exit points, or COPs (an enlarged number of company routes has been used instead).

It was not possible to verify an optimal length of DCT segments. ANSPs in general would prefer longer segments while AOs are in favour for shorter segments.

Some ATM systems of adjacent / subjacent ACCs have demonstrated not being capable for automatic processing of UPR flightplans. In order to allow UPR flights from Munich e.g. the UPR flight had to be laterally outside the AoR of Munich ACC (even if well above Munich ACCs vertical limit, i.e. FL 315) or the respective DCT has to be implemented in the system. Due to the use of company route for FRAMaK UPR flights the problem could be solved easily by system adaptations. However, “real UPR” in terms of random routeings would not have been possible with the present ATM systems.

Vertical step climbs could only be planned and filed at waypoints. Therefore the optimum vertical profile could not be followed as closely as on (RAD conform) routes with a higher number of waypoints.

On the other hand, 3 OSL-MUC flights benefited from the chance not to climb and descend during cruise flights according RAD restrictions on an UPR routing. This had a planning influence of around 100 kg (planned Trip Fuel) per flight.

As all actually performed flights were always on a continuous cruise altitude, the fuel savings were only 3.5 kg per 100 kg planned Trip Fuel (Transport Fuel).

6.6.3.2.4 Quality of Demonstration Results

During the Demonstration a total of 136 UPR test flights have been planned. Due to the involvement of many stakeholders (different ANSPs, LH Dispatch, Flight Crews, Crew scheduling….) many of these flights have been cancelled, rerouted or could not been evaluated (due to problems described before). In some cases subjacent ACCs offered tactical directs potentially hampering the UPR routing. This problem has been solved in the course of the demonstration by means of communication with ACCs. On the other hand, despite the briefings, some flight crews asked for tactical directs potentially hampering the UPR routing.

The analysed 62 flights listed in Table 57 were in line with the specifications of the demonstration plan. The quality of these flight data is valuable.

According to the UPR Flight Trial procedures both flight crews and ATCOs were requested to stick to the UPR flightplan. For 13 UPR flights deviations from the FPL routing were reported. In one flight a deviation was reported due to weather. In 10 cases deviations were initiated by ATC which could have happened due to military activity (reported for 3 cases) or of course for safety reasons. However, in some cases subjacent ACCs offered tactical directs potentially hampering the UPR routing. This problem has been solved in the course of the demonstration by means of communication with ACCs. On the other hand, despite the briefings, in 2 cases flight crews asked for tactical directs potentially hampering the UPR routing.

6.6.3.2.5 Significance of Demonstration Results

As all flights entering the NATS sector were only allowed at weekends, the influence on ATCOs’ workload was probably not comparable to normal workdays.

Furthermore all other KPAs (Fuel saving etc.) could probably be further increased on weekdays. On the weekends due to the closure of TRAs, DCT options close to the Minimum Cost Track are already in place.

6.6.4 Conclusions and recommendations

6.6.4.1 Conclusions

Focussing on FR-CAP-02 “Cross-Border User Preferred Route” demonstrations in EXE-0201-D006 were accomplished on six citypairs under study (3 of them inner-European, 3 transatlantic). In total 62 flights have been executed following a User Preferred Routing.

With the short-haul flights mean route lengths reductions between 1 NM and 16 NM were achieved, corresponding to fuel savings between 6 kg and 87 kg; on average the fuel reduction for short-haul flights is 5.5 kg per NM saved. Route lengths of transatlantic flights were reduced by 12-25 NM, accounting for fuel savings between 280 kg and 618 kg; average fuel reduction is 23.6 kg per NM saved.

From an Airspace User’s perspective the UPR demonstration showed with promising fuel and time savings that the further UPR development and implementation is desirable. As capacity constraints can already be found throughout Europe, technical improvements like a useable planning tool, FPL filing standards, i4D trajectories etc. have to be established beforehand.

On the other side ANSPs experienced throughout the FRAMaK UPR trials, that airspace capacity and efficiency might be reduced in particular in complex sectors of the Core Area if full Free Route with UPR (comprising entry, exit, and intermediate points) is implemented today.

Therefore, as an overall result ANSPs consider UPR operations possible in low to medium complexity areas or even in (usually) more dense areas at certain times, such as winter season, night. An implementation in more dense airspace will require further investigation and the availability of enhanced technical means, e.g. controller support tools, and enhanced working procedures / positions.

The FRAMaK trials based on the original UPR Test Area have shown that the size of FRAMaK is near the minimum size to allow for UPR optimization within a single FRA. Through the support of Avinor, LFV, NATS, and Naviair it was possible to significantly enlarge the UPR Test Area in order to properly accomplish the UPR demonstrations. However, due to the restricted size of the demonstration area, the shortness of some routings within this area, the finite amount of waypoints and routings, the limitations of LIDO and the variability in airway charges, it was not possible to demonstrate significant savings due to wind effects and full free flight routings.

In the course of the demonstration deficiencies of today’s flight planning tools were identified and possible solutions have been outlined.

Where mainly long directs have been planned vertical step climbs could be planned and filed only at waypoints. Due to lacking intermediate points the optimum vertical profile could not be followed as closely as on RAD conform routes comprising a higher number of waypoints.

The trial showed that for the majority of UPR flights DCT routing options were available or have been made available as new FRAMaK Cross-Border DCTs which in most cases properly matched the respective UPR routing for the specific citypair. Therefore, improvement in available DCT connections should be feasible as interim solution for the near future.

Special Use Airspace (SUA) may prevent the establishment of optimized routing options in various places. SUAs have been avoided within the FRAMaK trials by executing flights on weekend or in areas clear of those areas.

UPR Live Trials have been useful in order to identify specific issues related to the compatibility of UPR routings with existing systems and structures. However, since UPR has been demonstrated on a case-by-case basis with a maximum of three flights per day this FRAMaK demonstration did only partly show operational issues and impacts not considering a large-scale application of this operational concept.

From the beginning of the project a conflict became visible between flight crews and ATCOs both aiming for shortest routes and shortcuts in order to straighten the routing on the one side and dispatch staff trying to find the best routing from an economical point of view which is not necessarily the shortest (see e.g. Figure 70) on the other side.

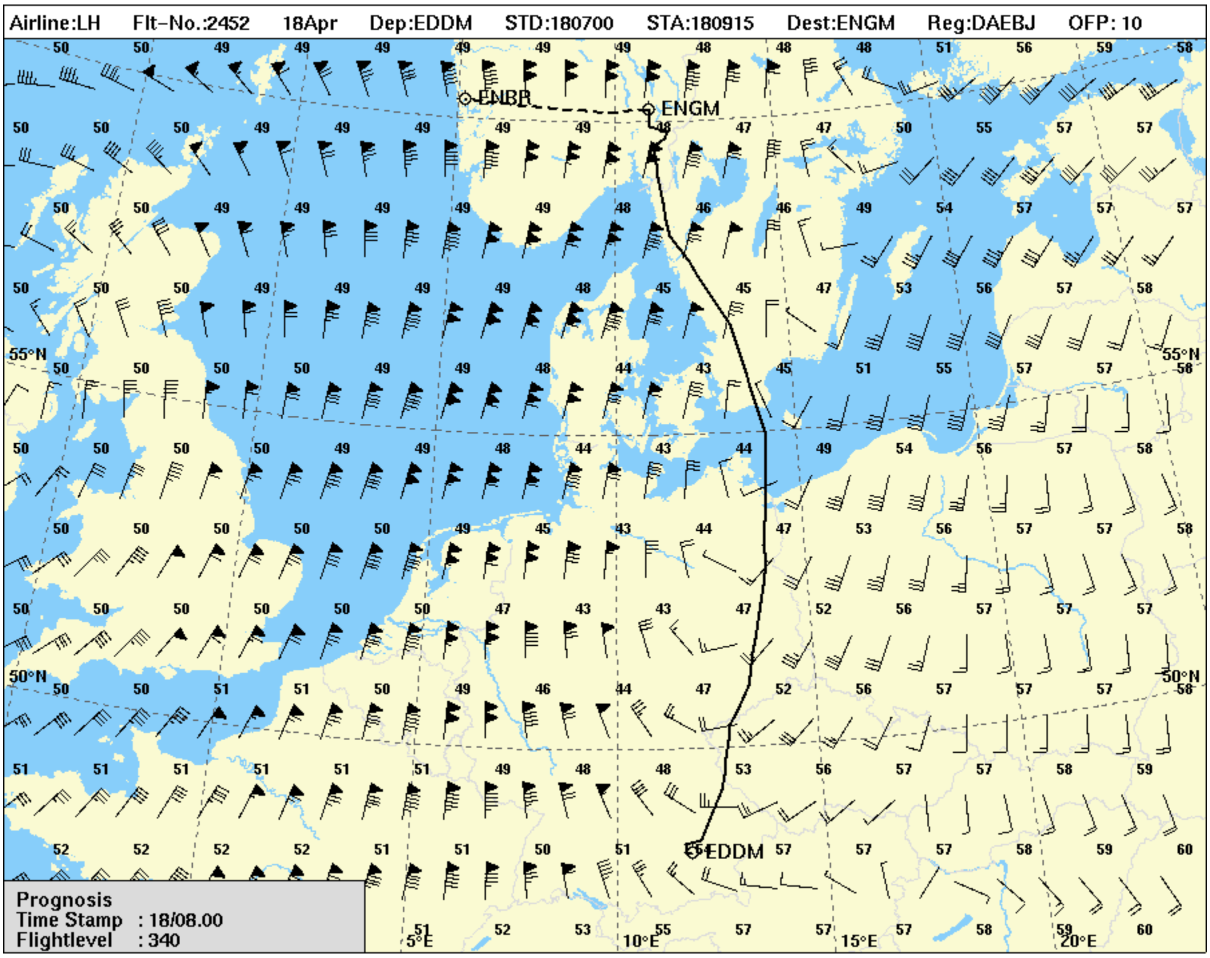


Figure 70: "Ideal free flight day": Northbound flights as shown probably follow an easterly routing while southbound flights would go more westerly.

From ANSPs' perspective there is in general no positive contribution of UPRs to Capacity. The challenge for ANSPs is to find the right balance between freedom of routing selection and Capacity. Due to crossing flows and/or sector issues, FRA capabilities might be limited to existing (local/regional, non-Cross-Border) Entry-Exit DCTs in some sectors / sector groups.

Complex and small sectors with a lot of vertical movements are not conducive to UPR operations on a large scale although individual UPR flights are manageable with pre-notification.

A UPR flight demands a lot of attention from the ATCO. As the ATCO needs to stick to the flightplan, a lot of time is needed to fit the flight into the actual air picture. This can involve taking other measures for the other flights, just to avoid touching the UPR. As a result, the workload goes up significantly. If the number of UPRs would increase, it could become very cumbersome to follow what the UPRs are doing especially when the flights are climbing or descending combined with some unexpected turns in or at the boundary of the sector. Complete awareness of what the other aircraft are doing is then essential.

Regarding sectorization it was found that UPRs along the ANSP unit's (zig-zag) boundary cause multiple re-entering situations (e.g. EDDM-ENGM). In addition, some UPRs do not represent actual flown tracks, but create completely new flows. This might cause issues with sectors that are already to the limit of their capacity and complexity.

For UPR flight planning it has to be ensured that waypoints (navigation aids, 5LNCs etc.) used in the flight plan are known in the affected ACCs' / UACs' systems. In the FRAMaK demonstrations this was achieved by the publication of the respective Test Plan with waypoint information.

The system of Compulsory Transition Routes connecting aerodromes' SIDs and STARs with the UPR Test Area applied for UPR trials has shown good results in terms of operational feasibility.

The accomplishment of dry-runs by means of the LIDO Flight Planning Systems supported the development of the operational concept.

6.6.4.2 Recommendations

Free Route Airspace Design

In order to ensure beneficial UPR operations the connectivity between FRA and Non-FR airspaces as well as between multiple (possibly smaller) FRA cells shall support UPR operations in a way that available routeing options approximate the optimal path, e.g. by offering a sufficient number of waypoints to pass from one cell to the other.

During the development ATCOs, AOs, NMOC and computer flight planning service providers should work together, as common problems like intermediate waypoint definitions have to be elaborated.

In order to make use of large scale wind fields a FRA feasible for UPR operations needs a minimum size in terms of DCT segment lengths and clearly the highest benefits are to be expected in big airspaces.

For a widespread implementation of UPR operations more flexible handling options (A-FUA) regarding Special Use Airspace have to be in place. Operational needs of the stakeholders, for example preceding handling time of the flightplan and of fuel calculations have to be considered in order to implement operationally significant route changes.

For DCT planning it would be helpful, but for UPR route planning it is essential to have common regulations regarding the safety buffer around restricted/danger areas. The reserved airspace should comprise the safety buffer.

UPR operations at all levels at night could be a possibility in the future but a Cost Benefit Analysis has to prove whether the effort is a good investment.

UPRs will only be possible if the flights are not climbing and/or descending within the airspace and they have to be at the highest flight levels. Traffic that is departing or arriving close or within the area of responsibility would have to be on transition routes while climbing or descending.

For future UPR operations (e.g. northbound zig-zag routing) the flight level allocation (odd/even) might cause problems both for AOs because of too many intermediate FL changes, and for ATC due to incompliance in case of intended deviations from FLOS for flow separation purposes (e.g. track 010° might be required to be even instead odd).

Operational Considerations

Under certain meteorological conditions tactical DCTs might jeopardize benefits of (planning-based) User Preferred Routings. Therefore under UPR operations ATCOs and pilots should stick to the FPL routeing. In order to evaluate potential benefits of tactical DCTs offered by ATC the cockpit crew would need a tool in the cockpit which makes use e.g. of real-time weather information.

Flight Planning Tools

To calculate and file UPR routes flight planning tools have to be developed further. As a basis for the development of such Free Flight planning tools a framework of commonly agreed requirements is needed. For this purpose general rules have to be determined and published in AIP or RAD which should not be of local or temporary nature.

Flight planning systems need to be capable to cope with restrictions arising from e.g. a step-wise implementation of FRA concepts.

ATM Systems

In mixed mode operation an indication to the controller in the label would be required for UPR operations to indicate which aircrafts are following a UPR.

ATCO feedback showed that conflict detection might become an issue and as such more system support might be required in the future.

7 Summary of the Communication Activities

Due to their size the copies of communication activities are comprised in the respective internal deliverable D10 [15] only.

7.1 Planned Communication Activities

No.	Media	Lead	Date	Subject	Status
1.	Intranet newsflash	MUAC	04/06/12	Signature of FRAMaK consortium agreement	closed
2.	EUROCONTROL E-Newsletter To be also reproduced in the SESAR communication channels	MUAC	18/10/12	One article about the project and the benefits expected, background info, interviews of key players in the Project.	closed
3.	DFS Intranet Report	DFS	13/12/12	Successful initiation of FRAMaK project and start of Live Trials	closed
4.	Internet – dedicated page To be also reproduced in the SESAR communication channels	MUAC DFS DLH	13/12/12	Background info on the project Note: this information should be the same for all partners' websites.	closed
5.	Internet top story	MUAC	Oct 2012	Based on same article as E-newsletter	closed
6.	Insight (internal EUROCONTROL staff magazine)	MUAC	Sept/Oct	Based on same article as E-newsletter but tuned to internal audience	cancelled
7.	MUAC customer consultation meeting	MUAC	27/09/12	Background info on the project	confidential
8.	RNDSG Meeting	MUAC	2-4/10/12	Information about FRAMaK DCTs to be implemented with AIRAC 1213	closed
9.	Lufthansa Policy Brief	DLH	Q1 2013	Update SESAR and introduction FRAMaK	cancelled see LH Balance report
10.	FABEC newsletter, No. 17	MUAC/ DFS	Dec 2012	Based on same article as E-newsletter	closed

No.	Media	Lead	Date	Subject	Status
11.	LH staff magazine LH Passage staff magazine	DLH	Dec 2012	Introduction FRAMaK	closed
12.	Press release	MUAC SJU	13/12/12		closed
13.	5th North Sea Regional Focus Group	MUAC	07-08/02/13	Inform adjacent ANSPs about FRAMaK activities	cancelled
14.	CANSO World ATM Congress 2013, Madrid	MUAC DFS DLH	12-14/02/13	Information on the project and expected benefits, progress report.	closed
15.	AOG Meeting, ECTL Brussels	DFS	05/03/13	Inform European AOs about on-going activities FRAMaK / SENEKA and relocation of upper airspace Munich	cancelled
16.	SJU internal Meeting	DFS	Q4 2013	Inform other Demonstration Activities projects	closed
17.	LH Group "Balance" report	DLH	May 2013 → May 2014	Annual sustainability report: FRAMaK introduction	closed
18.	Annual reports 2012	MUAC DFS DLH	May 2013	Information on the project and expected benefits, progress report. Note : this information should be the same for all partners' publications	closed (DFS, DLH: cancelled)
19.	SESAR Demonstration Activities Yearly Report	DFS	Dec 2013	Yearly report on project activities	cancelled
20.	CANSO World ATM Congress 2014, Madrid	MUAC DFS DLH	Feb 2014	Information on intermediate project's results and expected benefits, progress report.	closed
21.	SJU internal Meeting	DFS	Q1 2014	Inform other Demonstration Activities projects	cancelled

No.	Media	Lead	Date	Subject	Status
22.	Annual reports 2013	MUAC DFS DLH	May 2014	Information on the project and expected benefits, progress report. Note : this information should be the same for all partners' publications	closed (DFS, DLH: cancelled)
23.	Annual reports 2014	MUAC DFS DLH	May 2015	Information on the project's results. Note : this information should be the same for all partners' publications	open
24.	Operational communication through various channels (eBrief, meetings, briefings, intranet)	MUAC/ DFS/ DLH OPS/ project experts	Regular process	Share essential operational information to ensure the success of the project	closed
25.	B2B communications through usual channels	MUAC/ DFS/ DLH OPS/ project experts	Regular process	Share essential operational information to ensure that Free Routes are used to a maximum extent by airlines	confidential
26.	DFS "TE im Fokus"	DFS	TBD	FRAMaK project description, schedule, expected benefits	open
27.	Media Release	MUAC/ DFS/ DLH SJU	TBD	Subsequent key developments	open

7.2 Additional Communication Activities

No.	Media	Lead	Date	Subject	Status
28.	RNDSG Meeting	DFS	06/02/13	Presentation regarding changes in Karlsruhe regarding VOLMUK and SENEKA in connection with FRAMaK	closed
29.	Air France Customer Meeting	DFS	11/04/13	Presentation of FRAMaK DCT routeing options and potentials for AOs	confidential

No.	Media	Lead	Date	Subject	Status
30.	DFS Karlsruhe UAC Customer Information	DFS	17/05/13	DFS Karlsruhe UAC – Customer Information "Free Route Airspace Karlsruhe and Update AIRAC 30MAY2013"	closed
31.	DFS Transmission	DFS	June 2013	Magazine article about FRA activities DFS Karlsruhe, including FRAMaK	closed
32.	ERNIP	ECTL	each AIRAC cylcle	European Route Network Improvement Plan/ERNIP – Implementation Monitoring	closed
33.	FRAM briefing to NAMEUR	ECTL	16/06/13	Briefing with several references to FRAMaK.	closed
34.	Customer Meetings	ECTL	Q3 2013	Long-haul and oceanic flights in relation to Free Routing in Europe.	cancelled

7.3 Press about FRAMaK

No.	Article	Date
35.	Turner, A., Going Large, Air Traffic Management Net	23/10/2012
36.	NN, MUAC cooperates with DFS to extend Free Route Airspace, ATC Global Hub	24/10/2012
37.	Turner, A., Lufthansa pioneers large-scale Free Routing, Air Traffic Management Net	14/12/2012
38.	NN, MUAC, DFS and Lufthansa pioneer large-scale Free Routing, Air Transport News	14/12/2012
39.	NN, Airplanes and routes, "Framak" project. SESAR: MUAC, DFS and Lufthansa pioneer large-scale Free Routing, Avio News	14/12/2012
40.	Paylor, A., FRAMak implements large-scale free routing in Maastricht, Karlsruhe, ATW online	31/12/2012
41.	Moxon, J., Single European Sky Still Fragmented, AIN online	17/06/2013
42.	Turner, A., Europe continues Free Route airspace roll-out, Air Traffic Management Net	10/07/2013

8 Next Steps

8.1 Conclusions

For a general synthesis of exercises' conclusion please refer to 5.5.3.1.

With regard to future activities arising from FRAMaK demonstrations the following conclusions were derived:

- Based on KUAC FTS and RTS (EXE-0201-D003 and EXE-0ß201-D004) new Direct routing options in the Karlsruhe UAC core area are foreseen for implementation in winter 2014/2015.
- The promising results of demonstrations related to Vertical Optimisation Directs should lead to further investigations regarding connectivity between Upper Airspace (DCT or UPR) with aerodromes using optimised descent profiles which allow for a late descent.
- In the context of both enhanced operational availability of Direct routing options and Full Free Route Airspace, Flexible Use of Airspace has to be further developed. DFS and EUROCONTROL will elaborate on this concept in the framework of FABEC. Many operational questions are to be discussed, e.g. on how to circumnavigate MIL area? Which controller takes action? What is the impact on ATFCM? What kind of support tools are needed for exchange of airspace status information, system alert or coordination between involved ACCs/UACs? In which way could CPDLC future operations?
- Based on the results of User Preferred Route demonstrations options for FRA implementation should be investigated in less dense areas (e.g. Northern Germany) above a certain FL, at certain times with connections to adjacent and similar airspaces.
- For a wide-spread application of the full FRA concept support tools are needed which optimize trajectory and minimize workload and environmental impact.
- New route options from and to Manchester will be further investigated by NATS in cooperation with KUAC and MUAC.

8.2 Recommendations

For a complete description of recommendations please refer to 5.5.3.2 and the respective exercise results in chapter 6.

For further steps towards enhanced availability of RAD-published and therefore planable long direct routes with COP-less functionalities following recommendation are derived from the demonstrations:

- OLDI exchange should support an automatic FPL processing based on dynamic COPs; in this context interoperable OLDI ACT implementations are required.
- ACT should be correctly sent based on system boundary, instead of national boundary.
- OLDI message formats like OLDI SDM (Supplementary Data Message) / SCO (Skip Communication Message) which inform on new frequencies if sector sequence is modified should be available.
- HMIs should cope with dynamic LAT/LONG-defined COPs.
- In current system it was observed that if the exit point is too far outside the own AoR, this point and the trajectory are not calculated and displayed on the HMI. Therefore, for long-range DCTs the exit points need to be represented in the system.

Sector Clipping should be duly investigated as they may cause operational issues and negatively affect controller workload and thus capacity. Sector Design and dynamic sectorisation concepts should be investigated as mitigation means.

For an enhanced operational availability of DCTs all Special Used Areas above a certain FL (e.g. FL245 as this was the vertical limit in this project) should be AMC-manageable in order to optimise flight efficiency of civilian airspace users.

Since SAAM Fast Time Simulations are considered more and more a standard step in airspace design projects the capabilities of SAAM should be enhanced with regard to

- Utilization of data available in the Enhanced Tactical Flow Management System (ETFMS), i.e. operational data comprising RAD constraints etc., for the generation of traffic examples,
- Optimisation of flights based on different criteria such as wind, route charges, airspace availability etc.

In view of further progress towards full Free Route Airspace the following topics should be addressed in due time:

- In order to ensure beneficial UPR operations the connectivity between FRA and Non-FR airspaces as well as between multiple (possibly smaller) FRA cells shall support UPR operations in a way that available routeing options approximate the optimal path, e.g. by offering a sufficient number of waypoints to pass from one cell to the other.
- In order to make use of large scale wind fields a FRA feasible for UPR operations needs a minimum size in terms of DCT segment lengths and clearly the highest benefits are to be expected in big airspaces.
- For a widespread implementation of UPR operations more flexible handling options (A-FUA) regarding Special Use Airspace have to be in place. Operational needs of the stakeholders, for example preceding handling time of the flightplan and of fuel calculations have to be considered in order to implement operationally significant route changes.
- To calculate and file UPR routes flight planning tools have to be developed further. As a basis for the development of such Free Flight planning tools a framework of commonly agreed requirements is needed. For this purpose general rules have to be determined and published in AIP or RAD which should not be of local or temporary nature.
- Flight planning systems need to be capable to cope with restrictions arising from e.g. a step-wise implementation of FRA concepts.
- With regard to ATM Systems, in mixed mode operation an indication to the controller in the label would be required for UPR operations to indicate which aircrafts are following a UPR.
- ATCO feedback showed that conflict detection might become an issue and as such more system support might be required in the future.

In general, findings, conclusions and recommendations of the FRAMaK project should be properly distributed and should be made available to a broader audience.

9 References

9.1 Applicable Documents

[1] EUROCONTROL ATM Lexicon https://extranet.eurocontrol.int/http://atmlexicon.eurocontrol.int/en/index.php/SESAR

9.2 Reference Documents

The following documents provide input/guidance/further information/other:

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[3] DFS Deutsche Flugsicherung, Deutsche Lufthansa AG, Eurocontrol (2013), SESAR Joint Undertaking (ed.), FRAMaK - Cross-Border User Preferred Routes Demonstrations - Test Plan, 00.02.01

[4] DFS Deutsche Flugsicherung, Deutsche Lufthansa AG, Eurocontrol (2013), SESAR Joint Undertaking (ed.), FRAMaK - Operational Procedure for Cross-Border User Preferred Routes Demonstrations, 00.02.02

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[8] DFS Deutsche Flugsicherung, Deutsche Lufthansa AG, Eurocontrol (2012), SESAR Joint Undertaking (ed.), FRAMaK D04 - Demonstration Plan (A1), 00.02.01

[9] DFS Deutsche Flugsicherung, Deutsche Lufthansa AG, Eurocontrol (2014), SESAR Joint Undertaking (ed.), FRAMaK D05 - SAAM Network Assessment Report, 00.02.01

[10] DFS Deutsche Flugsicherung, Deutsche Lufthansa AG, Eurocontrol (2014), SESAR Joint Undertaking (ed.), FRAMaK D06 - KUAC Central Sectors Validation Report, 00.02.01

[11] DFS Deutsche Flugsicherung, Deutsche Lufthansa AG, Eurocontrol (2014), SESAR Joint Undertaking (ed.), FRAMaK D07-I - Routes Validation Report (MUAC RTS), 00.01.01

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[27] Single Sky Committee (2013), SESAR Deployment – draft Commission Implementing Regulation on PCP, 52nd Single Sky Committee, 17-18/12/2013, SSC/13/57

Appendices

A. FRAMaK D02 - Concept of Operations, 00.01.01

B. FRAMaK D03 - Route Design Catalogue, 00.03.01

C. FRAMaK D04 - Demonstration Plan (A1), 00.02.01

D. FRAMaK D05 - SAAM Network Assessment Report, 00.02.01

E. FRAMaK D06 - KUAC Central Sectors Validation Report, 00.02.01

F. FRAMaK D07-I - Routes Validation Report (MUAC RTS), 00.01.01

G. FRAMaK D07-II - Routes Validation Report (KUAC RTS), 00.01.01

H. FRAMaK D08 – Operational Validation Report, 00.02.01

I. FRAMaK D09 - Safety Assessment Summary Report, 00.01.01

J. FRAMaK D10 - Copy of communication material, 00.01.01

K. FRAMaK D11 - Technical Test Report, 00.01.02

L. FRAMaK - Operational Procedure for Cross-Border User Preferred Routes Demonstrations

M. FRAMaK - Cross-Border User Preferred Routes Demonstrations - Test Plan

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