NTM/DIK WG

FABEC NTM / DIK - SWAP

Validation report

EUROCONTROL

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GLOSSARY

Abbreviation	Definition
3D	Three dimensions
ACC	Area Control Centre
AIP	Aeronautical Information Publication
AMC	Airspace Management Cell
ANSP	Air Navigation Service Provider
APP	Approach Centre / Control
ATC	Air Traffic Control
ATFCM	Air Traffic Flow and Capacity Management
ATM	Air Traffic Management
ATS	Air Traffic Services
BADA	Base of Aircraft Data
CBA	Cross Border Area
CDR	Conditional Route
CFMU	Central Flow Management Unit
CWP	Controller Working Position
DFS	Deutsche Flugsicherung - (ATS provider for Germany)
DIK	Diekirch
DSNA	Direction des services de la navigation aérienne (French Directorate Air Navigation Services)
DVR	Dover
EC	European Commission
EEC	EUROCONTROL Experimental Centre
EFL	Entry Flight Level
E-OCVM	European Operational Validation Methodology
ESCAPE	EUROCONTROL Simulation Capability And Platform for Experimentation
EU	European Union
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAB	Functional Airspace Block
FABEC	Functional Airspace Block Central Europe
FAF	French Air Force
FIR	Flight Information Regions
FL	Flight Level
HMI	Human Machine Interface (Interaction)
HS AD CC	Hot Spot Airspace Design Coordination Cell
ICAO	International Civil Aviation Organisation

Abbreviation	Definition
IFR	Instrument Flight Rules
IP(s)	Implementation Plan(s)
IPAS	Integrated Preparation and Analysis System
ISA	Instantaneous Self Assessment
KPA	Key Performance Area
MUAC	Maastricht Upper Area Control Centre
nm	Nautical Miles
NoAs	Northern Airspace
NTM	Nattenheim
P-RTS	Prototyping Real Time Simulation
RAD	Route Availability Document
RKN	REKEN
RNDSG	Route Network Development Sub-Group
RTS	Real-time Simulation
SAAM	System for Assignment and Analysis at a Macroscopic level
SES	Single European Sky
SESAR	Single European Sky ATM Research (Programme)
SID	Standard Instrument Departure
STAR	Standard Arrival Route
TMA	Terminal Manoeuvring Areas
TSA	Temporary Segregated Area
UIR	Upper (Flight) Information Region
WG	Working Group
XFL	Exit Flight Level

SWAP Validation report

Executive Summary

This document is the validation report of the large scale Real Time Simulation (RTS) conducted at EUROCONTROL Experiment Centre, of the SWAP airspace reorganisation proposal developed within the FABEC - Nattenheim-Diekirch (NTM/DIK) hotspot Task Force.

The objective of the SWAP validation activities was twofold:

- Assess the operability and acceptability, from the controller perspective, of the SWAP Version 1 (V1) and Version 2 (V2) airspaces ;
- Provide initial trends regarding the related expected benefits in terms of safety (removal of current Hot spot), efficiency (optimised distance/time flown and ensured military mission effectiveness) and capacity (optimised airspace usage and reduced controller workload).

The SWAP validation methodology consisted of a series of two Real Time Simulations, the second of which built upon the first and increased the scope. These simulations were expected to address the NTM/DIK hotspot issues and are complementary to the other “hot spot projects” identified in FABEC (e.g. Northern Airspace).

The large scale RTS followed a small scale simulation (prototyping session of 4 days) that focused on specific issues at the interface between Reims/Geneva Area Control Centres in the SWAP V2 airspace. Its content and focus were defined and agreed by the SWAP Sub Working Group and SWAP simulation Core Team. The main large scale RTS objective was to provide an initial comparison between current airspace and two variants of SWAP airspace by providing trends over identified Key Performance Areas (KPA). Results are mainly expressed in terms of:

- Operability: Controllers subjective feedback on the feasibility and acceptability of the proposed airspace organisations;
- Safety: Both objective and subjective data on workload and on any safety issues.

The RTS took place at EUROCONTROL Experimental Centre and lasted 2 weeks from 16th to 30th of April 2010. There were 35 controller positions with 6 different HMIs involving a total of 46 controllers from 5 ANSPs and 7 ATC centres: Skyguide (Geneva and Zurich), DSNA (Reims and Paris), Belgocontrol, French Air Force (FAF) and EUROCONTROL (MUAC). The simulated airspace was based on the current network and the agreed FABEC SWAP V1 and V2 designs with the addition of elements of the Paris HARMONIE project. It included ATC sectors from Reims, Geneva, Zurich, and Paris with a portion of CANAC and MUAC ACC airspace. The proposed route networks had new transfer levels for flights leaving Reims and new CBA/TSA boundaries were developed for the French military areas. The traffic samples were derived from actual traffic although adaptations (e.g. traffic increase) were made to meet stakeholders’ needs and the simulation objectives. Results were obtained from 21 measured exercises analysed over a 1 hour period.

The subjective view of the controllers was that the SWAP V1 airspace was rejected by the majority (80%). The bottleneck at GTQ was considered more problematic in the Reims sectors and there was increased complexity for arrivals and departures in/out of Geneva. As a consequence the V1 network was not considered feasible and was seen as potentially degrading today’s level of safety and capacity.

The SWAP V2 airspace was accepted by 90% of participants and considered feasible for the main En-Route controllers tasks (separation management, conflict detection and traffic delivery). The segregation of northbound and southbound flows provided a better organisation of traffic in the Reims sectors and removed the current hot spot between Reims and Geneva. In the lower Geneva sector, when CBA25 was active, the traffic was found easier to handle than today. The subjective view of the controllers was that SWAP V2 did not degrade safety and capacity with half of the participants suggesting that both could be even improved. Objective results on distance flown and the ability to achieve the agreed transfer levels show no degradation of today’s flight efficiency and quality of service. In terms of transfer levels between Reims and adjacent sectors, the RTS concludes that of the options tested FL200 was the best for Zurich arrivals and suggests that aircraft transferring between Reims and MUAC/CANAC could be delivered at higher flight levels than in the case today. For Paris

arrivals, the use of even levels (with FL340 max and aircraft released early with the option for Paris controllers to effect a turn) seems to be the most acceptable.

The military participants expressed equivalence in terms of military mission effectiveness between the SWAP airspaces and today’s situation.

Although a major part of the SWAP V2 airspace has been assessed and validated by the RTS, it still requires agreement on dimension of current military areas (e.g. CBA22), the definition of new SIDs and STARs in/out of Geneva airport and a new route north of GTQ into Germany airspace to segregate the flows.

Table of Contents

1 Introduction

1.1 Purpose of the document

The document presents the Validation report for the SWAP Real Time Simulation (RTS) carried out in the context of the FABEC - Nattenheim-Diekirch (NTM/DIK) hotspot. It summarises the preparation, conduct and main outcomes of the SWAP RTS conducted at the EUROCONTROL Experimental Centre between the 19th and 30th April 2010 to assess the operational acceptance, from ANSPs perspective, of the swap in direction of flight on ATS routes UN852 and 853.

The validation report addresses the step 4 of the European Operational Concept Validation Methodology (E-OCVM) [1]. It includes all information necessary to understand the conduct and outcomes of the RTS and complements the SWAP validation strategy [2] and SWAP validation exercise plan [3].

1.2 Intended audience

The validation strategy is intended for use by the FABEC project leaders and involved actors, in particular:

- The Hot Spot Task Force manager and members,
- Th e SWAP Working Group manager and members,
- The SWAP simulation manager and SWAP RTS Core Team members,
- Representatives of the ANSP concerned by the SWAP project (DSNA, Skyguide, MUAC, Belgocontrol, DFS);
- Representatives of the military organisations concerned by SWAP (French, Swiss and German military);
- Members of other FABEC projects (e.g. NoAs) potentially impacted by SWAP outcomes/findings.

1.3 Document structure

The document is structured as follows:

- Chapter 2 summarises the experimental plan (objectives, environment and design);
- Chapters 3 and 4 respectively describe the experiment conduct and results according to the simulation objectives;
- Chapter 5 provides conclusions and recommendations.

1.4 Background

1.4.1 FABEC Context

The airspace located in the core of the European continent around the six States: Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland is amongst the busiest and most complex in the world. Many of the large European airports, major civil ATS routes and numerous military bases and training airspace are located in this area.

To cope with the forecast traffic growth and fragmentation in airspace and air traffic management, the European Commission launched the Single European Sky (SES) initiative. This will redesign European Air Traffic Management (ATM) into a flexible, harmonised and seamless network, independent of national boundaries within so-called functional airspace blocks (FABs). Airspace design is oriented towards supporting more efficient traffic flows and not towards national boundaries, without interfering with national sovereignty. Although Switzerland is not a member of the EC, it participates in the SES.

The FABEC airspace (Figure 1) comprises the flight information regions (FIRs) of Bremen, Langen, Munich, Amsterdam, Brussels, Paris, Reims, Marseille, Bordeaux, Brest, the upper information regions

(UIRs) of Hannover, Rhein, Brussels, France and the FIR/UIR of Switzerland. These FIRs and UIRs contain around 240 airports with instrument flight rules (IFR) operations, some 410 military/special areas and around 370 control sectors.

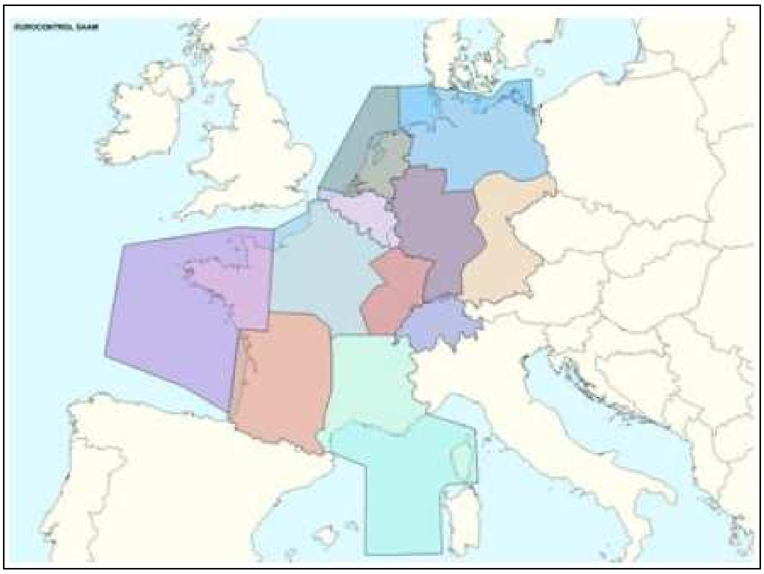


Figure 1. FABEC airspace.

The feasibility study report ([4]), delivered in summer 2008, reported that FABEC could improve air traffic management performance in the area. The report foresees that a 50 per cent growth in air traffic volume could be handled by 2018 at the same high level of safety. In addition, delays per flight could be kept low, and emissions reduced. A cost-benefit analysis showed a potential benefit for airspace users of 7,000 million EUR by 2025.

The validation of FABEC environment requires a series of Real time simulations punctuated with prototyping sessions (about 1 week long each) conducted over three years (2009-2012) for the following FABEC Hot Spots:

- Nattenheim (NTM) / Diekirch (DIK): Swap in direction of flights on UN852 and the UN853 (SWAP), the redesign of the Northern Area (NoAs) and the modification of CBA22 with the creation of a cross border military area between France and Germany;
- ARKON / REKEN (RKN): The redesign of the northern and southern parts of this complex airspace interfacing with several FABEC ACCs;
- KOKSY / Dover (DVR): The redesign of the interface between the FABEC and the FAB UK/IRELAND (e.g. the interactions between the London and Paris terminal areas).

1.4.2 SWAP Context

As stated, the introduction of FABs has encouraged airspace planning to be made at a regional level where the benefit to the wider network is identified rather than being restricted to that of individual ACCs.

During the FABEC feasibility study phase, one point for discussion was the so-called SWAP. Two major airways cross in the Nattenheim-Diekirch area (NTM/DIK), which is squeezed in between three military training areas in the triangle formed by France, Germany and Luxembourg. With the current ATS route network, flows of traffic on UN852 and UN853 cross twice, once in Brussels UIR airspace then again south of Geneva. Two TSA/CBAs restrict the volume of airspace available to Reims ACC for vectoring traffic. Changing the direction of flight has the potential to further reduce the airspace available to controllers for radar vectoring by altering the conflict/crossing points.

The original proposal to investigate the possibility of swapping the direction of flights on UN852 and UN853 predates the introduction of Functional Airspace Blocks. This double crossing of traffic flows was identified by the Airspace User Organisations as penalising in terms of flight efficiency and capacity and has been on their wish list of airspace improvements for a decade. This wish has been supported by the EUROCONTROL Route Network Development Sub-Group but to date a solution acceptable to all the

ACCs involved has not been found.

In addition, it is important to note that the SWAP proposal cannot be looked at in isolation. It is a significant part of a larger airspace redesign but the full benefit of the change in parity will only be realised when additional airspace improvements are made farther north. (Northern Airspace Working Group).

1.5 References

[1]. E-OCVM European Operational Concept Validation methodology (E-OCVM), Version 2 , 17 march 2007

[2]. SWAP Validation Strategy

[3]. SWAP Validation exercise plan

[4]. FABEC Creating the Functional Airspace Block Europe Central Feasibility Study Report, Version 2.0, 18 September 2008 (http://www.fab-europe-central.eu/fab/english/inhalt/download/feasibility_study_report_v2_0.pdf)

2 Experimental plan

This chapter summarises the SWAP validation exercise plan [2], and describes in particular real time simulation settings developed to validate the acceptability of the airspace changes induced by the SWAP project.

2.1 SWAP high level expectations

The change of the direction of flight on UN852 and UN853 and the removal of the two crossings of traffic flows is expected to reduce the number of crossing points. The SWAP has the potential to improve the ATS route network, segregate flows, shorten the track mileage and increase the capacity. The SWAP is also expected to reduce the safety risks associated to the two crossings of flows. However, the SWAP is not expected to fully solve the complicated traffic flows crossing on the N/S and E/W axis within MUAC airspace , but should be considered as a building block for future additional improvements of the airspace (e.g. in Northern Airspace) under development in other FABEC working groups. As a consequence, stakeholders did not expect benefits to be measured, but wished to prove that there was no detrimental impact.

2.2 Simulation objectives

The main stakeholders' expectations from the SWAP project were to assess the respective impact of the SWAP V1 and V2 in comparison with the current airspace (Baseline). In addition, an investigation into the feasibility of using higher flight levels for the transfer of flights between Reims and adjacent ACCs (Zurich, MUAC, CANAC, Paris and Geneva) was requested. This involved defining the transfer levels for specific destination airfields.

To meet these objectives, the RTS was broken down into two complementary sub-sessions with two different objectives Figure 2):

- Objective 1 (Week 1): Refinement/feasibility of the SWAP V1 and SWAP V2 airspaces in terms of transfer levels;
- Objective 2 (Week 2): Initial comparison of the refined SWAP V1, SWAP V2 and a Baseline (current airspace including HARMONIE ATS routes).

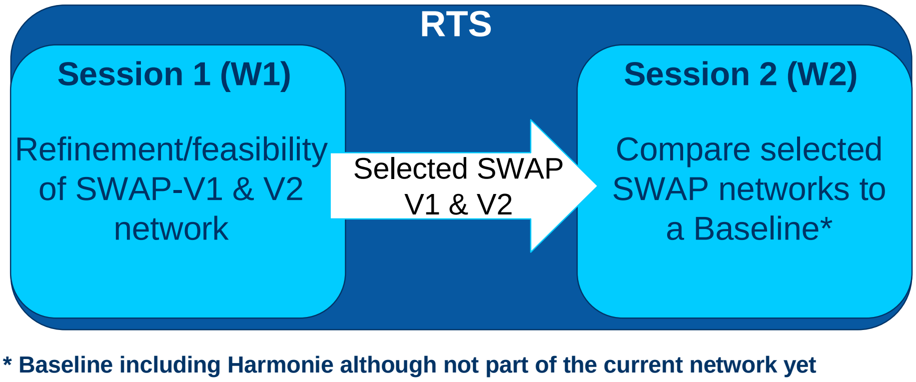


Figure 2. Organisation of SWAP RTS objectives.

Note: the outcomes from the first objective (the most feasible and acceptable configuration of transfer levels for SWAP V1 and V2 airspaces) was used as input to assess the primary objective of comparing networks.

2.2.1 High level objectives

The identified high level objectives are listed below:

- Operability: Feasibility, acceptability and compatibility;
- Safety: Workload and situation awareness;
- Efficiency: Flight efficiency and quality of service;
- Military mission effectiveness: Military flight efficiency;
- Capacity: Airspace able to cope with high traffic load.

2.2.2 Low level objectives

For each of the simulation objective, high level objectives are decomposed into lower level ones, as reported in Table 1, with an indication of the simulation objective addressed (SO1 and SO2).

For further details, refer to SWAP Experimental Plan document ([3]).

Table 1. Low level validation objectives per KPA, high level and simulation objectives (SO).

KPA	High level objectives	Low level objectives	SO
Operability	Feasibility	To assess the respective suitability of both the SWAP airspaces from the civil and military perspectives.	1-2
		To assess the feasibility of achieving transfer levels	1
		To assess the compatibility between civil and military networks.	1
		To compare the compatibility between civil and military networks in the 3 airspaces Baseline, SWAP V1 and V2.	2
	Workload	To evaluate the respective impact of both the SWAP airspaces on controllers' workload.	1
		To compare the controllers' workload in the 3 airspaces Baseline, SWAP V1 and V2.	2
		To evaluate the respective impact of the different configuration of transfer levels on controllers' workload.	1
	Acceptability	To determine the most acceptable configuration of transfer levels in terms of achievement (transferring sectors) and reception (receiving sectors)	1
Safety	Workload	See above.	1-2
	Situation awareness	To assess the respective impact of the both the SWAP airspaces on controller situation awareness.	1
		To compare the controllers' situation awareness in the 3 airspaces Baseline, SWAP V1 and V2.	2
	Level of safety	To assess the safest SWAP airspaces in terms of bunching area.	1
		To compare the 3 airspaces in terms of bunching/conflict areas.	2
Efficiency	Flight efficiency	To assess the most efficient SWAP airspaces from airlines perspectives (distance and time flown)	1

		To compare the 3 airspaces from airlines perspectives (distance and time flown)	2
	Quality of service	To assess which of the configuration levels options provides the best quality of service in terms of respect of delivery conditions (Flight level).	1
		To compare the quality of traffic delivery (flight level) in the 3 airspaces Baseline, SWAP V1 and V2.	2
Military mission effectiveness	Military flight efficiency	To assess military flight efficiency within both SWAP airspace	1
		To compare military flight efficiency in the 3 airspaces Baseline, SWAP V1 and V2.	2
Capacity	Workload	See above.	1-2

2.3 Simulated environment

2.3.1 Airspace

2.3.1.1 General sectorisation

The simulation airspace included all or parts of the Swiss, French, German and Belgian FIR/UIRs. It was based on current (April 2010) Reims, Geneva, Zurich, Paris sectors and French military areas (Figure 3). Sectors from MUAC and CANAC ware collapsed to create areas for feed sectors.

In this context, 3 variants of the airspace were simulated in the RTS:

- Baseline or;
- SWAP V1 or;
- SWAP V2.

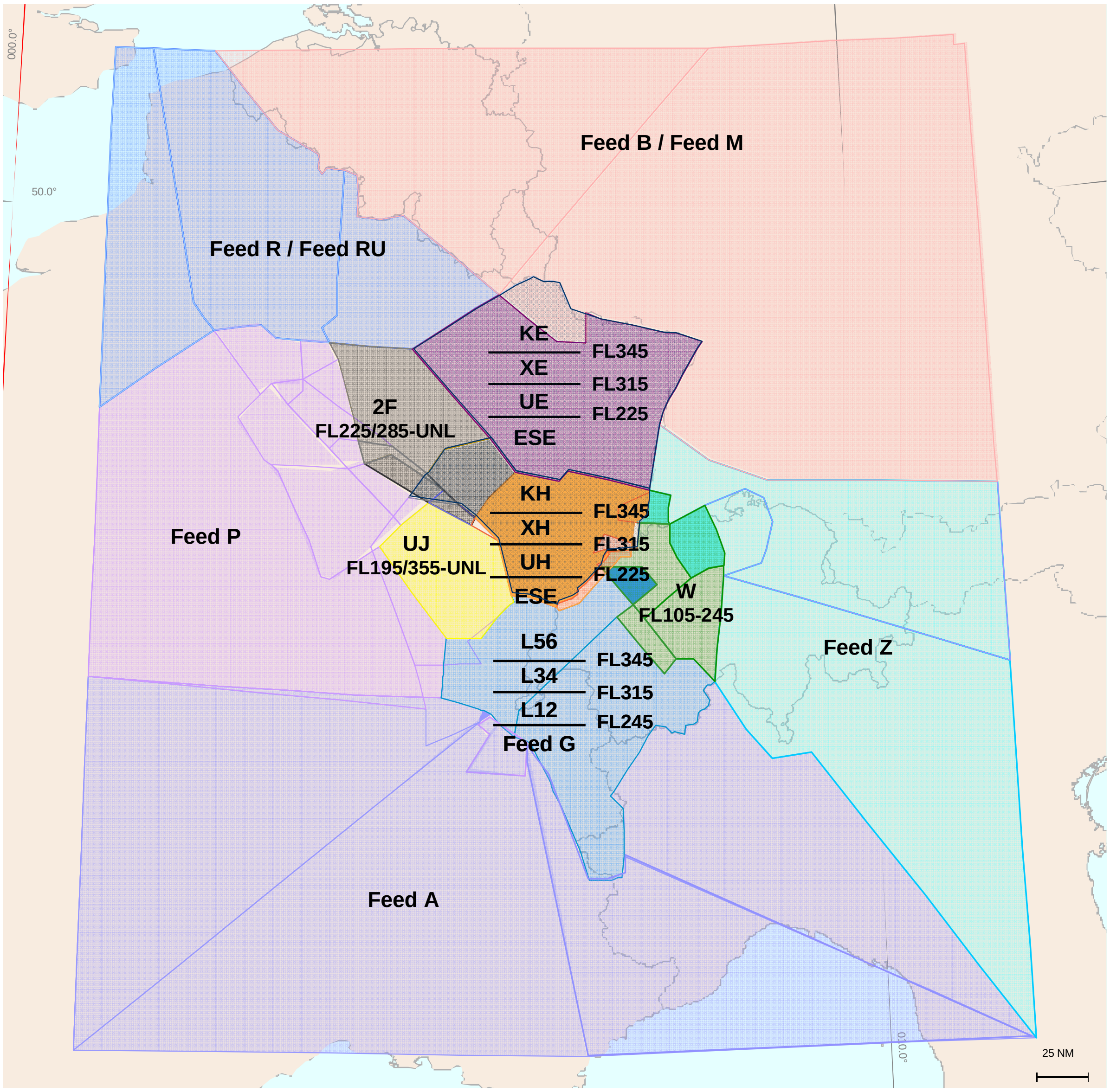


Figure 3. Overall map of simulated airspace (civil).

2.3.1.2 *Baseline (V0)*

The Baseline airspace included the current route structure for all the ACCs with the flows of traffic on UN852 and UN853 crossing twice, once in Brussels UIR airspace (at DIK) and again south of Geneva (Figure 4). TSA200 / TSA200REW (north west)[1] was included in the V0 airspace although it will not be in place until the implementation of the HARMONIE project (HARMONIE - Paris Airspace re-organisation-).

In addition, routes developed within the HARMONIE project were included at the interface between Paris and Reims ACC although they were not part of the current network.

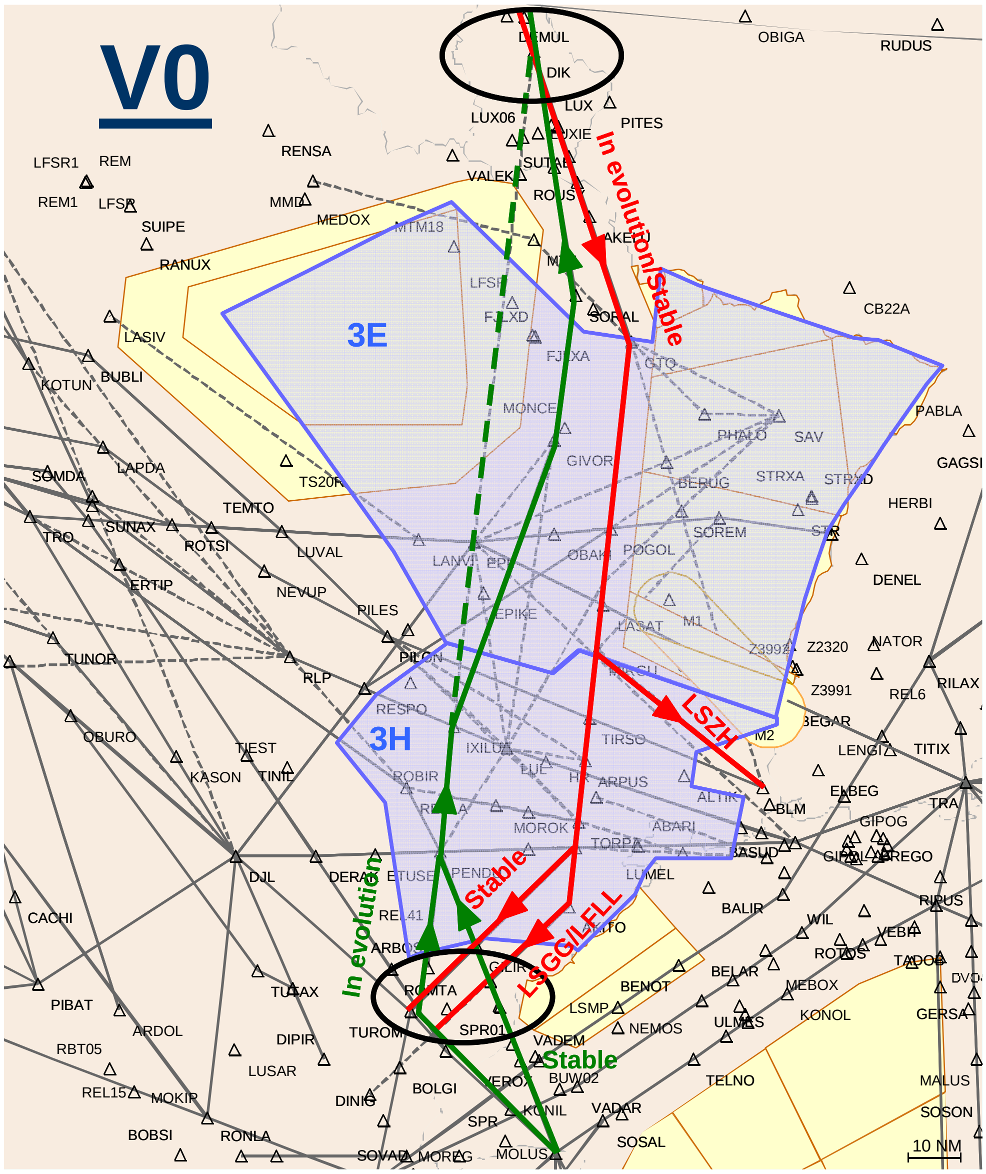


Figure 4. Northbound and southbound flows in Baseline airspace.

2.3.1.3 *SWAP V1*

The SWAP V1 airspace (Figure 5) represents one option for the change to the direction of flight on

[1] TSA200/TSA200REW is the proposed military areas to replace current TSA20 according to Harmonie project, in order to provide slightly more space to civil in the south of the area..

UN852 and UN853 and includes changes to the Reims, Zurich and Geneva sectors (reshaped to accommodate the SWAP). This option does not require modifications for Geneva Approach airspace as the SWAP V1 network connects to the existing SIDs/STARs for Geneva airport.

Compared to the Baseline airspace, it included the following modifications:

- For Reims and Geneva:
    - o Flow of stable aircraft going southbound (in red) is swapped from east to west and separated from the flow in evolution from the north of 3E sectors. .
    - o Northbound flows (in green) are located in the middle with a route created for Geneva and Lyon departures separated from aircraft in level flight.
- For Paris: The route ETUSE-TIEST was created in order to avoid strategic conflict at the sector entry.
- For MUAC and CANAC: Northbound and southbound flows are swapped (northbound to east and southbound to west).
- For military, the CBA22 (north east) is enlarged to the north and to the east (still under negotiation within the CBA22 Working Group).

SWAP V1 provides a limited swap of northbound and southbound routes as southbound flow of aircraft in evolution (in red) still crosses northbound flow (in green).

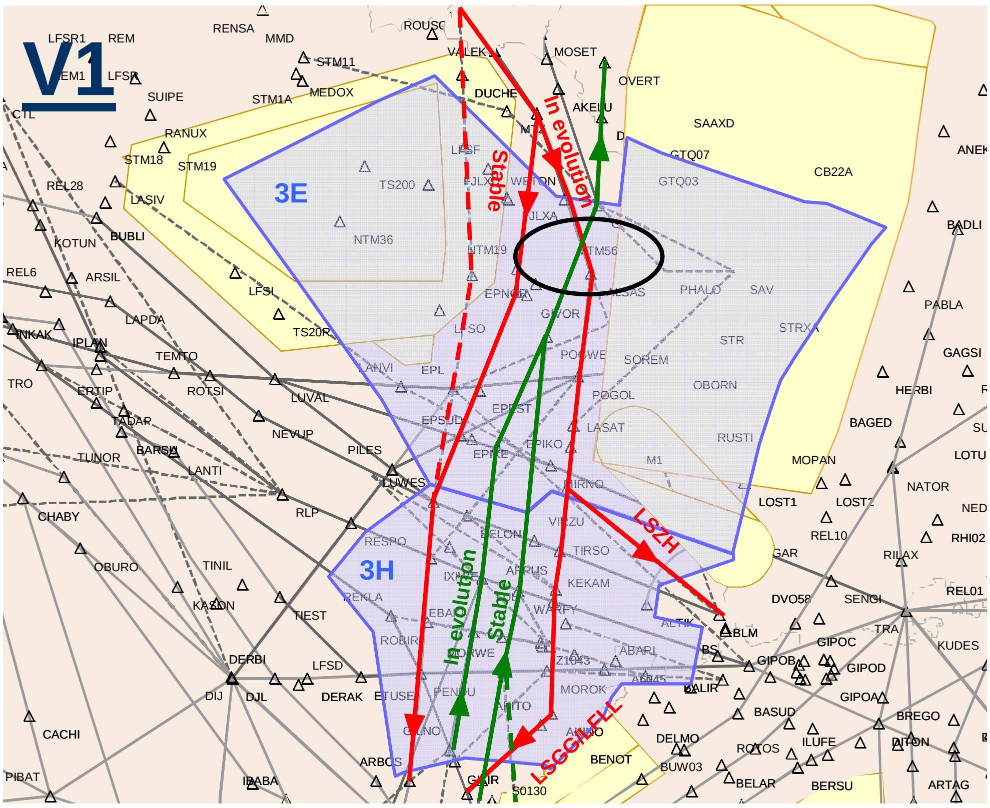


Figure 5. Northbound and southbound flows in SWAP V1 airspace.

2.3.1.4 SWAP V2

The SWAP V2 airspace (Figure 6) represents the second option for the change to the direction of flight on UN852 and UN853 and included changes to the Reims, Zurich and Geneva sectors (reshaped to accommodate the SWAP). This option does not connect to the existing SIDs/STARs (to/from the north) for Geneva airport and therefore will require the development of new arrival and departure routes[2].

Compared to the Baseline airspace, it included the following modifications:

- For Reims and Geneva:
  - o Both flows of stable aircraft and aircraft in evolution going southbound (in red) are fully swapped from east to west. Aircraft in cruise and aircraft landing LSGG and LFLL are separated within 3E sectors (at EPEST). New SIDs and STARs will be required to accommodate this new route.
  - o Northbound flows (in green) are fully swapped from west to east.
- For Paris: The route ETUSE-TIEST was created in order to avoid strategic conflict at the sector entry.
- For MUAC and CANAC: Northbound and southbound flows are swapped (northbound to east and southbound to west).
- For military, the CBA22 (north east) is enlarged to the north and to the east (sill under negotiation within the CBA22 Working Group).

SWAP V2 provides a full swap of northbound and southbound routes.

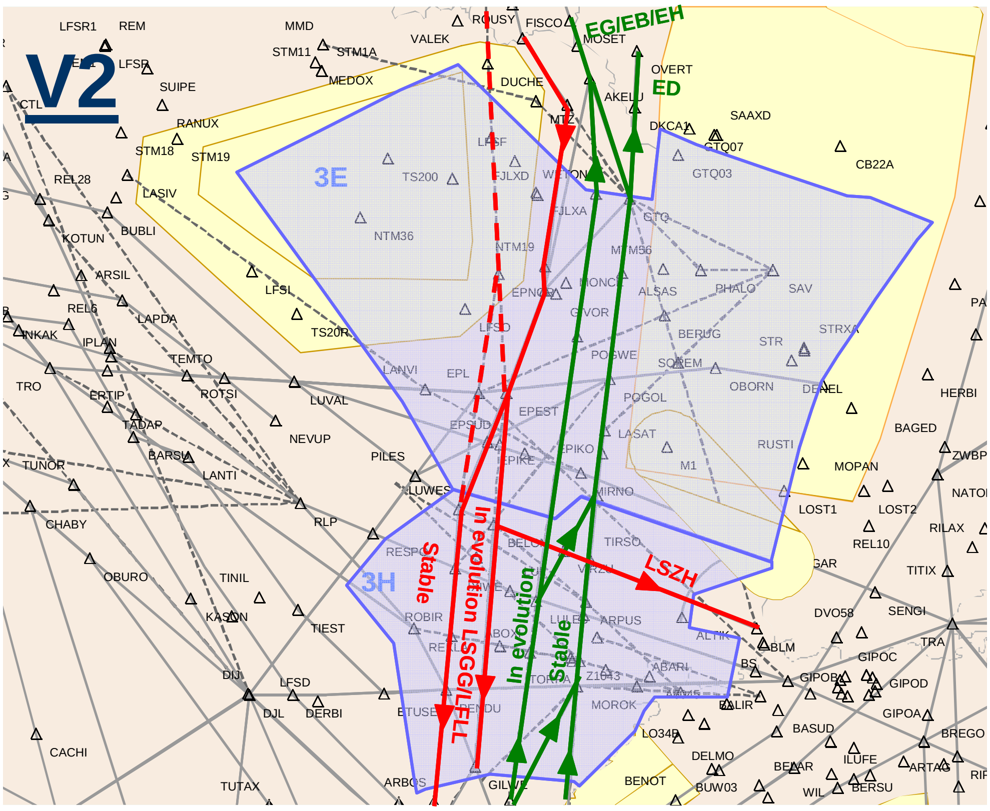


Figure 6. Northbound and southbound flows in SWAP V2 airspace.

2.3.2 Measured and feed sectors

The simulated airspace comprised 13 En-Route measured sectors and 7 En Route feed sectors (Table 2). In addition, 2 military sectors were measured. Each civil measured sector was manned as in current ACC operations (with 1 Executive and 1 Planning controller). Most of the feed sectors were manned by 1 Executive controller to ensure coordination and correct delivery conditions to measured sectors. Two feed sectors were automated using script for traffic delivery (Feed A for Geneva and Feed RU for Reims).

[2] The design of these routes is under the responsibility of Skyguide.

As a result, at least 36 controllers were required to man the sectors.

Table 2. Measured and feed sectors.

ANSP	Centre	Sector Code	Sector Type	Category	Vertical Limits	Nb. position
Skyguide	Geneva	L12	Measured	En-Route	FL245 - 315	2 (EXC, PLC)
		L34	Measured	En-Route	FL315 - 355	2 (EXC, PLC)
		L56	Measured	En-Route	FL355 - UNL	2 (EXC, PLC)
		Feed G	Feed	-	-	1 (EXC)
		Feed A	Feed	-	-	Automatic
	Zurich	W	Measured	En-Route	FL105 - 245	2 (EXC, PLC)
		Feed Z	Feed	-	-	1 (EXC)
DSNA	Reims	UH	Measured	En-Route	FL225 - 315	2 (EXC, PLC)
		XH	Measured	En-Route	FL315 - 345	2 (EXC, PLC)
		KH	Measured	En-Route	FL345 - UNL	2 (EXC, PLC)
		UE	Measured	En-Route	FL225 - 315	2 (EXC, PLC)
		XE	Measured	En-Route	FL315 - 345	2 (EXC, PLC)
		KE	Measured	En-Route	FL345 - UNL	2 (EXC, PLC)
		2F	Measured	En-Route	FL225/285-UNL	2 (EXC, PLC)
		ESE	Measured	En-Route	FL145 - 225	2 (EXC, PLC)
		Feed R	Feed	-	-	1 (EXC)
		Feed RU	Feed	-	-	Automatic
	Paris	UJ	Measured	En-Route	195-355, 355-UNL	2 (EXC, PLC)
		Feed P	Feed	-	-	1 (EXC)
FAF	Drachenbraun	MIL1	Measured	En route military	-	1 (EXC)
		MIL2	Measured	En route Military		1 (EXC)
Belgocontrol	CANAC	Feed B	Feed	-	-	1 (EXC)
Eurocontrol	MUAC	Feed M	Feed	-	-	1 (EXC)
						Total= 36

2.3.3 Segregated areas

The simulated restricted areas CBA25 (C and D), TSA200 (including TSA200REW) and CBA22 (A and B) were active during the simulation (Figure 7). Military traffic was controlled by 2 military controllers using the current military network, or radar vectors regardless of the SWAP airspace.

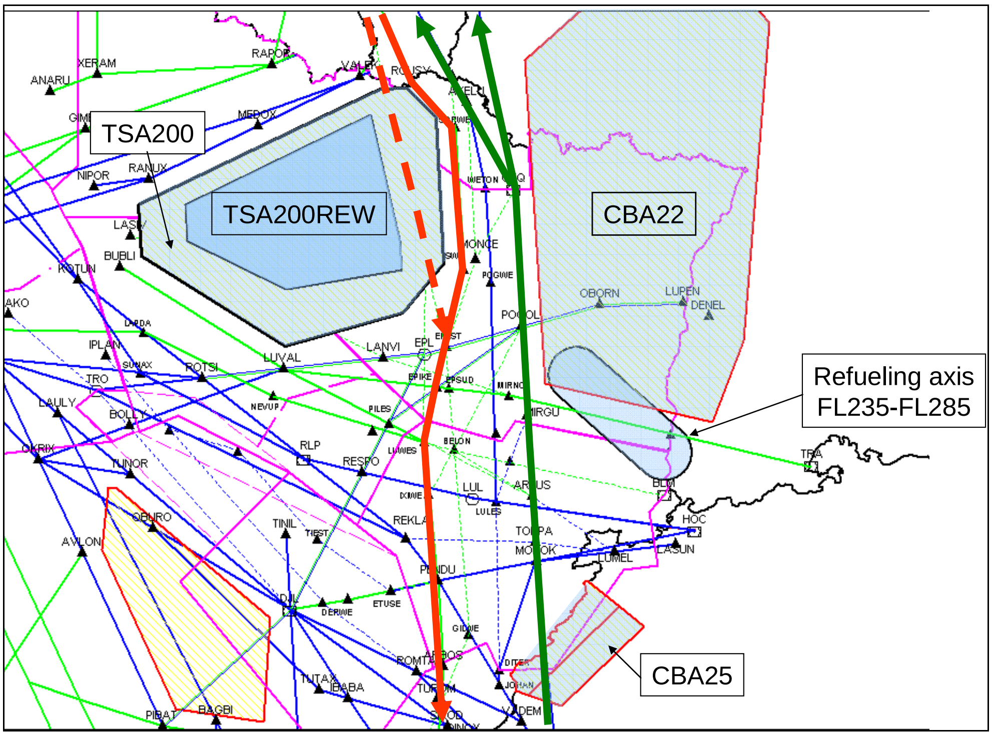


Figure 7. Restricted areas with the two main SWAP V2 flows (red and green) in Reims.

To assess various military activity conditions, it was decided to start the run with largest restricted areas active and then progressively reduce them during the run. The restricted areas were considered as active or inactive during each run as described in Figure 8.

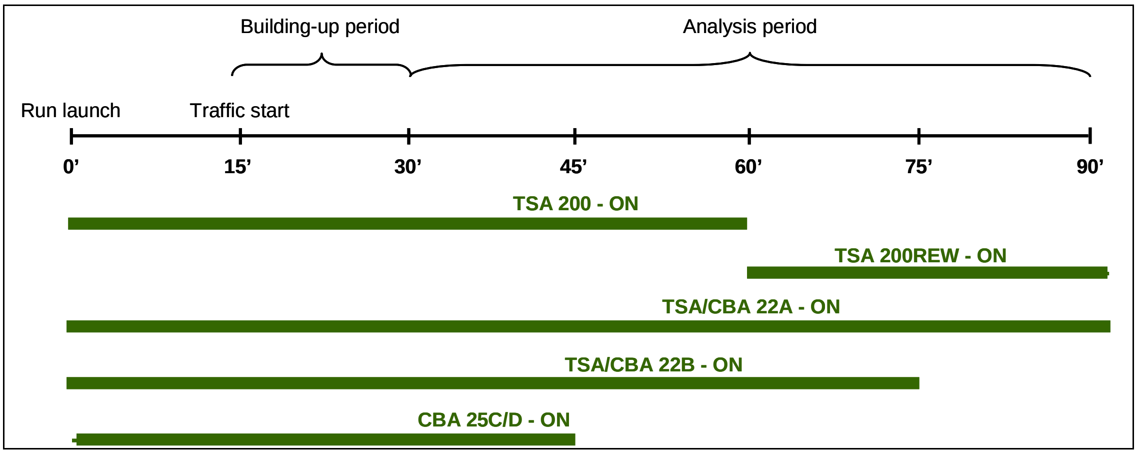


Figure 8. Restricted areas activity periods.

2.3.4 Separation standard

Table 3. Horizontal and vertical separation minima.

Horizontal Separation		Vertical separation	
Application	**Separation**	**Application**	**Separation**
En-Route	5 NM	Above FL410	2000 FT
		Below FL410	1000 FT (RVSM)

2.3.5 Meteo

The general meteorological conditions are described in Table 4. To accommodate request from Paris ACC, an additional wind scenario (north wind) was prepared.

Table 4. General meteorological conditions.

METEO Condition	Environmental Setting
Temperature	15°C
Wind	230°/15 kts (at ground level) or 0°/15 kts (at ground level)
Atmospheric Pressure (QNH)	1013.2

2.3.6 Traffic

The simulated traffic contained a combination of civil and military traffic. All the traffic samples were validated by FABEC representatives during a series of validation sessions and by a pool of controllers during pre- acceptance and acceptance tests.

They contained aircraft with capabilities and performances as close as possible to the current levels. To fit with current aircraft performances and behaviour, the BADA aircraft performance model have been modified using real radar data (e.g. different rate of climb according to airlines although same aircraft type)

2.3.6.1 Civil traffic samples

Civil traffic samples used for the RTS were derived from the actual traffic on the 27th of June 2008. This 24h traffic sample taken from CFMU was cut into two timeframes (07:00 to 09:00 and 16:00 to 18:00) to obtain AM and PM traffic samples. These samples were assigned to the three networks (Baseline, SWAP V1 and V2) on SAAM and then validated by the FABEC experts.

The SWAP RTS Core team, including ACC representatives, increased traffic levels to load sectors not considered busy enough during the measured period. This was done to test the new SWAP airspaces in demanding conditions including complex situations although it was stressed that this could lead to “unrealistic” situations (e.g. high traffic load). It should be emphasised that the same additional flights were included in all equivalent samples to ensure direct comparison between the different simulated networks. As a result, both AM and PM traffic samples include ~290 flights.

Note: the aircraft routeings included the availability of CDRs in accordance with the activation and deactivation of military airspace.

2.3.6.2 Military traffic samples

The military traffic was developed independently by the military representatives, for each of the simulated airspaces. It included ~20 military flights performing different missions (e.g. from base to refuelling area, transit flights etc.).

2.3.7 Controllers tasks and roles

During the measured runs, the participants had to perform the following tasks:

- Civil controllers' tasks: Handle the traffic as today either within the Baseline or SWAP airspaces, i.e. sequencing arrivals/departures in terminal sectors and crossing overflights in En-Route sectors.
- Military controllers' tasks: Deliver traffic to/from the airbases (Dijon, Nancy, St Dizier, and Luxeuil) to the CBAs/TSA/TRA and control traffic transiting between the airbases.
- Feed controllers' tasks:
    - o Respond to inbound co-ordination requests and instruct the pilots according to the co-ordination requests;
    - o Ensure correct delivery condition to measured sectors (e.g. deconflicting traffic);
    - o Avoid issuing direct instructions to aircraft;
    - o Climb or descend aircraft when prompted by the system to do so (failure to do this could result in wrong sector sequence and interfere with analysis in the measured sectors).
- All controllers on measured sectors: When prompted, assess perceived level of workload using the ISA box[3].

[3] Device enabling the Instantaneous Self Assessment of workload, see 2.4.4.

2.3.8 Simulation platform

2.3.8.1 Room layout

The room layout is illustrated in Figure 9 below.

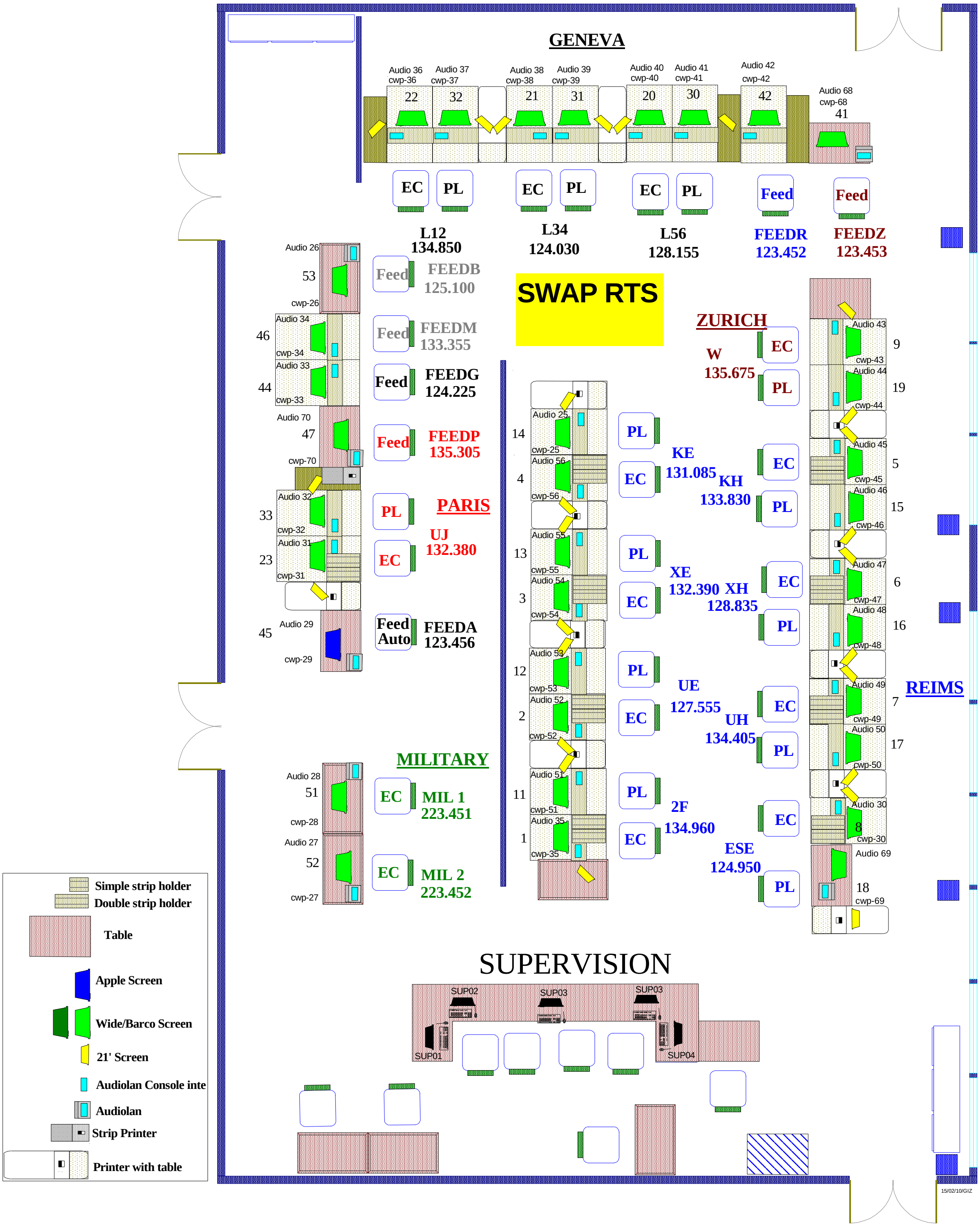


Figure 9. Simulation room layout.

2.3.8.2 Controller working position and HMI

The environment and HMI were defined in collaboration with FABEC ACC representatives. They were as close as possible to the current environment (only minor differences) With the exception of Geneva controllers who work with a stripless environment, all sectors made use of progress strips.

Each controller working position was equipped with:

- A BARCOTM or WIDE LCD 2k*2K monitor, with a multi-window working environment;
- A three-button mouse;
- A digital voice communication system (Audio-LAN) with a headset, a footswitch and a panel-mounted push-to-talk facility;
- An ISA (Instantaneous Self-Assessment) subjective workload input device.

2.3.8.3 Simulator piloting/pseudo pilots

The simulator ‘pilots' have the ability to answer and execute controllers' orders through simplified pilot position. However, some simulator simplifications/limitations (e.g. one pilot handling up to a dozen aircraft at once and limited radar screen view) can lead to pilots' mistakes (e.g. callsign confusion) and slow response times.

2.4 Experimental design

2.4.1 Experimental variables

The experimental design of the whole RTS is built around 2 main variables: Airspace (ATS route network, sectorisation and military airspace) and transfer levels.

- Airspace with 3 modalities:
    - o Baseline (V0);
    - o SWAP V1 (V1);
    - o SWAP V2 (V2).

The three modalities of this variable were used to assess both simulation objectives.

- Configurations of transfer levels with four modalities:

The transfer levels concerned the agreed levels from Reims to the adjacent centres (Zurich, MUAC, CANAC and Paris[4]). The four configurations of transfer levels are illustrated in Table 5 below with detailed transfer levels used in each modality in Table 6.

[4] It was not necessary to define options for the transfer levels between Reims and Geneva ACC. The relevant transfer levels had been tested in the Prototype Simulation and were designed to take account of the FL and distance to Geneva airport.

Table 5. Modalities of transfer level tested from Reims.

Zurich	CANAC/MUAC	Paris	
Current: FL200 at BLM	Current: descent to agreed FLs	Current: At odd with max 350	C1
FL230 before BLM	In level flights	All FLs with max of FL350 (+ LFPO odd 350 Max)	C2
Current: FL200 at BLM	At intermediate FLs	At even FLs with max of FL340 (+ LFPO odd 350 Max)	C3
Current: FL200 at BLM	Current: descent to agreed FLs	At even FLs with max of FL340 (+ LFPO odd 350 Max)	C4

Table 6. Detailed transfer levels.

ADES	C1		C2		C3		C4	
	Point	From SAAM (current FLs)	Point (varies - V1 or V2)	(FABEC delivery FLs)	Point (varies - V1 or V2)	(Interm. delivery FLs)	Point (varies - V1 or V2)	(Interm. delivery FLs)
Reims / CANAC or MUAC								
EBBR/ EDDL /EDLV/EDL W/EHEH/ ETNG	DIK/ AKELU	FL 320 Max	GTQ/ AKELU/ OVERT	RFL	GTQ/ AKELU/ OVERT	FL 340 Max	DIK/ AKELU	FL 320 Max
EDDK	DIK/ AKELU	FL 300 Max	GTQ/ AKELU/ OVERT	FL 320 Max	GTQ/ AKELU/ OVERT	FL 300 Max	DIK/ AKELU	FL 300 Max
EBLG	DIK/ AKELU	FL 240 Max	GTQ/ AKELU/ OVERT	FL 280 Max	GTQ/ AKELU/ OVERT	FL 240 Max	DIK/ AKELU	FL 240 Max
EDFH	DIK/ AKELU	FL 200 Max	GTQ/ AKELU/ OVERT	FL 240 Max	GTQ/ AKELU/ OVERT	FL 240 Max	DIK/ AKELU	FL 200 Max
ELLX	DIK/ AKELU	FL 160 Max	GTQ/ AKELU/ OVERT	FL 160 Max	GTQ/ AKELU/ OVERT	FL 160 Max	DIK/ AKELU	FL 160 Max
EBCI	DIK/ AKELU	FL 320 Max	GTQ/ AKELU/ OVERT	FL 320 Max	GTQ/ AKELU/ OVERT	FL 340 Max	DIK/ AKELU	FL 320 Max
EDDF	DIK/ AKELU	FL 320 Max	GTQ/ AKELU/ OVERT		GTQ/ AKELU/ OVERT	FL 340 Max	DIK/ AKELU	FL 320 Max
EDLN	DIK/ AKELU	FL 240 Max	GTQ/ AKELU/ OVERT	FL 320 Max	GTQ/ AKELU/ OVERT	FL 280 Max	DIK/ AKELU	FL 240 Max
EHBK	DIK/ AKELU	FL 240 Max	GTQ/ AKELU/ OVERT	FL 320 Max	GTQ/ AKELU/ OVERT	FL 280 Max	DIK/ AKELU	FL 240 Max

Reims / Paris								
LFPG/LFPO/LFOB	PENDU	FL 350 Max ODD FLs	PENDU	FL 350 max Odd + Even FLs	PENDU	FL 340 Max EVEN FLs	PENDU	FL 340 Max EVEN FLs
Reims / Zurich								
LSZH	BLM	FL200 Max	BLM	FL 230 Max Released 15nm before BLM	BLM	FL 200	BLM	FL200 Max

2.4.2 Experimental conditions

Both variables were crossed to address both simulation objectives, i.e. to retain the most acceptable transfer levels for each SWAP airspace (objective 1 - Week 1) and to compare retained SWAP airspaces to a Baseline (objective 2 - Week 2).

2.4.2.1 Objective 1

First, the V0 (Baseline) airspace was only crossed with C1 transfer level configuration corresponding to current situation. Then to address the first objective, the SWAP V1 and V2 variables were fully crossed with the 4 transfer level conditions in order to test as many configurations as possible. This results in the 9 following conditions (Table 7).

Table 7. Experimental conditions for objective 1.

	Airspace		
Transfer level configuration	**Baseline (V0)**	**SWAP V1**	**SWAP V2**
C1	V0C1	V1C1	V2C1
C2	**-**	V1C2	V2C2
C3	**-**	V1C3	V2C3
C4	**-**	V1C4	V2C4

2.4.2.2 Objective 2

To address the second but primary objective, the 4 following conditions were tested (Table 8). As the conditions tested for the second objective result from the achievement of the first objective, the rationale for the choice of these conditions is discussed in the results chapter (see §0 and 4.2.3).

Table 8. Experimental conditions for objective 2.

	Airspace		
Transfer level configuration	**Baseline (V0)**	**SWAP V1**	**SWAP V2**
C1	V0C1	-	V2C1
C2	**-**	-	-
C3	**-**	V1C3	V2C3
C4	**-**	-	-

2.4.3 Other variables

Other variables were introduced in order to prevent controllers from becoming over familiar with the traffic scenarios:

- Controller position: Where possible each controller manned the Executive and Planner controller positions on the different sectors the same number of times;
- Traffic samples: Different but comparable[5] traffic samples were used in order to prevent the controllers from becoming over familiar with the traffic scenarios. This also allowed the data from the two samples to be grouped and analysed together for each condition;

Wind conditions: Two different wind conditions were defined:

- o West wind: 230°/15kt at ground level;
- o North wind: 0°/15kts at ground level.

2.4.4 Measurements

The measurements were made over an analysis period of 1h and consisted of:

- Subjective assessment collected through questionnaires and debriefing conducted with the participants at the end of each run and at the end of each week;
- Objective measurements collected through simulator and system recordings (ISA ratings, aircraft data and Telecom).

Note: Due to the limited number of runs, it should be emphasized that the results of the RTS should be considered as initial trends rather than statistical results.

To assess the simulation objectives, a set of metrics was defined. Considered as dependent variables, each metric is expected to provide an indication on one or more KPA, as summarised in Annex A.

[5] The traffic variations were matched as far as possible in terms of load and complexity. The two AM and PM samples presented the similar characteristics (same load level, same aircraft capabilities). Their difference mainly lay in aircraft callsigns and a slightly different structure of the traffic.

3 Simulation conduct

3.1 Simulation program and schedule

3.1.1 General program

The RTS was conducted over 2 weeks from the 19th to the 30th of April 2010 in EUROCONTROL Experimental Centre. It consisted of:

- Training session: Briefings and hands on exercises were conducted in order for participants to get familiar with the simulated environment and the airspaces options. This took place during the first day of the RTS;
- Measured session: 21 measured exercises of 1h15 each were performed over two weeks. An exercise program with rostered positions was published in the operations room. A typical daily schedule is shown in Table 9;
- Debriefings: held at the end of each exercise and at the end of the each week.

Table 9. Daily simulation program.

Daily programme	
0845	Set-up in Operations Room
0900 – 1015	**Exercise 1**
1015 – 1045	Debriefing and questionnaire
1045 – 1100	Break
1100 – 1215	**Exercise 2**
1215 – 1245	Debriefing and questionnaire
1245 – 1400	Lunch
1400 – 1515	**Exercise 3**
1515 – 1545	Debriefing and questionnaire

3.1.2 Detailed schedule of week 1

The objective of the first week was to retain most acceptable transfer levels for SWAP V1 and V2. After 4 short training runs on SWAP V1 and V2, the participants tested the four transfer level configuration (C1 to C4) with each of the SWAP airspaces during measured runs (Table 10). In addition, one Baseline (V0) was performed. The spare run on Friday morning was used to assess the impact of a north wind on the Paris pre-sequencing tasks.

The final debriefing and a dedicated meeting with the SWAP RTS Core Team was used to decide which condition to retain during the second week.

Table 10. Schedule conducted for RTS week 1.

Briefing	Training Run	Debriefing	Break	Measured Run

Time	19/04/2010	20/04/2010	21/04/2010	22/04/2010	23/04/2010
09:00	Welcome + Briefing	Measured Run 1 V0AMC1	Measured Run 4 V1AMC3	Measured Run 7 V2AMC2	Spare Run V2PMC1 (nw)
09:45					
		Debriefing + Questionnaire	Debriefing + Questionnaire	Debriefing + Questionnaire	Week 1 Debrief to decide on Week 2 conditions (selected options)
10:30	Training Run 1 V1AMC2	Break	Break	Break	
		Measured Run 2 V1PMC1	Measured Run 5 V1PMC4	Measured Run 8 V2PMC3	
	Debriefing				
11:45	Training Run 2 V2PMC2				
12:15		Debriefing + Questionnaire	Debriefing + Questionnaire	Debriefing + Questionnaire	
	Debriefing	Lunch	Lunch	Lunch	
12:45	Lunch				
13:45	Training Run 3 V2AMC1	Measured Run 3 V1AMC2	Debriefing V1	Measured Run 9 V2AMC4	
	Debriefing	Debriefing + Questionnaire	Measured Run 6 V2PMC1	Debriefing + Questionnaire	
15:00	Training Run 4 V1PMC3			Final Debriefing and questionnaire	
16:00	Debriefing		Debriefing + Questionnaire		
16:45					

3.1.3 *Detailed schedule of week 2*

The objective of the second week was to compare retained SWAP V1 and V2 airspaces to a Baseline. After a refresh run, 12 measured runs were performed on Baseline (V0), SWAP V1 and V2 airspaces (Table 11).

Table 11. Schedule conducted for RTS week 2.

Time	26/04/2010	27/04/2010	28/04/2010	29/04/2010	30/04/2010
09:00	Welcome + Briefing	Measured Run 3 V2AMC3	Measured Run 6 V0PMC1	Measured Run 9 V1PMC3	Measured Run 12 V2AMC1
09:45	Training/Refresh Run 1 V2AMC1				
		Debriefing + Questionnaire	Debriefing + Questionnaire	Debriefing + Questionnaire	Debriefing + Questionnaire
10:30	Break	Break	Break	Break	Break
11:00	Measured Run 1 V0AMC1	Measured Run 4 V2PMC3	Measured Run 7 V2AMC1	Measured Run 10 V2AMC3	Spare Run V2PMC3 (+odd G --> P)
12:15	Debriefing + Questionnaire	Debriefing + Questionnaire	Debriefing + Questionnaire	Debriefing + Questionnaire	Debriefing + Questionnaire
12:45	Lunch	Lunch	Lunch	Lunch	Final Debriefing and questionnaire
13:45	Measured Run 2 V2PMC1	Measured Run 5 V1AMC3	Measured Run 8 V2PMC1 (nw)	Measured Run 11 V2PMC'3 (nw)	
15:00	Debriefing + Questionnaire	Debriefing + Questionnaire	Debriefing + Questionnaire	Debriefing + Questionnaire	
16:00					
16:45					

3.2 Participants

At least 36 controllers over the two weeks simulations were required to man the sectors. Although it would have been preferable to have the same participants throughout the whole simulation, some participants could only attend to the first or the second week due to ACC internal constraints.

As a result, 45 controllers participated in the SWAP RTS as illustrated in Table 12.

Table 12. Participants' distribution.

	Geneva	Zurich	Reims	Paris	FAF	CANAC	MUAC
Number	8 (including 1 new during week 2)	4 (including 1 new during week 2)	18	11 (including 6 new during week 2)	2	1	1

Results provided in Table 13 show that most of the participants (>85%) were less than 40 year old (33 in average) with an average ATC experience of 8 years. In addition most of them were at least quite familiar with the SWAP prior starting the simulation, mainly through participation at the SWAP prototyping session (in November 2009) or platform acceptance tests (Figure 10).

Table 13. Participants' age and experience distribution.

	Age			ATC experience		
	30<	[30;40]	>40	5<	[5;10]	>10
Number	16	23	6	17	19	9
Average	33			8		

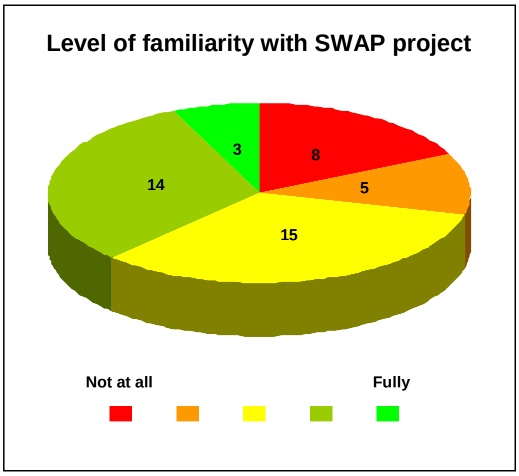


Figure 10. Participants' level of familiarity with SWAP project.

3.3 Controller seating plan

A seating plan was available in the operational room (Annex B). It considered, as far as possible, the following aspects (mainly possible for Reims due to the high number of positions and possible rotations):

- Ensured that each controllers worked on different positions all along the simulation;
- Ensured, as much as possible that each controller acted equally often as Executive and Planner controller on the different sectors;
- Ensured that each controller did not work on the same sector with the same traffic sample;

- (For Paris) Ensured that each controller saw the different delivery conditions from Reims to Paris as the executive controller in UJ sector.

3.4 Deviation from initial plan

Although the different transfer level conditions were agreed with the SWAP RTS Core Team before the RTS, during the first day of simulation the Reims representative asked for an additional one. As it did not imply technical modifications, the simulation team agreed to add a C4 condition including transfer from Reims to:

- Zurich: aircraft delivered at FL200 (as today);
- MUAC/CANAC: aircraft delivered in descent to agreed levels (as today);
- Paris: aircraft delivered at even levels (with FL340 max) except LFPO (Paris-Orly) arrivals that could be delivered at FL350.

3.5 Simulation caveats and limitations

Considering the simulation settings, the RTS includes limitations in terms from operational and validation perspectives.

From operational point of view, the following limitations were identified:

- MUAC and CANAC were feed sectors implying that no measurements were conducted in those sectors which will need additional investigation and possible simulations. Indeed, one of the current double crossings that should be removed by SWAP occurs in MUAC/CANAC airspace. As a consequence, not all the airspace impacted by the SWAP was assessed during this RTS. .
- Paris controllers acted in the sensitive context of the HARMONIE project that is yet to be implemented. Therefore, from the Paris perspective, the RTS investigated the compatibility between HARMONIE routes and the SWAP network (i.e. LOA between Reims and Paris for traffic delivery) rather than changes implied by SWAP V1 and V2 airspaces.
- As the Geneva representatives (part of the SWAP RTS Core Team) did not request the MTCD tool due to confidentiality issues, it was not available on Geneva positions although it is part of the controllers' current toolkit. During the simulation some controllers complained about the missing MCTD tool suggesting its absence reduced the realism of the simulated environment. .

From validation point of view, the following limitations were identified concerning:

- Traffic samples:
    - o Only 2 traffic samples (AM and PM) were used for 2 weeks of simulation. Although different airspaces were tested with controllers switching positions over the simulated positions (sectors and role), the low number of traffic sample could lead controllers to be "too familiar" with the traffic and to boredom or weariness.
    - o Although the AM and PM traffic samples were comparable in terms of global number of flights, the use of different airspaces (Baseline vs. SWAP V1 and V2) resulted in a different distribution of flights within the simulated sectors. As illustrated in Figure 11, some aircraft (~10) flying through ESE sector in Baseline airspace (V0C1) fly in the UE and XH sector in SWAP V1 (V1 C3) and SWAP V2 (V2C1 and V2C3) networks.

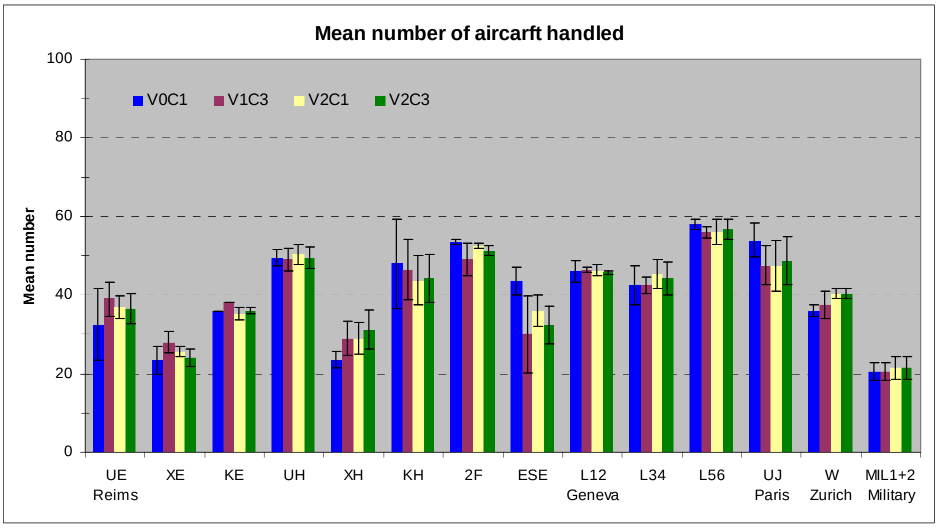


Figure 11. Mean number of aircraft handled per condition and per sector (objective 2).

- Analysis:
    - o Given the large number of controllers, simulated sectors and conditions tested, the experimental design can not ensure that the same controller acts in the same sector in all conditions. Therefore, the analysis is possibly subject to individual practices.
    - o Due to the large number of sectors and conditions and for comprehension and readability purposes, the analysis presented in this report remain at a macroscopic level, with all positions gathered in some graphs.
    - o During the first week of simulation, 9 different conditions were tested over 9 runs resulting in 1 run per condition. To prevent controllers from boredom, it was decided to use both traffic samples although it makes it harder to compare objective results (not the same traffic sample among the different conditions). Therefore, the results from the first week mainly focus on subjective data.

Given these limitations, the results described hereafter provide overall trends rather than statistical analysis.

4 Results

Following the executed simulation schedule, it was decided to start presentation of results with a summary of the main outcomes on the different simulated transfer levels (objective 1; week 1) prior focusing on the benefits/limitation of SWAP network compared to today (objective 2; week 2). Although transfer levels could be seen as a detailed part when validating a new airspace design, it allows being in line with the planned validation process (definition of the most appropriate transfer level for SWAP V1 and V2 to be then compared to a Baseline) and providing evidence on the choice made for the comparison. As a result, the core of the result part focuses on the primary objective of the SWAP RTS which was to compare SWAP and today's airspace.

4.1 General feedback on simulation settings

At the end of the simulation, the participants were asked to rate the quality of training provided and the level of simulation realism – i.e. whether the simulation environment was suitable enough to evaluate the impact of SWAP. Results provided in Figure 12 show first that the training was found appropriate to evaluate the SWAP "concept" (>60% of controllers rated the quality of training as high or very high). The simulation environment (e.g. HMI and traffic) was also found highly suitable by ~75% of participants to evaluate the SWAP. A few comments were made concerning the traffic that could have been more varied (i.e. with more traffic samples) and more complex. Some Geneva controllers also mentioned the lack of MTCD tool as a lack of realism. As was previously mentioned, due to confidentiality issues it was not possible to include this tool in the simulation.

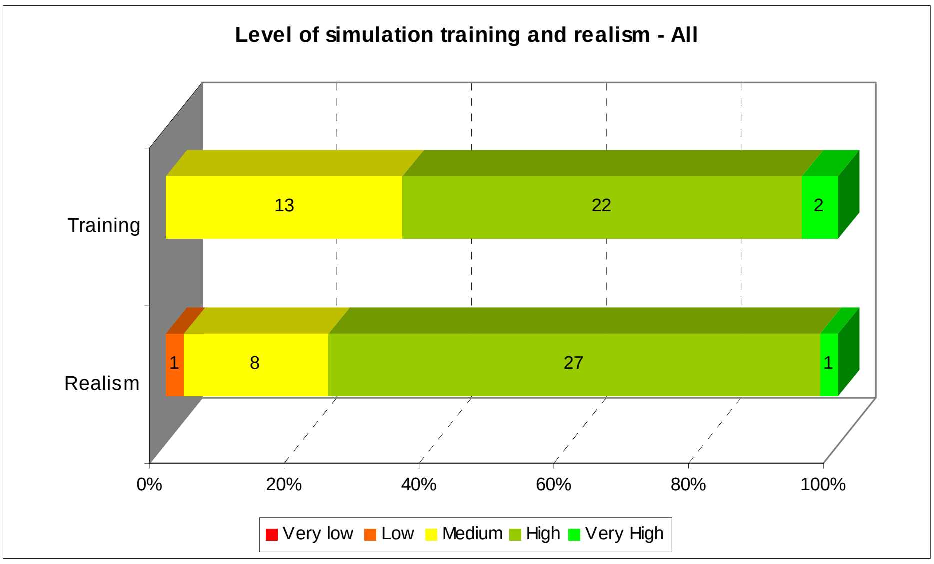


Figure 12. Post simulation ratings: Quality of training and simulation realism.

4.2 Objective 1: Transfer levels for SWAP airspaces

The following chapter mainly focuses on the simulated transfer levels between Reims and adjacent sectors: Zurich MUAC/CANAC, Paris and Geneva. Controllers feedback expressed on SWAP V1 and V2 during week 1 are included in chapter (0) as rather addressing the second objective.

As the core objective of the RTS remains the comparison between SWAP and today's airspaces, this chapter only summarises main outcomes on transfer levels. For readability purpose further details and figures concerning the transfer levels are provided in Annex C.

4.2.1 Feasibility of transfer levels

4.2.1.1 Workload

Results on workload obtained through different techniques (post run ratings, ISA ratings and frequency occupancy) show no clear differences among the transfer level configurations tested (C1 to C4) or simulated airspaces (V0, V1 and V2) at a macroscopic level. According to the participants, the overall workload among the measured sectors was medium and mainly due to traffic load.

4.2.1.2 Quality of delivery

To objectively assess the quality of delivery, the achieved flight level (FL) is compared to required FL over the delivery waypoint (Figure 13, Figure 14 and Figure 15)[6][7]. It addressed transfer levels from Reims to Zurich (Z), MUAC/CANAC (M), Paris (P) and Geneva (G). It is calculated over exit waypoint for Zurich, MUAC/CANAC and Geneva and at sector boundary for Paris arrivals.

Overall, the results provided in Figure 13 first show that the transfer levels were globally, well achieved: ~84% of aircraft delivered correctly out of a total of 370 aircraft. In addition, it can be observed that the quality of service (ability to achieve the agreed transfer level) was slightly improved with SWAP V2 (89% of correct transfer) compared to SWAP V1 (82%) and V0 (80%). Regardless of the airspace tested, it is observed that the main difficulty was to deliver traffic towards Zurich and to some extent Geneva.

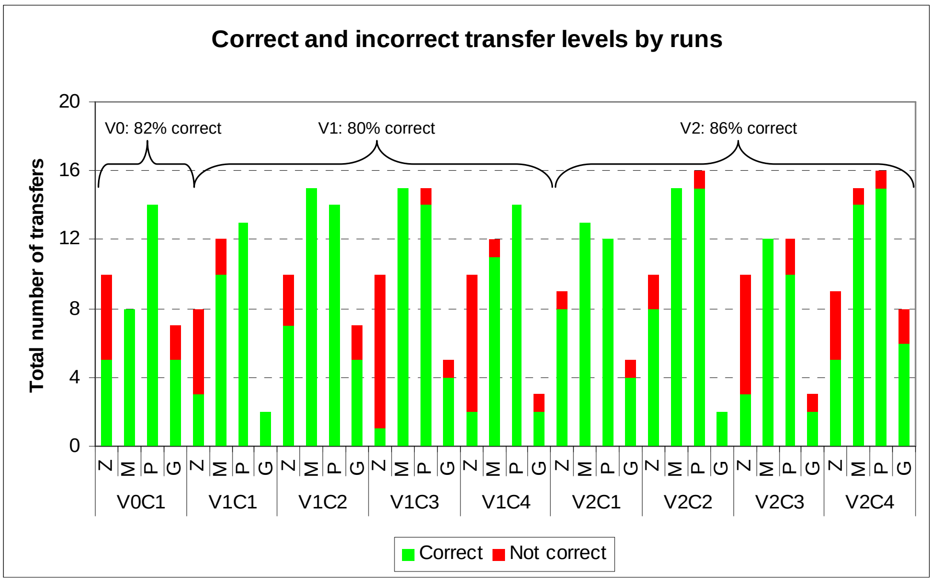


Figure 13. Quality of delivery from Reims to adjacent sectors per condition.

To assess the quality of delivery in greater details, Figure 14 represents the number of correct and incorrect transfer levels by specific transfer level/point instead of per condition as in previous figure. It is calculated over exit waypoint for Zurich, MUAC/CANAC and Geneva and at sector boundary for Paris arrivals. Note that a different number of runs were performed with a given transfer level (e.g. to Zurich, FL200 is part of C1, C3 and C4 (7 runs) whereas FL230 is only part of C2 (2 runs)).

In addition, the mean deviation compared to the required flight level is calculated only for the incorrect deliveries (Figure 15).

The results illustrated in Figure 14 show that the Reims controllers mainly experienced difficulties when

[6] For the purpose of analysis, it was considered that aircraft were delivered at the correct level if the achieved level was equal to or below the required flight level with a margin of 600ft (i.e. if (achieved level – 600ft) <= required level).

[7] Different transfer levels (from to what is expected) which have been coordinated between controllers during the RTS, could not be measured and therefore counted as an incorrect delivery level.

delivering traffic to Zurich. Globally, ~51% of aircraft were delivered above the required flight level over the waypoint BLM. In details, when FL200 was required ~60% of aircraft were delivered on average 3000ft above (Figure 15). Although it was obviously easier when FL230 was required, 25% of aircraft were still delivered 2000ft above. In addition, as in current situation, Reims controllers had problems delivering traffic to Geneva at the correct level: ~24% of aircraft were delivered ~1500ft above the required level.

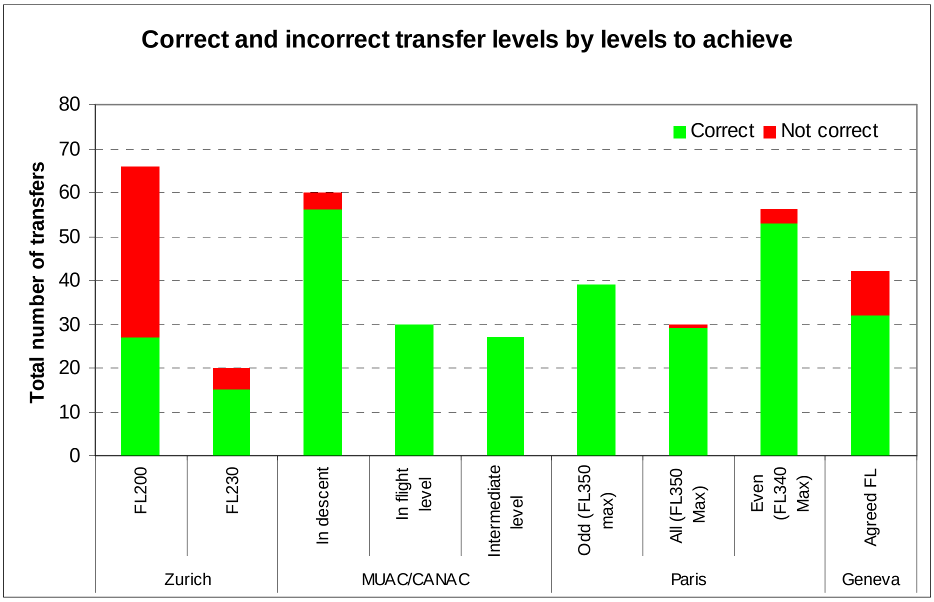


Figure 14. Quality of delivery from Reims per required flight level.

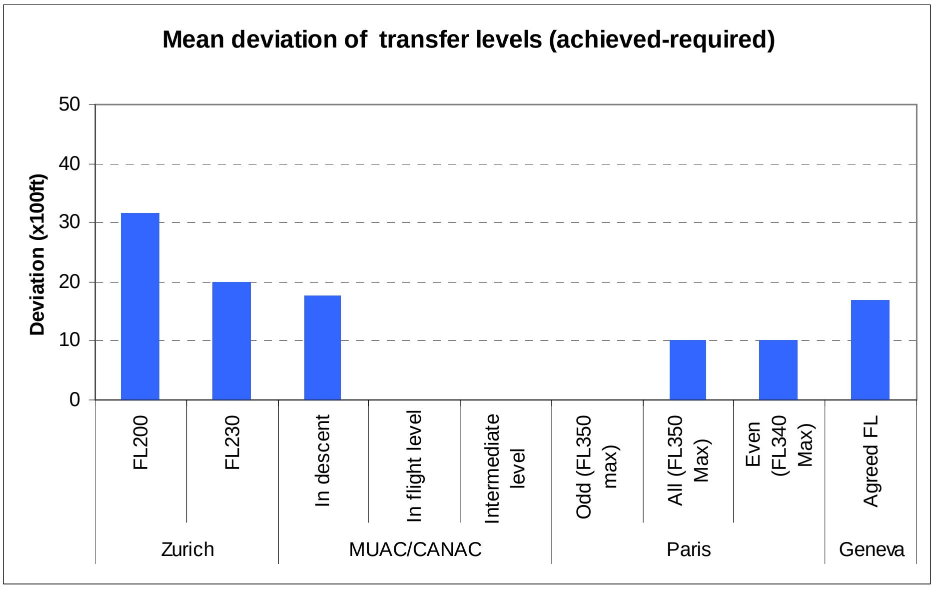
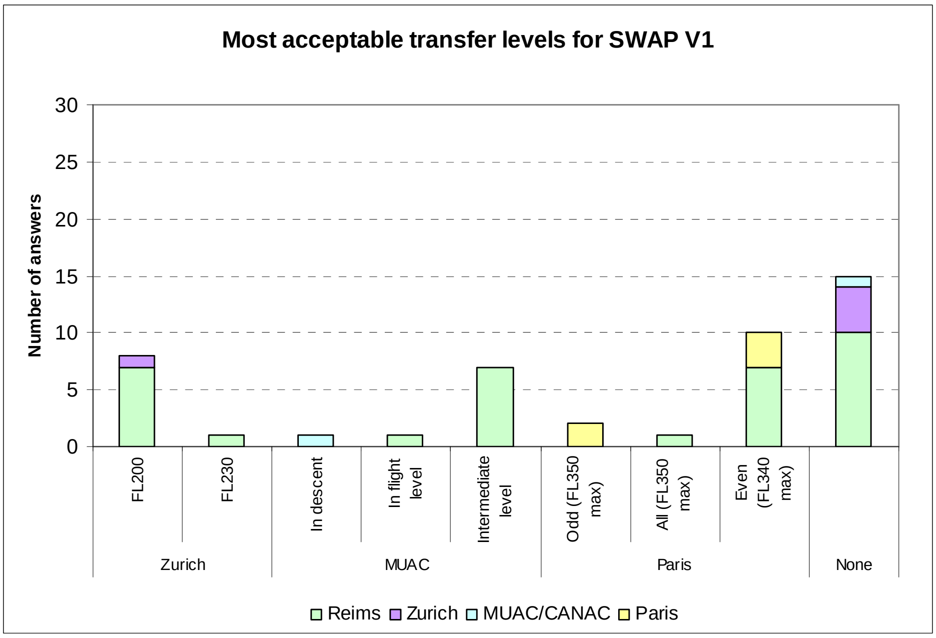


Figure 15. Mean deviation from required flight level when missed.

4.2.2 Acceptability of transfer levels

At the end of the first week of simulation, the controllers were asked to rate "their" most acceptable transfer levels for the SWAP V1 and V2 airspaces (Figure 16). These results were used as input to support the decision on which transfer levels should be included in SWAP airspaces (V1 and V2) when comparing them against a Baseline. Note that although the controllers rated for a given configuration (C1 to C4), their ratings are gathered according to each simulated transfer level as configurations provided redundancy (e.g. C1, C3 and C4 are the same for Zurich-FL200). In addition, only concerned centres (transferring and receiving) are represented in the graphic.

First, it is observed that 15 of 36 controllers did not choose any of the tested transfer level options for SWAP V1 airspace ("none" rating). This was because they did not consider the V1 network acceptable (Figure 16). However, results on the most acceptable transfer levels provide quite similar trends for SWAP V1 and V2. Detailed results for concerned centres are described below.



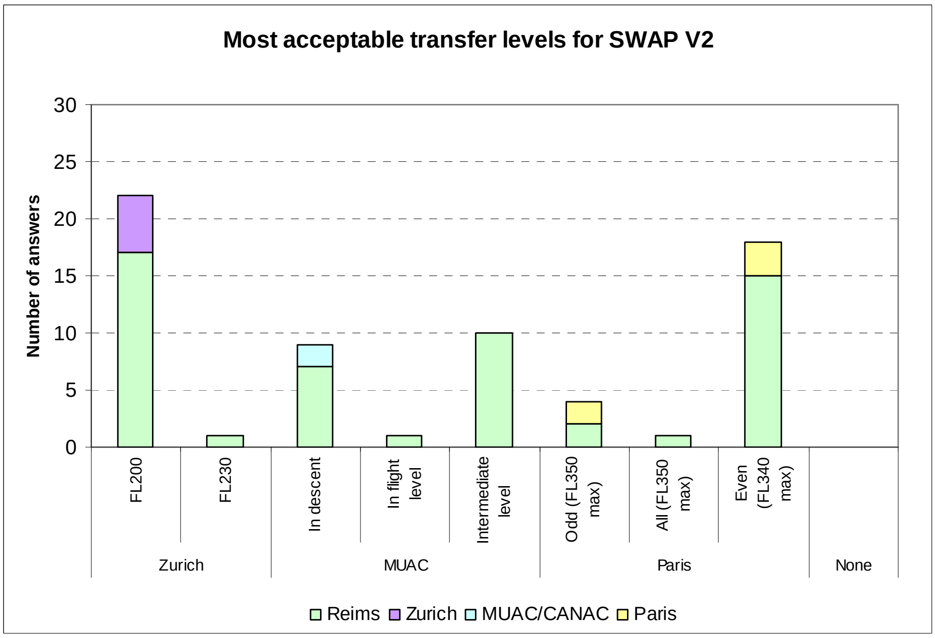


Figure 16. Post simulation ratings: Most acceptable transfer levels in SWAP V1 (top) and SWAP V2 (bottom) airspaces.

4.2.2.1 Delivery Reims/Zurich

Both Reims and Zurich centres agree that FL200 over BLM waypoint (as today) was the most acceptable transfer level for both SWAP V1 and V2 airspaces (Figure 16). Indeed, FL230 was considered too high by the Zurich controllers as they had insufficient time and airspace to pre-sequence and descend LSZH arrivals. The Reims controllers suggested that a release area or procedure could be defined in Reims airspace to allow the UH sector to transfer flights directly to Zurich without having to coordinate with the ESE underneath (vertical limit at FL225). LSZH arrivals would be therefore transferred directly from UH to W in descent towards FL200, saving coordination calls.

The simulation suggested that the current transfer levels from Reims to Zurich should be retained in both SWAP airspace options.

As a result, current transfer levels from Reims to Zurich could be retained within SWAP airspaces.

4.2.2.2 Delivery to MUAC/CANAC

The controllers considered that of the options tested only delivery in flight level (cruise level) was unacceptable for MUAC controllers in both the SWAP V1 and V2 airspaces. Due to the complex airspace north of GTQ and the merge/crossing with the major west/east flows it would not be possible to descend traffic inbound to airports (e.g. Dusseldorf, Brussels, Liege and Amsterdam) until they were clear of the other flows. This would leave insufficient time and airspace for a successful approach into the airports. The only realistic option is to commence the descent earlier. Therefore, the MUAC and CANAC controllers prefer receiving aircraft in descent as is the case today, although it should be possible to raise the agreed transfer FLs. From the Reims perspective, the controllers considered both delivery options, in descent to current FLs or at intermediate flight levels, achievable and acceptable especially in the SWAP V2 airspace (Figure 16 bottom).

The simulation results show that the current transfer levels or delivery at intermediate levels from Reims to MUAC/CANAC are both achievable with the SWAP airspaces.

4.2.2.3 Delivery to Paris

The swap of southbound and northbound routes and the interaction with the new airspace design coming from the HARMONIE project meant that the transfer levels to be used for Paris arrivals was discussed extensively.

From the Reims perspective, although both deliveries at even or odd levels were achievable, the controllers considered delivery at even levels (+FL350 for LFPO arrivals) the most acceptable. Indeed, due to the swap of routes there was less confliction between the flow into Paris from the east and the southbound flow at odd levels (at even levels in todays' network). As for the LSZH arrivals, when even levels were used (with FL340 max) the Reims controllers also mentioned the possibility of a release area in order to avoid transfer or coordination between KH and XH as vertical limit is FL345.

From Paris perspective, the outcomes were inconclusive concerning the parity of transfer levels from Reims. Whatever the SWAP airspace considered (V1 or V2), half of controllers preferred odd levels (as today) and half preferred even levels (Figure 16). Indeed, both solutions have opposite pros and cons.

- Odd levels with FL350 max
    - Pros: Segregate incoming flows from Geneva and Aix centre (at even) from Reims (coming at odd as today);
    - Cons: Result in a late transfer from Reims centre which needs to ensure a safe crossing between Paris arrivals and southbound flow (both at odd levels) before delivering traffic to Paris.

- Even levels with FL340 max (+ LFPO at FL350)
    - Pros: Allow aircraft to be transferred early to the Paris sector (as traffic is separated from the southbound flow at odd levels) which facilitates pre-regulation;
    - Cons: Even level convergence of three inbound flows (Reims, Geneva and Aix) al at even levels.

Although, the outcome on the parity of transfer levels was inconclusive the Paris controllers clearly found the option of delivery at all levels unacceptable. According to them, this leads to a lack of predictability for the pre-regulation task in the UJ sector.

The simulation results show that the current transfer levels from Reims to Paris (odd with FL350 max) may need to be changed to fit SWAP airspaces.

4.2.3 Conditions retained for airspaces comparison

The second, but primary objective of the simulation was to compare SWAP airspace (V1 and V2) to a Baseline. As a result of the first week of simulation described above, the SWAP RTS Core Team agreed to retain the following conditions:

- **V0C1**: Represented the Baseline situation with current airspace (but including HARMONIE ATS routes and military airspace) and current transfer levels. The V0C1 condition was performed over 2 runs (AM and PM traffic samples) for comparison purposes.
- **V1C3**: Represented SWAP V1 airspace including the most acceptable configuration: Zurich at FL200, MUAC/CANAC at intermediate levels and Paris at even levels (FL340 max, + LFPO at FL350). The V1C3 condition was performed twice (one each for the AM and PM traffic samples) to allow objective comparison even though the SWAP V1 was considered unacceptable by some of controllers after the first week of simulation.
- **V2C1**: Represented SWAP V2 airspace with the current transfer levels: Zurich at FL200, MUAC/CANAC in descent to the current transfer levels and Paris at odd levels (FL350 max). This condition was performed over 4 runs including 1 with a northerly wind (requested by Paris). The V2C1 condition was used for comparison purposes and to assess feasibility/acceptability of delivery from Reims to Paris at odd levels (see Figure 17).

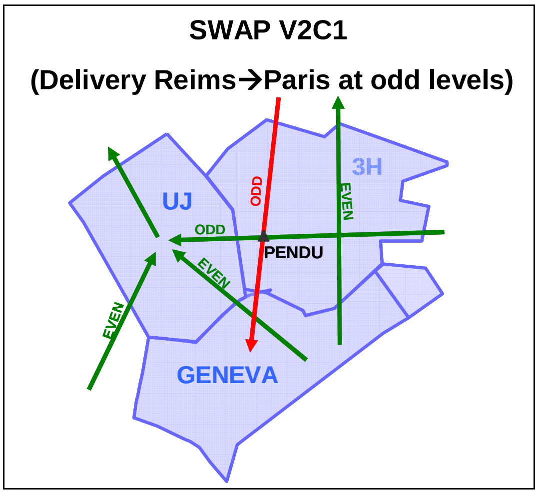


Figure 17. V2C1 - delivery to Paris diagram.

- **V2C3**: Represented SWAP V2 airspace with the following transfer levels: Zurich at FL200, MUAC/CANAC: at intermediate levels and Paris at even levels (FL350 max). This condition was performed over 3 runs including 1 with northerly wind (requested by Paris). A fourth run was performed with "hybrid" levels for Paris (C'3): at even levels (and FL340 max) plus FL350 and released to turn when cleared from southbound Reims traffic. The V2C3 condition is used for comparison purposes and to assess feasibility/acceptability of delivery from Reims to Paris at even levels (see Figure 18).

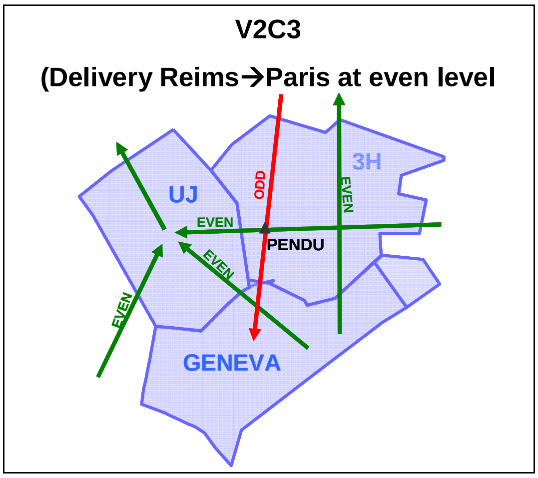


Figure 18. V2C3 - delivery to Paris diagram.

In addition, the spare run was used to test delivery at odd flight levels from Geneva to Reims and even levels from Paris (**V2'C3**)[8]. This allowed the UJ sector to segregate both delivery streams to Paris (see Figure 19).

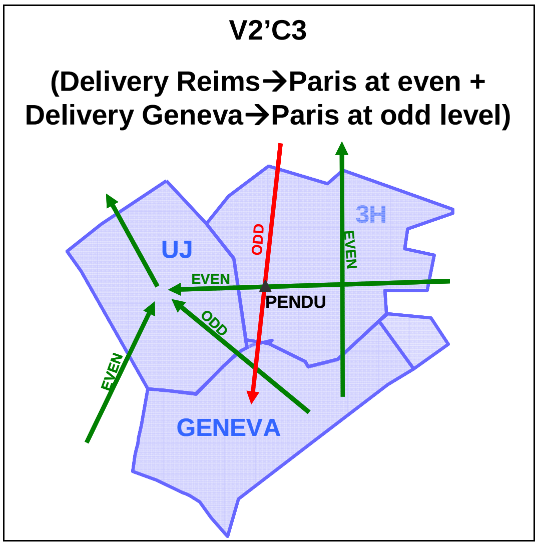


Figure 19. V'2C3 - delivery to Paris diagram.

[8] This configuration did not require any technical changes. The level selection was made tactically by the controllers. From validation and analysis perspectives, this run is part of V2C3 condition.

4.3 Objective 2: SWAP airspaces vs. Baseline

The comparison between the SWAP V1, V2 and Baseline airspaces is addressed using both objective (recordings) and subjective (questionnaire and debriefings) data. The results are organised around the following Key Performance Areas:

- Operability;
- Safety;
- Flight efficiency;
- Military mission effectiveness;
- And Capacity.

4.3.1 Operability

4.3.1.1 Impact of SWAP airspaces on workload

The results from post run questionnaire illustrate the global level of workload per condition with all centres grouped together (Figure 20).

Overall, no clear difference is observed between conditions with ~65% of controllers rating their workload as medium or low. In addition, less than 10% of controllers felt a very high level of workload during a whole run. This occurred mainly in the ESE and UJ sectors which had to manage a high traffic load.

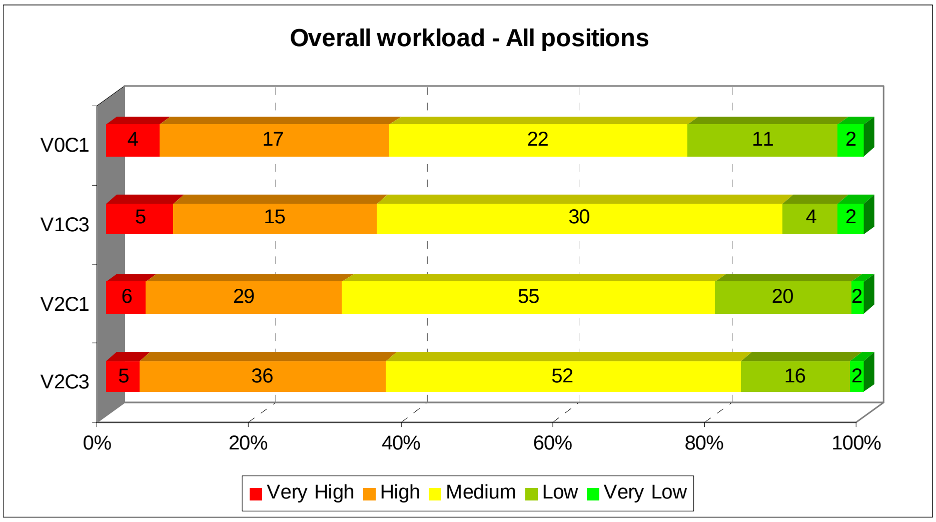


Figure 20. Post run ratings: Overall workload per condition.

The ISA workload results are consistent with the post run ratings. ISA ratings per centre show no clear difference between conditions with overall 80% of the time spent with, or below, a medium level of workload (Figure 21). Therefore SWAP airspaces (V1 and V2) imply neither an increase nor a decrease in workload compared to today's situation during the RTS.

The most loaded centres were in decreasing order Paris (with only one sector: UJ considered loaded due to high traffic load), then Reims and Geneva (moderately loaded whatever the conditions) and then Zurich (sector W) and finally the military positions with a low or very low level of workload more than 90% of time.

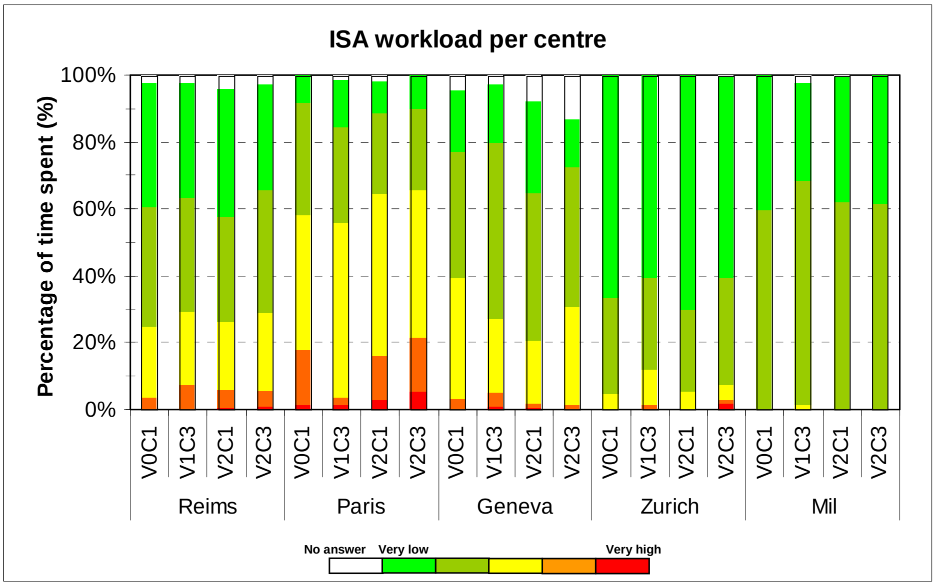


Figure 21. ISA ratings: Workload per centre and per condition.

The frequency occupancy per sector further addresses the controllers' workload using objective data (Figure 22). Globally, no impact of the condition is observed on Reims, Paris Zurich and military sectors. On Geneva sectors, SWAP V2 globally decreases frequency load compare to V0C1 and V1C3 especially in L56 (from 35% to 22%). In addition, in line with pervious results, the most loaded sectors remain UH, 2F and UJ (more than 40% of frequency load) due to the high traffic load.

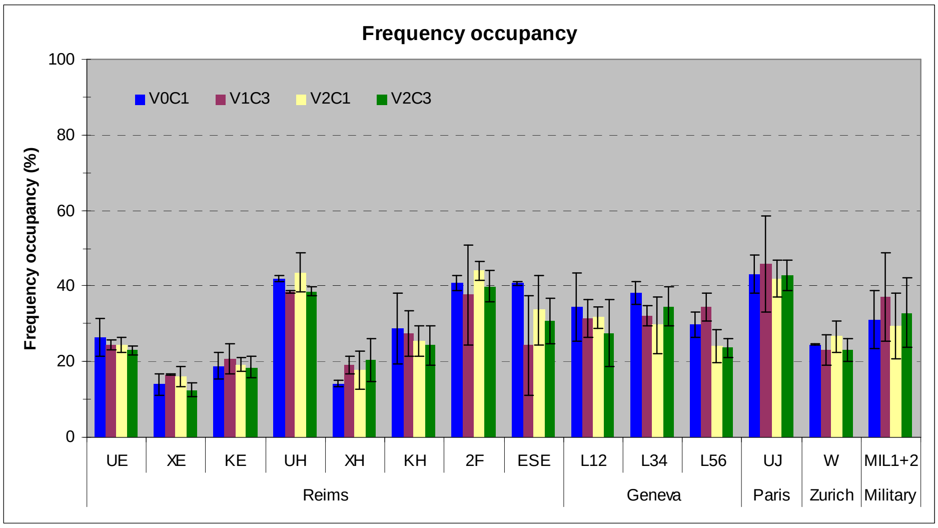


Figure 22. Frequency occupancy per sector and per condition.

4.3.1.2 Impact of SWAP airspaces on working methods

As illustrated in Figure 23, more than 70% of controllers find the suitability of controllers' tasks (separation management, conflict detection and traffic delivery) low or very low within SWAP V1. On the contrary, the controllers' tasks and especially for traffic delivery task were rated suitable (at least medium) within SWAP V2 by most of the participants.

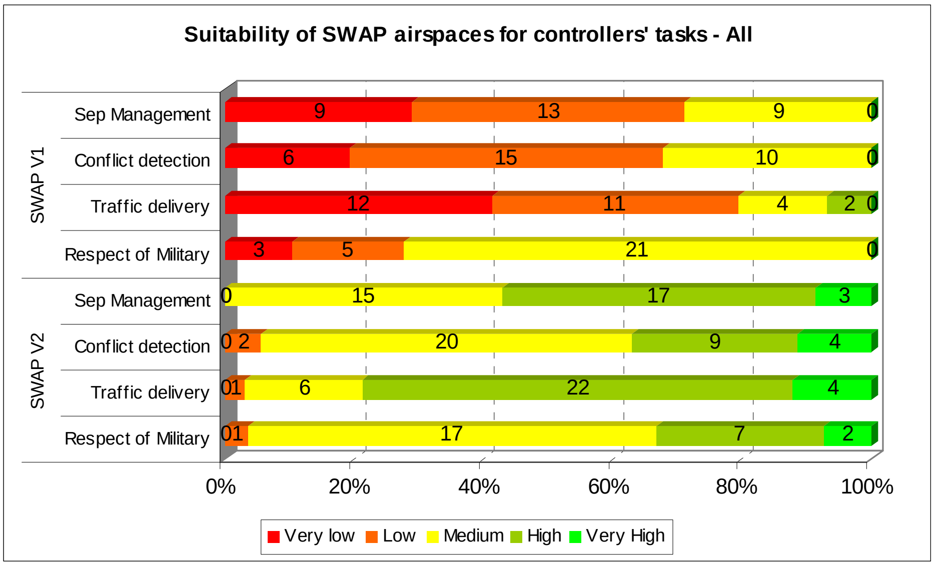


Figure 23. Post simulation ratings: Suitability of SWAP airspaces for controllers' tasks.

- **SWAP V1 airspace**

According to controllers, mostly Reims and Geneva centres were negatively impacted by the SWAP V1. As already mentioned, although cruising northbound and southbound flows are swapped, southbound flow of aircraft in evolution remains at the east (limited swap) compared to Baseline airspace (Figure 24).

From the Reims centre perspective, the existing "hot spot" in GTQ, with northbound and southbound flows crossing, was found worsened compared to today. Indeed SWAP V1 network provides flows in evolution (e.g. southbound LFLL/LSGG arrivals and northbound EDDL/EDDK arrivals) on opposite tracks in 3E area (Figure 25). According to them, this implies difficulties for separation management, conflict management and delivery (e.g. of EDXX arrivals) as the controllers need to wait for crossing to descend arrival aircraft.

From the Geneva centre perspective, the controllers did not raise significant issues. However, although the SWAP V1 was found suitable for upper sectors, the controllers mentioned departures and arrivals on opposite tracks in lower sectors. Indeed, the Geneva and Lyon arrivals merge at FL 320 and below, increasing complexity. With military airspace active, the L12 sector became more complex with an increased number of flights crossing.

Controllers from other centres did not express particular issue on SWAP V1 airspace as being globally close to today's situation. Note that for Paris centre, the impact of SWAP was minimal compared with the HARMONIE routes and the change of transfer levels from Reims

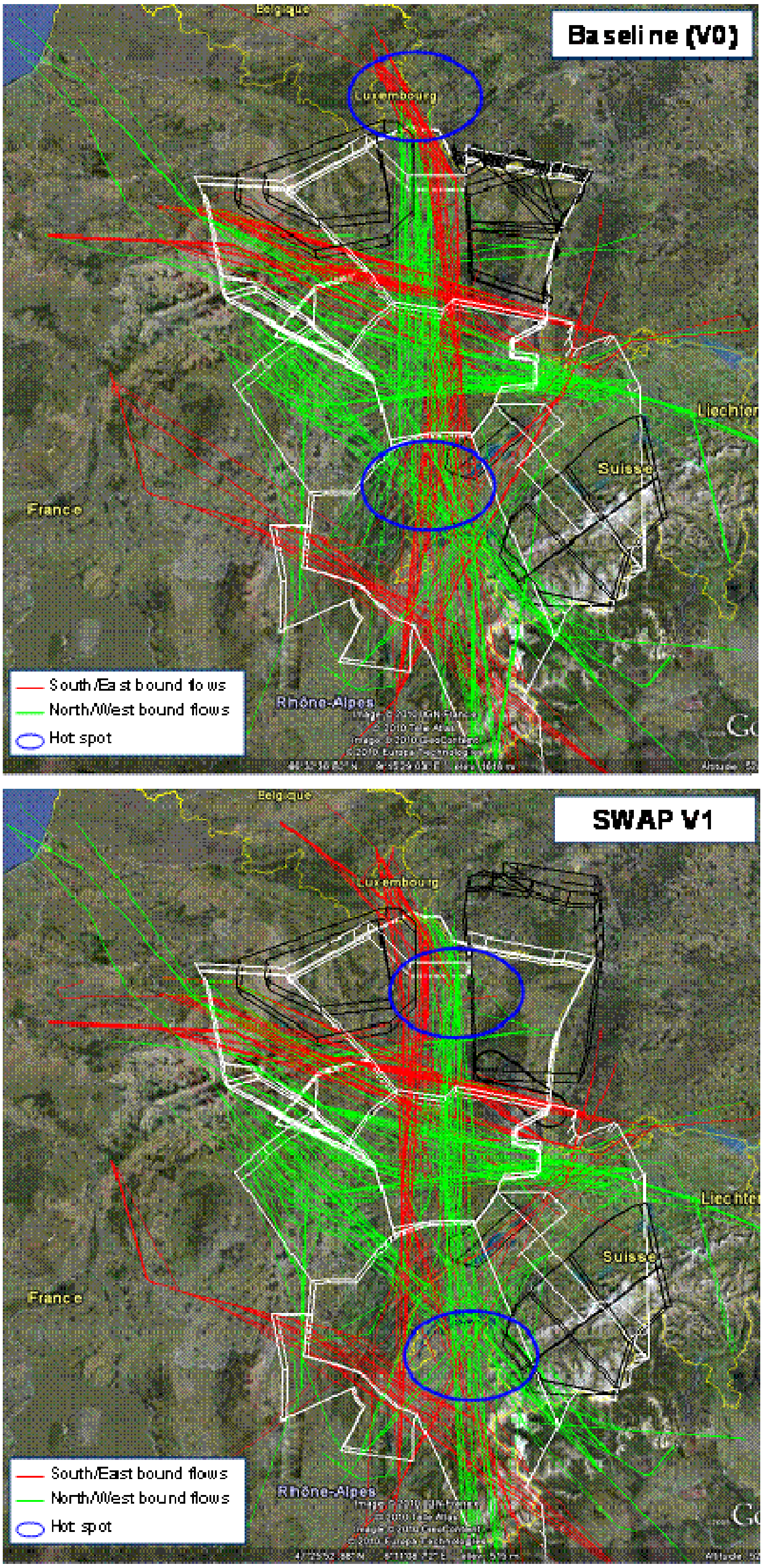


Figure 24. Flown trajectories (AM+PM) in Baseline (top) and in SWAP V1 (bottom) airspaces.

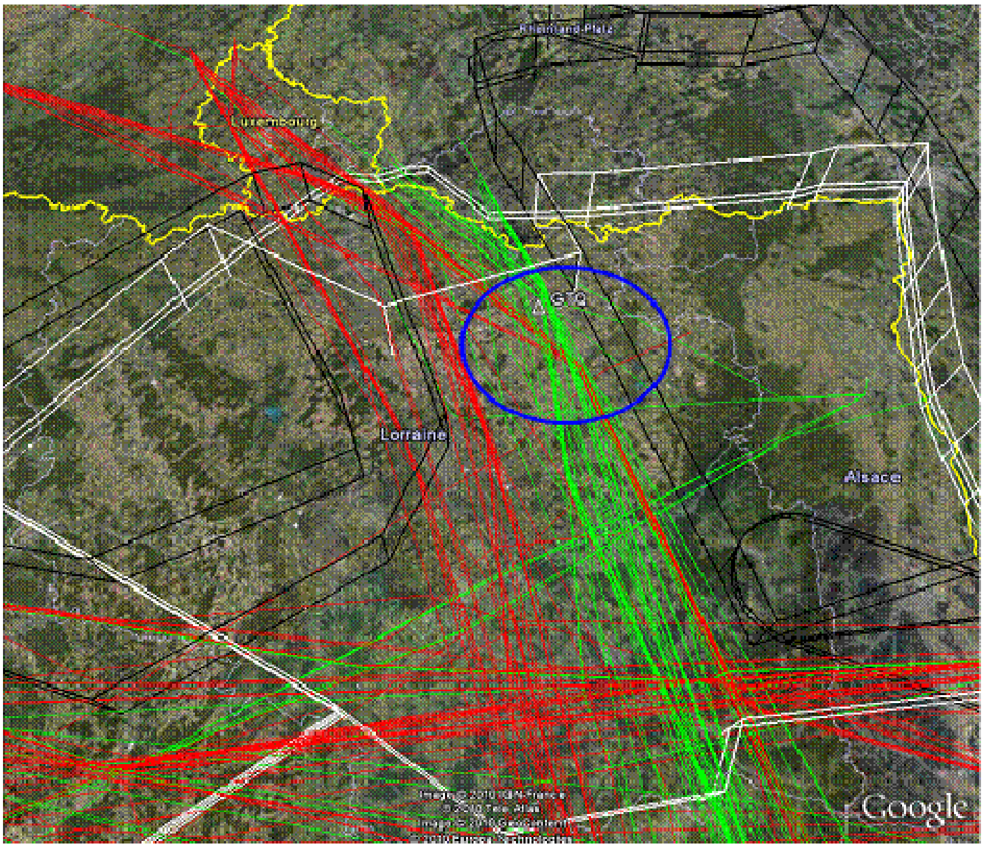


Figure 25. Southbound flows (red) crossing northbound flows (green) at GTQ.

- **SWAP V2 airspace**

As illustrated in Figure 26, the SWAP V2 provides a full swap of northbound and southbound flows. As for SWAP V1, the most impacted centres were Reims and Geneva but in a positive way.

From the Reims centre perspective, the full segregation of traffic flows greatly eased separation management and traffic delivery, in particular for evolving traffic (aircraft flying along separated routes instead of being vectored). However, as during the prototyping session, the controllers still mentioned the limit of the CBA25 that makes conflict detection and resolution difficult due to the late turn at MOROK (e.g. between LSZH departures and LFST arrivals).

From the Geneva centre perspective, the SWAP V2 airspace was also found suitable as it removed exiting crossings of traffic flows and segregates northbound and southbound flows. In addition, the Geneva controllers in L12 sector mentioned that they were less impacted when military area (CBA25) was active compared to today. This was also due to the better segregation of traffic flows with the LSGG and LFLL arrivals routed to the west of other flows. However, although SWAP V2 was found suitable for the Geneva ACC sectors, it will require the development of new SIDs and STARs in the TMA.

Although other centres were not really impacted by the SWAP V2 network, they profited from the better traffic management in the Reims and Geneva sectors. It first allowed LSZH arrivals to be at lower levels, hence making further descent and speed reduction in Zurich approach easier. In addition, military controllers found that the better organisation of flows in 3H and 3E areas made the prediction of civil traffic easier compared to SWAP V1.

Note that the subjective opinion from MUAC (feed) was that the extra route north of GTQ (to OVERT) allowed for better organisation of the northbound traffic flows. However, the implementation of this route will be the responsibility of DFS (not participating in the SWAP simulation).

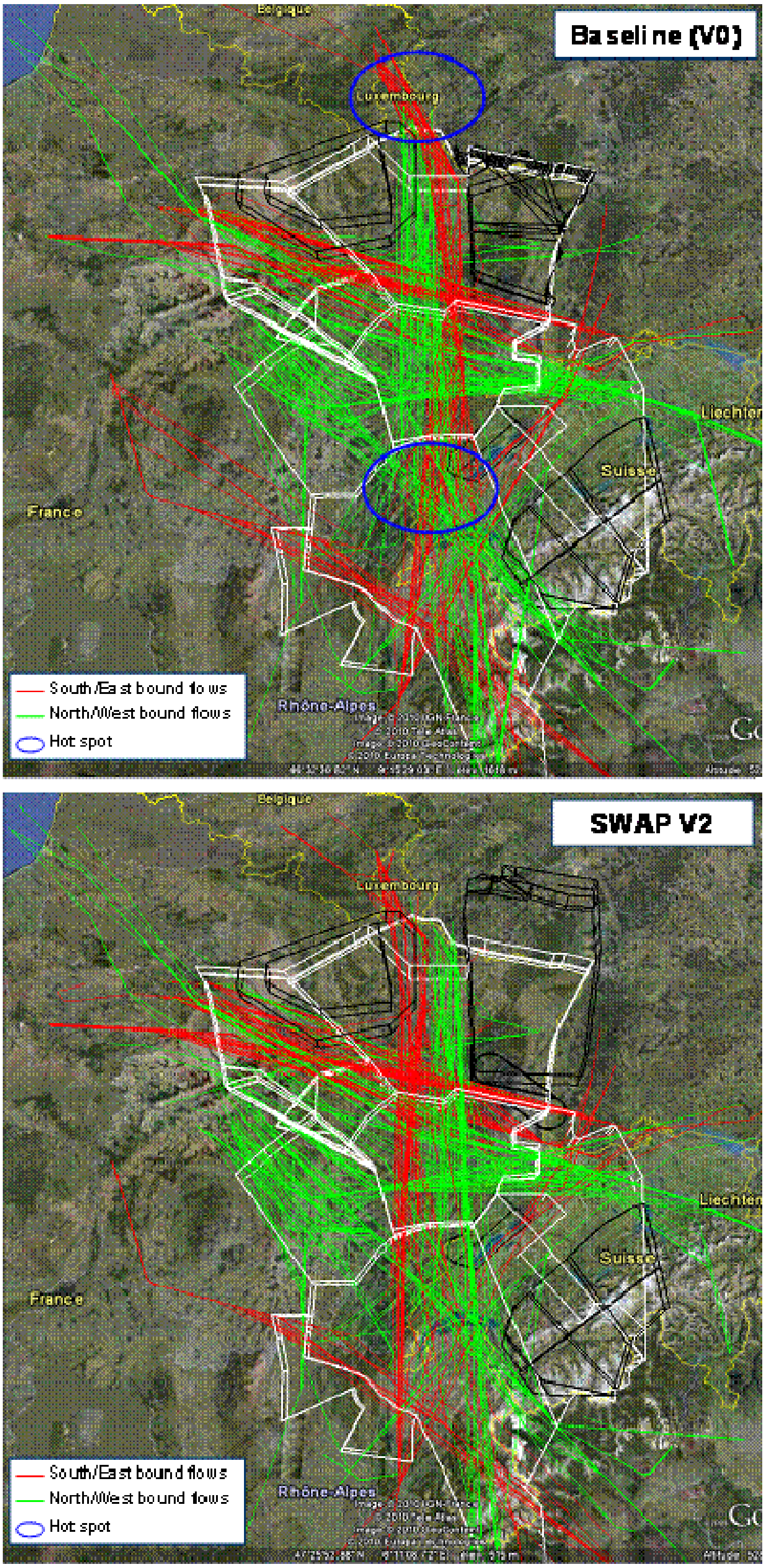


Figure 26. Flown trajectories (AM+PM) in Baseline (top) and in SWAP V2 (bottom) airspaces.

4.3.1.3 Crossing flows interference in UH sector

To address the feasibility of both SWAP airspaces, the vertical segregation of flows was calculated in the UH sector for each airspace organisation. To do so, the average flight levels were calculated for arrival and departure flows (to/from LFLL, LSGG and LSZH) crossing over specific waypoints (Figure 27).

The results show that the LSZH arrival and departure flows were vertically segregated by a greater distance from other flows in SWAP V2 airspace compared with SWAP V1. Indeed, in SWAP V2 airspace, LSZH arrivals (at ~FL250) were ~4000ft below LFLL departures and ~5000ft below LSGG departures over Z1 waypoint whereas those 3 flows cross over Z4 within a "'~1000ft layer" in SWAP V1 airspace. In a similar manner, LSZH departures (at ~FL300) were ~4000ft above LFLL and LSGG arrivals over Z2 waypoint in SWAP V2 whereas those 3 flows cross at TORPA within the same flight level band (~FL265) in SWAP V1 airspace.

No clear differences are observed between airspaces concerning the crossing of all departures over ROBIR, EBAKI or ABOXI (~2000ft separated) and all arrivals over TIRSO or BELON (~3000ft separated).

As a consequence, for the UH sector, the SWAP V2 airspace matches the vertical segregation of flows in the Baseline airspace whereas the SWAP V1 airspace leads to more 'vertical bunching'.

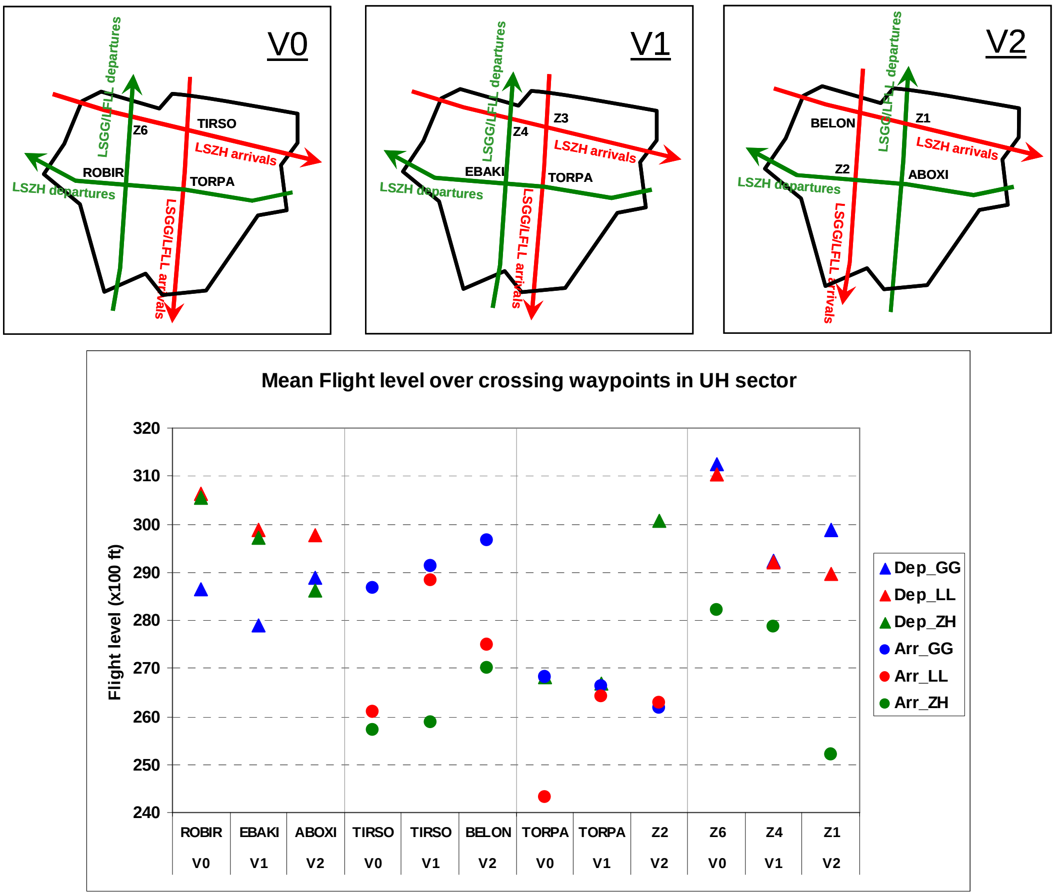


Figure 27. Flight level interactions in UH sector.

4.3.1.4 Acceptability

The controllers' feedback on workload, working methods and safety (see 4.3.2) explain the following results on acceptability of both SWAP V1 and V2 airspaces. SWAP V1 is rejected by ~80% of the participants as it was found to be more complex than today and raised specific safety issues (hot spot worsened at GTQ and opposite tracks on Geneva sectors). On the contrary, the SWAP V2 was accepted by ~90% of the participants although some refinements are still needed (e.g. transfer levels, military area). The controllers expressed that the full segregation of northbound and southbound flows eases the crossing task and provides a gain of safety compared to today.

Details results on SWAP implementation per ANSP are provided in Annex E.

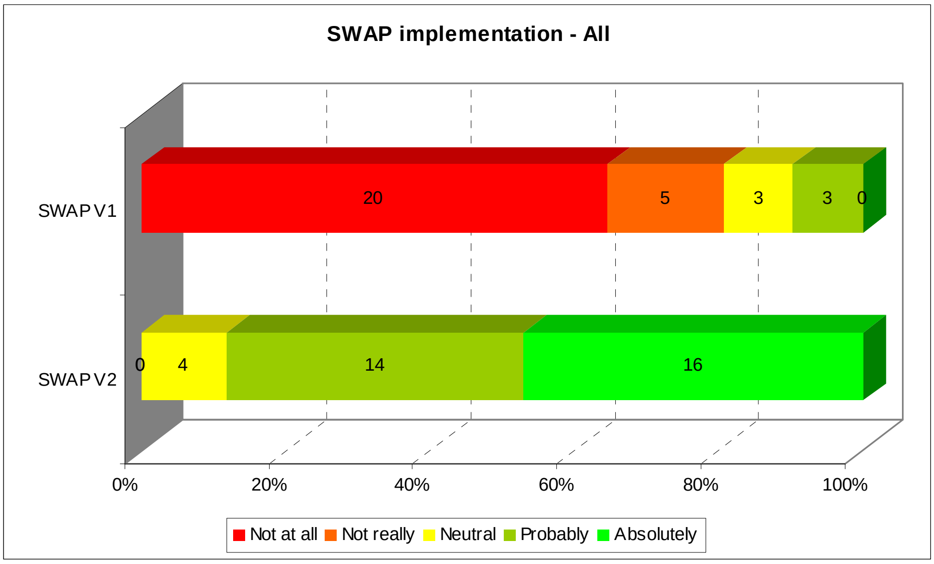


Figure 28. Post simulation ratings: Acceptability of SWAP airspaces implementation.

4.3.1.5 Transfer levels

4.3.1.5.1 Global analysis

Results provided in Figure 29 shows the quality of delivery from Reims to adjacent sectors by indicating the number of aircraft delivered at the required level (correct) and those which were not (not correct).

First, the results show that transfer levels were globally well achieved in all conditions (78% of correct transfer in the worst case). In addition, it is observed that quality of delivery was slightly degraded in V1C3 condition (78% correct) compared to Baseline (86% correct) while being slightly improved in V2C3 (92% correct).

As previously observed during the first week of simulation (4.2.1.2) it is observed in Figure 29 and Figure 30, that Reims controllers had most difficulty descending LSZH arrivals to FL 200 for Zurich (overall 3000ft above in average). In addition a few aircraft were also delivered slightly higher than planned (2500ft above in the worst case-V2C3) to the Geneva sectors.

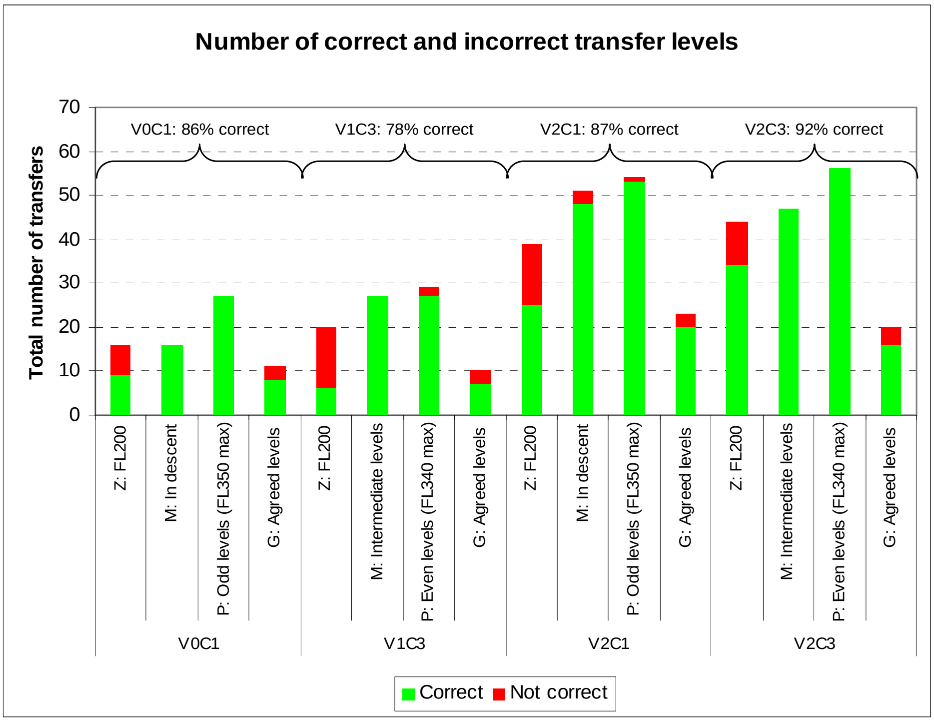


Figure 29. Quality of transfer levels achievement per condition.

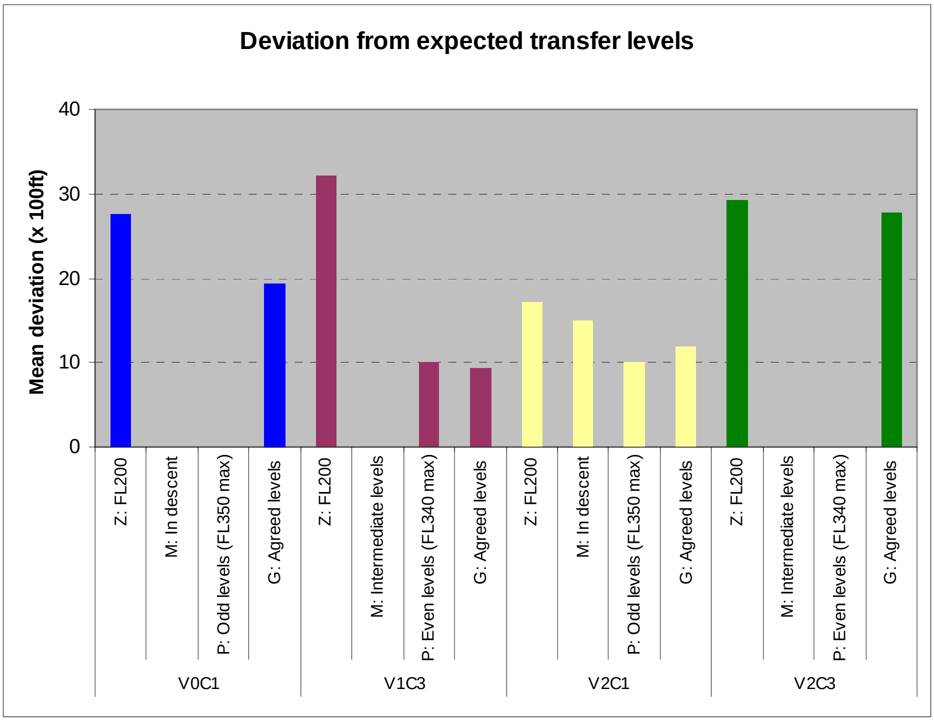


Figure 30. Mean deviation from expected transfer levels when missed.

4.3.1.5.2 Focus on transfer levels Reims/Paris

From Paris perspective, as there was no discernable difference between V1 and V2, the main objective was to assess the compatibility of SWAP airspaces with the actual delivery conditions from Reims to UJ sector that pre regulates Paris arrivals. From the first week assessment, Paris controllers were inconclusive concerning the parity of transfer levels that should be used (odd or even flight levels).

Deeper analysis was conducted to objectively assess the particular delivery from Reims to Paris, first, in plotting transfer "point"[9] from Reims sectors (mainly XH and KH sectors depending on FL) to UJ sector, on sector map[10] (Figure 31). In addition, to measure late/early delivery, orthogonal distance of transfer point from the PENDU waypoint was calculated, with distribution of those distances represented in Figure 32.

Results illustrated in Figure 31 and Figure 32 first show that V1C3 (even levels to Paris) and V2C1 (odd levels to Paris) led to a later transfer to Paris (50% of aircraft delivered between 3 and 20nm from PENDU). This was due to the need to ensure separation from traffic on the northbound flow towards SORWE. As expected, the late transfer in the V2C1 condition was due to the fact that XH controllers needed to cross Paris arrivals (at odd levels) with the southbound flow, also at odd levels, before delivering the arrivals to the UJ sector.

On the contrary, when even levels were used with SWAP V2 (V2C3 condition), it is observed in Figure 32 that 75% of aircraft were delivered to the UJ sector earlier, at 10nm prior PENDU. As a result, the V2C3 condition was the sole condition that met the Paris controllers' request - aircraft delivered early (15nm prior PENDU) and released to turn -. It can be noted that Paris controllers could also "accept" aircraft at FL350 so long as they respect the condition mentioned above (delivered early and released to turn).

In addition, the Reims controllers mentioned the possibility of a release area in order to avoid transfer or coordination between KH and XH (as vertical limit was FL345) when aircraft are delivered at FL350.

As a result, even delivery (FL340 max) and FL350 for LFPO seemed to be the most acceptable transfer levels to be used from both the Reims and Paris controllers' perspective even though this led to the merging of three incoming flows at even levels (from Reims, Geneva and Aix centres).

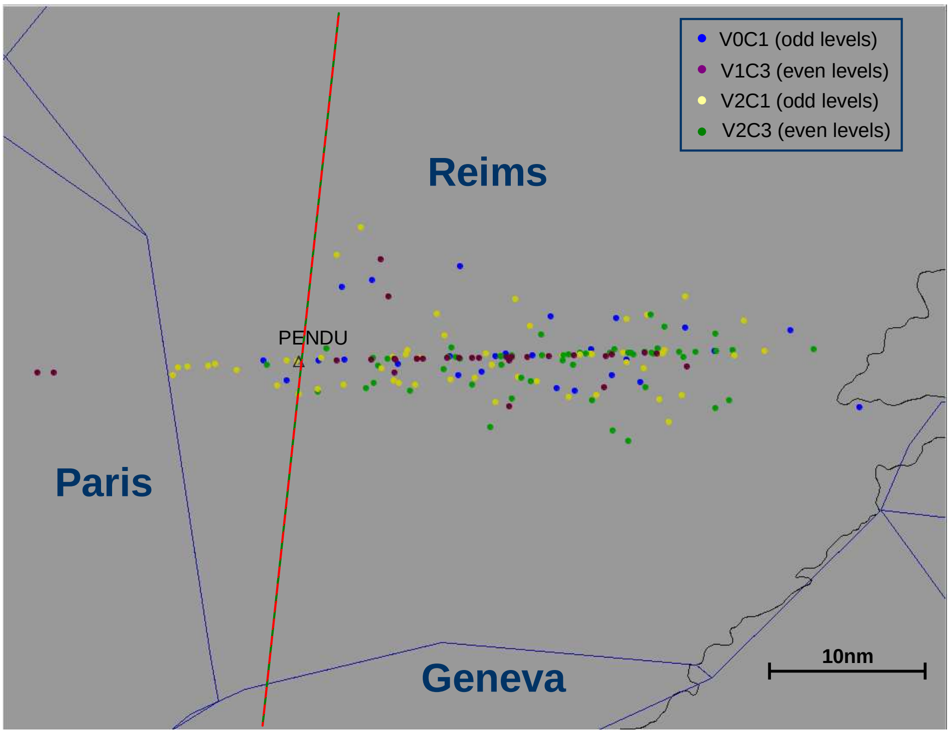


Figure 31. Geographical location of transfer from Reims to Paris.

[9] Corresponding to the pseudo pilot transfer action.

[10] In addition to the sector boundaries (in blue), the sector map also displays PENDU waypoint and north/south bound flow (depending on airspace V0, V1 or V2) in green and red dashed lines that Reims controllers have to cross with Paris arrivals.

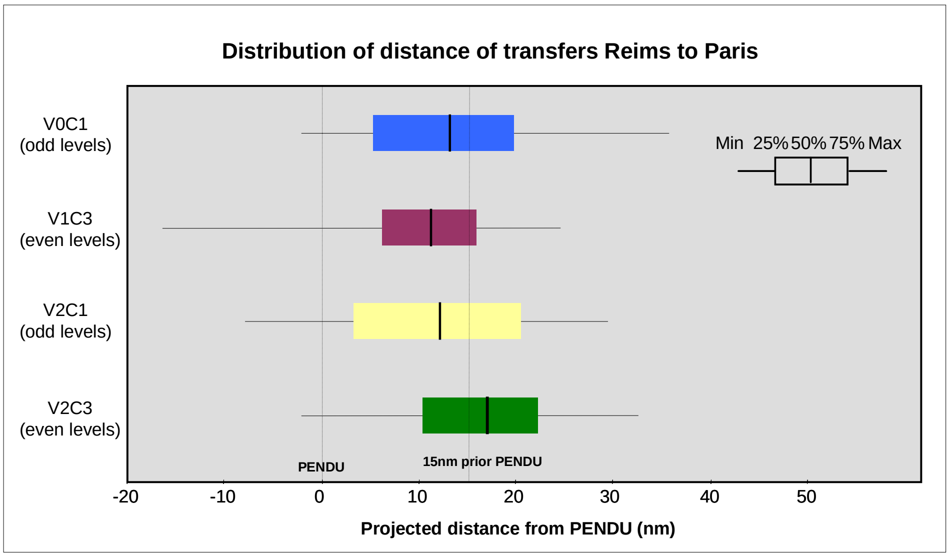


Figure 32. Distribution of distance of transfer Reims/Paris from PENDU.

Note that the spare run performed to test delivery at odd flight levels from Geneva to Reims and even levels from Paris (Figure 19) to segregate both delivery streams to Paris was not found acceptable by the Geneva controllers. Indeed, it only transfers the problem from Reims to Geneva controllers who had now to cross those eastbound and southbound flows both at odd levels leading to late delivery to Paris.

4.3.2 Safety

FABEC expects the current level of safety to be improved or at least maintained despite the forecast traffic growth. In the SWAP RTS context, the concerned ANSPs expected at least, to maintain the current level of safety with the SWAP airspaces. The safety indicators used for the RTS provide 'safety feasibility indications' and are mainly based on controllers feedback. Further detailed and deeper studies (e.g. safety case) are expected to be conducted over the whole FABEC environment.

Firstly, post run ratings on the perceived level of situational awareness were used to address the safety aspects (Figure 33). Overall, the results show that the situational awareness remained high with SWAP V2 compared to the Baseline: more than 80% of controllers with a high or very high situational awareness rating in V0C1, V2C1 and V2C3. Within SWAP V1 airspace, the Situational Awareness (SA) is degraded compared to the Baseline and SWAP V2 conditions with more than 40% of controllers expressing a medium or even lower level SA. According to the controller feedback SWAP V1 degrades SA in the 3E sectors (hot spot in GTQ), in Geneva (opposite tracks) and in UJ, UH and ESE which were heavily loaded with traffic.

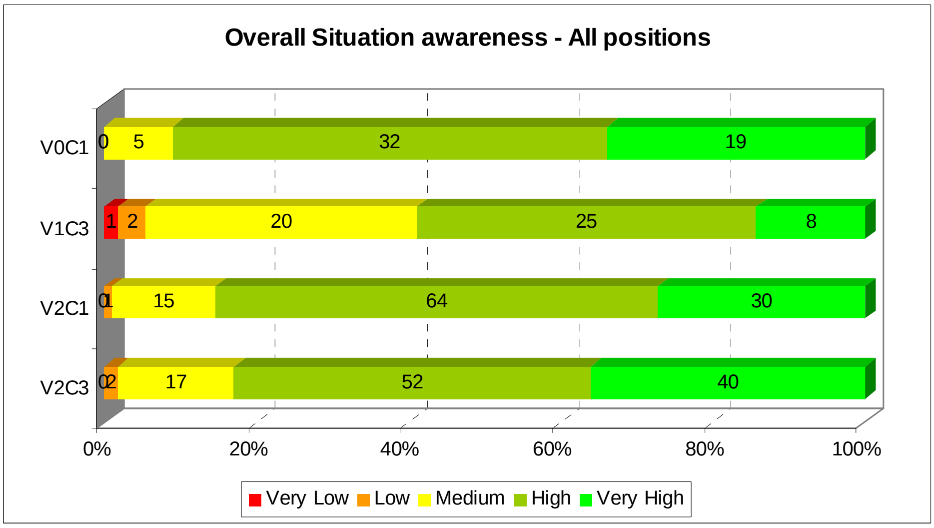


Figure 33. Post run ratings: Overall situation awareness per condition.

The results from post simulation ratings first show that the current level of safety was considered degraded with SWAP V1 by 76% of controllers (Figure 34). According to them, SWAP V1 creates "new" conflicts due to opposite tracks opposite at GTQ (for Reims) and between departures and arrivals in lower Geneva sectors.

In SWAP V2 airspace, the safety level was found to be at least equivalent to today's and even improved for 54% of controllers (Figure 34). According to them, the SWAP V2 design in itself provided an intrinsic gain of safety by reducing the number of crossings. Indeed, it provided segregation in both a northbound and southbound direction for evolving traffic in 3H area (Reims) and removed the current hot spot in Geneva (e.g. aircraft climbing from Reims are no longer opposite to transit flights from Geneva).

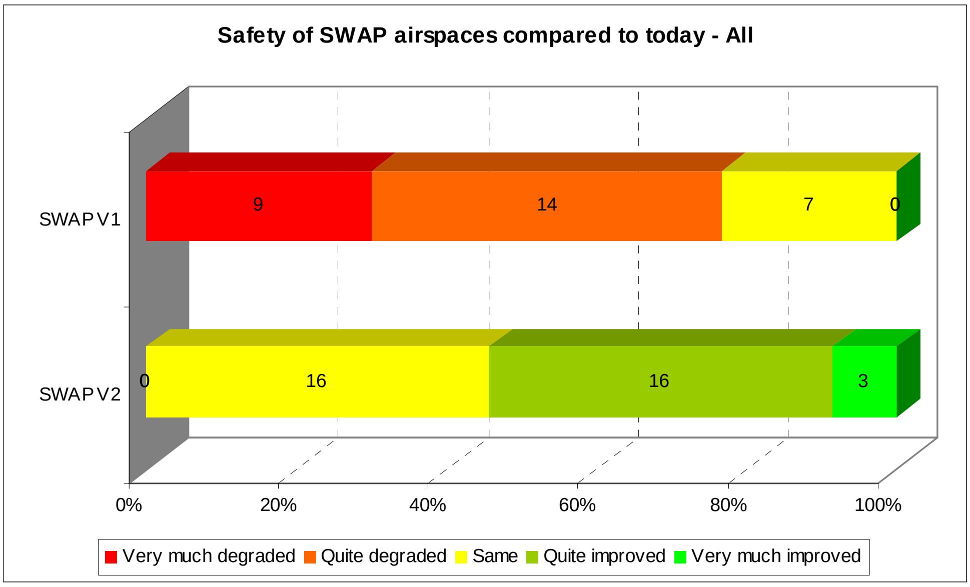


Figure 34. Post simulation ratings: Safety of SWAP airspaces compared to today.

In addition, it should be mentioned that some controllers raised some safety concerns implied by the SWAP V2 airspace and proposed some mitigations:

- The conflict detection and resolution remained difficult at MOROK in 3H area when CBA25 was active (above FL225). The dogleg (route JOHAN-DITER-MOROK) made it harder to predict conflicts upstream compared to the situations where aircraft routed direct KONIL-MOROK when CBA25 was not active (Figure 35).
- Conflicts points (EPIKE in 3E area and LUWES in 3H area) were adjacent and considered too close to the sector boundaries. This also led to late conflict detection and resolution (Figure 35).
- The bottleneck in MUAC airspace still exists and would require new routes alleviated it. To completely segregate northbound and southbound flows, the controllers stressed the importance of retaining the route GTQ-OVERT[11] . In addition it was suggested that an additional route from ROUSY to GISWE, cutting the edge of TSA200[12] would be advantageous.

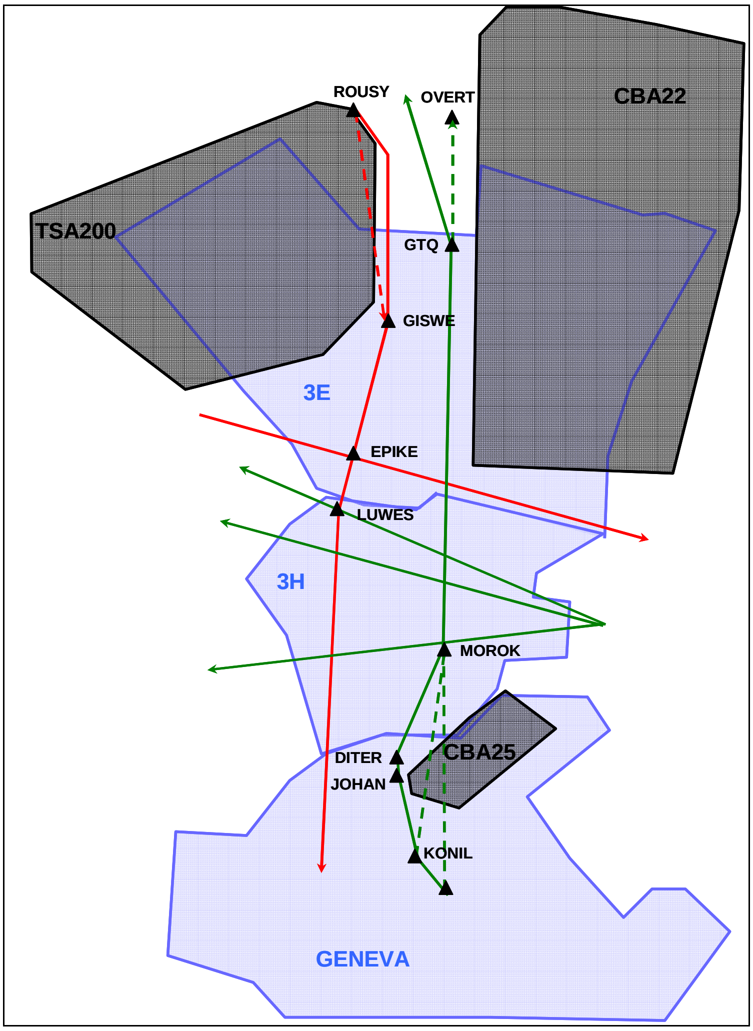


Figure 35. Map illustrated safety concerns for SWAP V2.

The number of losses of separation was also measured to compare SWAP airspaces to the Baseline. No clear impact was observed between the conditions: globally (over 12 runs), 1 loss of separation occurred in V0C1 condition (over 2 runs), 1 occurred in V2C1 condition (over 4 runs) and 1 in V2C3 (over 4 runs).

[11] Discussion concerning this route is part of the work of the FABEC ARKON/RKN working group.

[12] This would obviously require negotiations with military representatives.

4.3.3 Flight efficiency

The FABEC initiatives are expected to improve flight efficiency through optimisation of aircraft trajectories resulting in a reduction of the distance flown per aircraft. At a SWAP level, no particular expectations on flight efficiency have been expressed by the ANSPs as the improvements should come from the whole FABEC airspace implementation rather than local changes.

The distance flown in 3E and 3H areas is measured to assess the impact of the swap of routes in these two “sector blocks” (Figure 36). The measure considers southbound and northbound aircraft flying the whole 3E or 3H “blocks” laterally (lateral limits-north/south- considered to characterise 3E and 3E are illustrated in left part of Figure 36). This is done in order to take as many measurements as possible into account: 3E:~16 measurements/run and 3H blocks: ~26 measurements per run. In addition it should be emphasized that the removal of the double crossing of northbound and southbound flows, provided by SWAP compared to Baseline, could not be really considered in the calculation method. Indeed, aircraft were not really “controlled” in MUAC and Geneva approach airspaces (where existing crossings occur) as both were feed sectors.

Globally, the results show no significant degradation or improvement in terms of distance flown between the SWAP airspaces and the Baseline (V0C1) in both the 3E and 3H sector blocks (Figure 36). In the 3E block, aircraft flew ~76nm on average in all conditions. However, a slight reduction of the dispersion (reduction of standard deviation) and of the maximum distance flown is observed with SWAP airspaces compared to Baseline, especially in V1C3 condition. The reduction in variation implies that fewer radar vectors or direct instructions were given in V1 and V2 with more aircraft maintaining their flight planned profile.

In the 3H sector block, the aircraft flew on average ~57nm, less than in 3E block due to the smaller size or the areas (laterally north/south).

The dispersion and average distance flown were both reduced with SWAP V2 (V2C1 and V2C3 condition) compared the Baseline (V0C1). This was largely due to the straightening of the routes for both the north and southbound flows and the segregation of flows which made it easier for the controllers to allow flights to remain on their planned track without the need for intervention. Both V2 conditions showed a decrease in track mileage within the sector with approx 2nm distance saved by each flight. With ~40 aircraft per hour the cumulative savings in track mileage and emissions, from a single sector, could be significant.

In addition, it should be mentioned that both SWAP V1 and V2 was foreseen by the controllers as potentially improving flight efficiency compared to the current situation. They expressed the view that there would be benefits for airlines in terms of shortened tracks and fuel saving due to more direct and better organised flows of traffic.

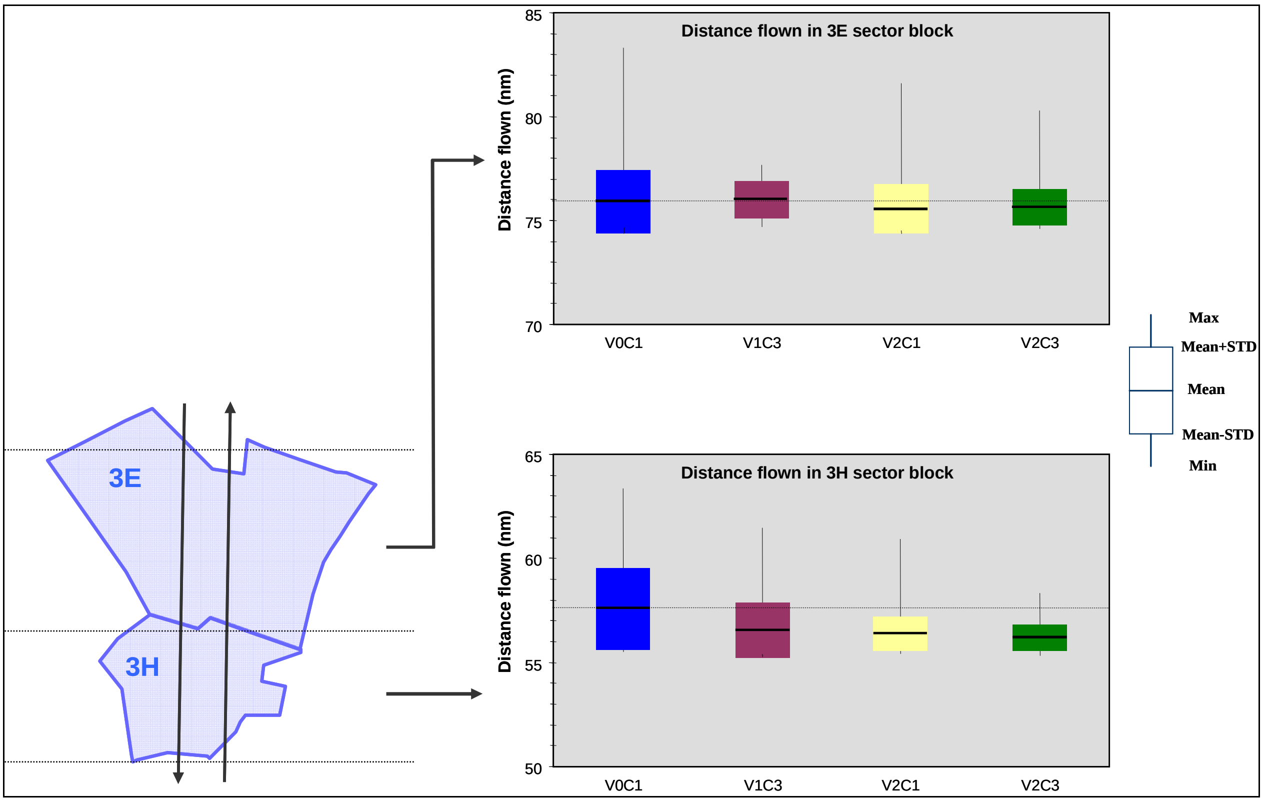


Figure 36. Distance flown in 3E and 3H sector blocks per condition.

4.3.4 Military mission effectiveness

Although further studies are required, Flexible Use of Airspace and closer civil/military collaboration is expected to improve military mission effectiveness at a FABEC level. In the SWAP context, military areas have been modified to facilitate better civil traffic management (reduction of TSA200) and to enhance military training capabilities (extension of CBA22 including addition of a refuelling axis). Although these modifications of military areas are still under negotiation, the RTS assessed military mission effectiveness through feedback from military controllers on military traffic management within new SWAP airspaces.

The military controllers expressed the view that their working methods were not significantly impacted by the SWAP airspace regardless of the version (V1 or V2) considered. Their assessment was that the military mission effectiveness was found equivalent to today's situation. However, they felt that the better organisation of traffic flows in Reims-3E sectors provided with SWAP V2 airspace better facilitated the crossing of west/eastbound military traffic. It was easier for the military controllers predict the track of civil flights and consequently easier to route military traffic through the airspace.

In terms of military intrusions, Table 14 shows that 7 civil aircraft violated the CBA22 over a total of 12 runs. Those aircraft flew a very limited time (from 5s to 130s) within this restricted area. It corresponds to eastbound aircraft from Reims cutting the south west corner of the CBA22 when going to Zurich Feed sector. Although not being measured, these intrusions should have required civil/military coordinations.

Table 14. Number and duration of military areas penetrations.

	V0C1 (2 runs)	V1C3 (2 runs)	V2C1 (4 runs)	V2C3 (4 runs)
TSA200	0	0	0	0
TSA200REW	0	0	0	0
TSA/CBA22A	0	2 (5s; 25s)	4 (85s, 130s, 60s, 20s)	1 (100s)
TSA/CBA22B	0	0	0	0
CBA25C/D	0	0	0	0

4.3.5 Capacity

One of the high level expectations of the FABEC project is that the capacity could be enhanced due to better traffic management and optimisation of flows. At the SWAP level, the concerned ANSPs expressed the requirement to, at least, maintain the current capacity.

As the different conditions were performed with the equivalent traffic load, the capacity aspect could not be assessed through objective measurements (e.g. the number of flights handled by each sector). However, one item of the post simulation questionnaire was used to get feedback on the perceived impact of SWAP Version 1 and 2 on capacity compared to today's situation (Figure 37)

The results show that with SWAP V1 ~68% of controllers thought the capacity could be potentially reduced compared to today. They considered that this was mainly due the increased complexity of the network that implies an increase of workload (e.g. increase of R/T communication) compared to today.

However, with SWAP V2, the level of capacity considered to be at least equivalent (34% of controllers) to today's situation. Moreover, 64% of controllers think that the SWAP V2 airspace could potentially increase current capacity thanks to the reduction in workload and increased safety resulting from the segregation of northbound and southbound flows.

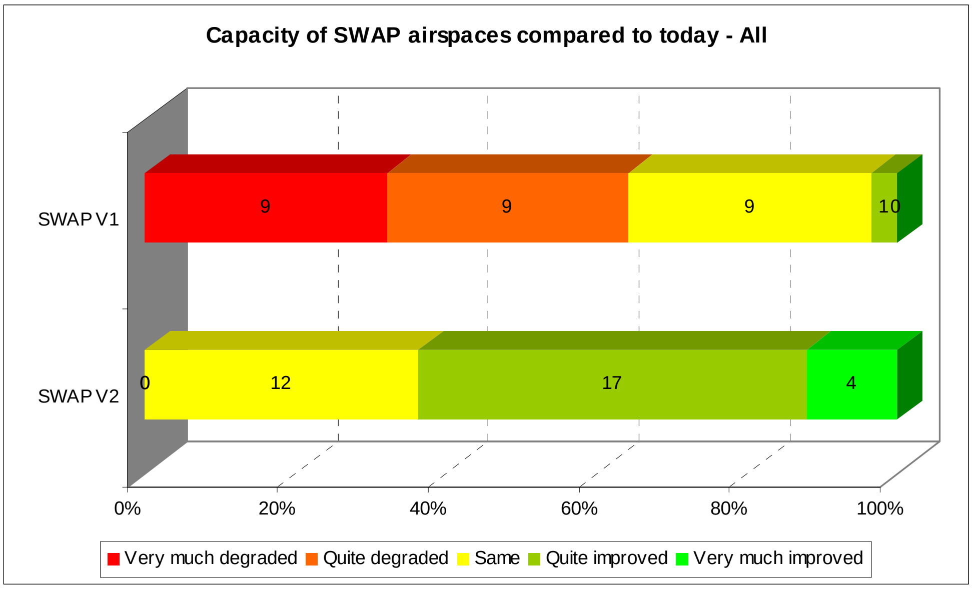


Figure 37. Post simulation ratings: Capacity of SWAP airspace compared to today.

5 Operational conclusions and recommendations

5.1 Conclusions

5.1.1 SWAP V1 and V2 VS. Baseline airspaces

The primary purpose of the RTS was to get controllers' opinions on the feasibility of two different versions of the SWAP airspace structure (V1 and V2). Similar traffic samples were tested on the current structure, SWAP V1 and V2 allowing direct comparison. The following paragraphs summarise the operational results, first by network and then delivery conditions.

5.1.1.1 SWAP V1

Concerning the SWAP V1 airspace, the subjective view of the controllers was almost unequivocal: 80% of participants rated the SWAP V1 airspace as operationally unacceptable for implementation.

Reims and Geneva controllers (the two ACCs most affected by SWAP) found the SWAP V1 structure not suitable for controllers 'tasks, in considering it harder to successfully manage both separation and conflict management tasks compare to current airspace. The main reason given by Reims controllers for their was the increased complexity near GTQ, with traffic in climb having to cross flows in descent. This was found as increasing the workload in the Reims 'E' sector group. In Geneva airspace, SWAP V1 was deemed acceptable for aircraft cruising in the higher flight level bands but there was increased complexity for flights arriving and departing to/from Geneva and Lyon airports with the crossing and/or merging of flows. In addition when CBA25 was active, workload in the L12 sector was found increased due to the added number of crossings. Zurich and Paris ACCs and the military controllers were less affected by the SWAP so were not as strong in their rejection of V1

For those reasons, significantly ~75% of the controllers felt the level of safety was degraded compared to today although no major differences were measured compared to the Baseline airspace in terms of controller workload or frequency occupation. In addition, ~70% of controllers thought that with V1 the capacity could be potentially reduced compared to today mainly due the increased complexity.

5.1.1.2 SWAP V2

The controllers' opinion of the SWAP V2 airspace was markedly different: it was rated operationally acceptable for implementation by 90% of participants and the majority of participants rated the SWAP V2 airspace as feasible and suitable for all the controllers' tasks.

From Reims ACC perspectives, this confirms the subjective view that the introduction of an additional route in the northern airspace allowed for better organisation of the traffic flows and the segregation of climbing and descending flights. In addition, Reims controllers found the segregation of traffic flows eased their workload near GTQ and led to fewer radar vector instructions. In the same way, the organisation of routes carrying the arrivals and departures into/out of Geneva and Lyon negated the merging and crossing of the flows that were problematic with V1 in the southern airspace. This made it easier for controllers to give unrestricted climb and descent instructions.

From Geneva ACC, the feasibility of the SWAP V2 airspace was subjectively rated as at least equivalent or even better to today's structure. The SWAP V2 design removes exiting crossings of traffic flows and segregates northbound and southbound traffic. In addition, when CBA 25 was active there was less negative impact on the L12 sector compared to Baseline airspace.

Although the other ACCs were less impacted by the SWAP V2 network, they benefited from the better traffic management in the Reims and Geneva sectors:

- SWAP V2 made it easier for Reims to descend the Zurich arrivals, thereby facilitating further descent and speed reduction in the Zurich approach sectors. Statistics showed that within Reims airspace the LSZH arrival and departure flows were vertically segregated by a greater distance from other flows in SWAP V2 airspace.
- Aircraft inbound to Paris sector were generally delivered earlier to the UJ sector when SWAP V2 was used (75% of aircraft were delivered 10nm prior to PENDU when even level was used).

- The military controllers found that the better organisation of flows in airspace under the responsibility of the 3 'H ' and 3 'E' sectors made the prediction of civil traffic flows easier than in the Baseline and SWAP V1 airspace.
- Although they were not a measured sector the subjective opinion of MUAC was that the extra route north of GTQ (to OVERT) allowed for a much better organisation of the northbound traffic flows delivered to MUAC and CANAC.

In terms of safety, the subjective view of controllers showed that SWAP V2 airspace was regarded as at least equivalent to today by all the controllers with even half of them who perceived the safety level to be improved. Similarly, 64% of controllers indicated that SWAP V2 airspace could potentially increase current capacity thanks to the reduction in workload and increased safety.

The RTS is not the best means to measure flight efficiency as the comparative routeing of aircraft on the different networks needs to be measured from airport to airport. Nevertheless, distance flown analysis shows that within the 3 'H' sectors there was a reduction of track mileage of 2nm per aircraft with SWAP V2 compared to the mileage flown on the current network. This is due to the organisation of a straighter network which also helps to account for the reduced variation from planned route (fewer radar interventions).

Although the simulated SWAP V2 network was accepted by the majority of the participants, they mentioned remaining issues that will require farther studies and agreements:

- The dogleg (VADEM-JOHAN-DITER-MOROK) round the active CBA 25 sometimes made it difficult for the Reims controllers to detect potential conflicts farther north (e.g. between Zurich departures and Strasbourg arrivals). I
- It will be necessary to design new SIDs and STARs to connect Geneva and surrounding airfields to the V2 network.
- As shown in the PRTS, negotiations will need to take place with the military authorities on options for relocating or reducing CBA 25 to accommodate departures from Geneva when runway 05 is in use.

5.1.2 Transfer levels from Reims to adjacent centres

The second objective of the simulation was to investigate different transfer flight levels on descending traffic from Reims to adjacent centres. The intention was to assess the feasibility of raising the transfer levels to flight levels that will allow flights to achieve a better descent profile. During the first week of the simulation a number of options were tested and those thought most suitable were applied in week 2. The interfaces involved were Reims/MUAC and CANAC, Reims /Paris and finally Reims /Zurich. The following paragraphs summarise each interface in turn.

5.1.2.1 Reims/MUAC

At the Reims/MUAC interface a significant number of flights are in the climb or descent. Channelled between two military areas flows in/out of many German airports merge with arrivals and departures from Belgium and the Netherlands. These North/South flows cross another set of busy traffic flows routing East/West in MUAC airspace. In order to facilitate a safe crossing, Reims descend the northbound flow and deliver to traffic at flight levels that allow MUAC and CANAC to continue the descent below the crossing flows. In the simulation three options were examined. The first option allowing flights to remain at their cruising FL was rejected. Although the easiest option for Reims, the controllers were unanimous is expressing the view that it would not be possible for MUAC to descend the traffic in sufficient time for transfer to the TMAs.

The second week was therefore able to concentrate on two options: transfers at the current FLs (C1) and an intermediate set of FLs (C3). The subjective view of the controllers was that both options were achievable especially with the V2 airspace. More Reims controllers rated the intermediate FLs as the most acceptable (Figure 16). However, with MUAC and CANAC only acting as feed sectors it was impossible to measure the upstream effect of raising the delivery flight levels.

5.1.2.2 Reims/Paris

Four delivery FL options were tested for the Paris arrivals from Reims to the Paris UJ sector. For the Reims sectors delivery at even or odd flight levels were achievable though they expressed a preference for the option of even levels plus +FL350 for LFPO arrivals. This was largely because with the SWAP networks there was less confliction between the flow into Paris from the east and the southbound flow at odd levels.

The outcome was inconclusive from the Paris perspective with the controllers split between the odd and even level delivery. They were however unanimous on rejecting the option to deliver flights at all levels as leading to a lack of predictability for the pre-regulation task in the UJ sector. During the debriefings two additional items were discussed. The first concerned the early release of flights to Paris (e.g. FL 350 at PENDU/MOROK) with the possibility to turn the flights 20˚ whilst maintaining flight level. The second issue concerned the correct sector for coordination when flights were descending to FL 340. Paris controllers were unsure whether they were still with the KH sector or had been transferred to the XH. One solution discussed was the creation of a 'release area' where flights would be permitted to descend in the XH sector but remain on the KH frequency.

5.1.2.3 Reims/Zurich

Only two variations were tested at the Zurich/Reims interface. There was general agreement by both sets of controllers that delivery at FL 200 over BLM was the best solution regardless of the V1 or V2 airspace although Reims controllers had difficulties to descend them to the required level. The Zurich controllers have limited airspace available to facilitate the continuing descent into Zurich and delivery at FL 230 did not afford them sufficient space and time. As with the Paris arrivals there was an issue over which sector was controlling the flight and who Zurich should coordinate with when FL 200 was used. The suggestion was made that a release area or procedure could be that would allow the UH sector to transfer flights directly to Zurich without having to coordinate with the ESE underneath (vertical limit at FL225).

5.2 Recommendations

The sequence of a Prototype followed by a full real time simulation for SWAP was successfully completed at the end of April 2010. Two airspace design options were tested and whilst the controllers rejected the SWAP V1 airspace they were positive on the potential benefits of SWAP V2. Their subjective view was that there could be gains in terms of safety, capacity and flight efficiency.

Therefore it is recommended that:

- The potential benefits of the SWAP V2 airspace be further investigated. In particular that in depth examination be made on the impact of the SWAP V2 on:
    - MUAC and CANAC airspace;
    - The Geneva TMA (adjoining the SWAP network with new SIDs/STARs).
- The CBA22 Working Group agrees on the military area dimensions being a "need to have" for the SWAP implementation;
- The creation of an additional route ROUSY and GISWE be considered;
- The benefit of the additional northbound route GTQ-OVERT be further investigated within FABEC;
- The possibility of changing the location/dimensions of CBA25 be further investigated;
- If SWAP V2 is implemented the use of higher FLs for transfer between Reims and MUAC be considered;
- Arrangements be made to allow Zurich arrivals to skip the ESE sector when transferring from Reims, in descent to FL 200;
- Consideration be given to transferring Paris arrivals at MOROK and with a procedure that permits the UJ controller to turn traffic (left/right 20˚) within Reims airspace;
- The SWAP V1 airspace option be discarded.

6 Lessons learnt

6.1 Project management

At a project level, the following lessons learnt were identified:

- Need for an early involvement from EUROCONTROL Experimental Centre (e.g. operational and validation experts) in the SWAP WG. This would allow a better understanding of the problems/solutions and could help focusing and structuring stakeholders' needs and expectations (e.g. type of simulation, schedule and sectors required according to maturity of the concept).
- Need for a "mature" concept to assess during the RTS in order to reduce the number of conditions tested, to focus on data collection (with numerous traffic samples), to perform rigorous comparison (control of tested conditions). If purpose is design, prototyping sessions may be more adequate (possibility to have multiple options and results rather based on "expert judgement").
- Need for a clear definition of the roles and responsibilities of the SWAP RTS Core Team and the (external) simulation manager.
- Confirmation of the importance of a strong involvement of the Core Team in all project phases: simulation preparation (including validation tasks and data prep), simulation conduct and reporting (e.g. review of analysis/report).

6.2 Data preparation and validation

The SWAP RTS Core Team members and EUROCONTROL spent a lot of effort on the data preparation and validation in using SAAM tool and database. Indeed, this stage covers very critical simulation aspects (airspace, routes and traffic definitions) for the success of an RTS in terms of objectives achievement and realism. However, the schedule planned for those tasks was nearly too tight to achieve the large amount of work required. As a consequence, the following lessons learnt were identified to enhance the data preparation and validation process:

- Need for more time devoted to the initial preparation of the data.
- Need for improvements to the SAAM tool and database, e.g. in conducting SAAM validation cycle sessions (update side effects).
- Need for traffic sample to be screened by concerned ANSPs before the input into IPAS to avoid duplication of the work;
- Need for a better role/task allocation/definition between FABEC WG and the SWAP RTS Core Team: FABEC WG for macroscopic airspace and traffic validation (providing airspace design solutions on 24h traffic sample) and the Core Team only in charge of RTS microscopic airspace and traffic sample validation (2h or 3h per traffic). To save time, the Core Team members may be trained on the SAAM tool.

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