CDM & Sector Team Operation Validation Report

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Abstract

The present document is the Validation Report for the CDM & Sector Team Operation validation activities conducted under the 04.03 project. It describes two validation exercises that took place between June and December 2011. These validation exercises consist in Shadow Mode Trials and Live Trials (both with Real-Time Simulations) performed in the Brest ATCC environment with licensed controllers specifically trained to the En Route Air Traffic Organizer ERATO.

The purpose of these validation exercises was to assess that the ERATO operational concept fulfils the service it has been developed for, *i.e.* :

- Enhancing cooperation between Executive and Planner Controllers;
- Monitoring the air traffic situation;
- Supporting conflict detection and resolution.

At the end of this validation phase, the ERATO concept has been validated.

In the French context, future validation work will deal with implementation of the ERATO tools inside the French legacy system (outside of SESAR scope).

It has been demonstrated that the concept can be applicable in certain environments other than the French one. However all the ERATO features might not be required in all environments. Furthermore, a total or partial implementation of the ERATO tools would require their adaptation to the specific environment of the foreseen control centre, taking into account the airspace and actual legacy system characteristics, as well as associated working habits.

Authoring & Approval

Prepared By		
Name & company	Position / Title	Date
[redacted] DSNA [redacted] (ENAV), [redacted] (DSNA) [redacted] DSNA	[redacted]	O6 January 2012 10 February 2012 5 March 2012

Reviewed By		
Name & company	Position / Title	Date
[redacted] DSNA [redacted] DSNA	[redacted]	<Date>05 March 2012 06 March 2012
[redacted] /ENAV		08 March 2012
[redacted] /ECTL		08 March 2012
[redacted] /Indra		08 March 2012
[redacted] Thales		08 March 2012

Approved By		
Name & company	Position / Title	Date
[redacted] /DSNA	[redacted]	06 March 2012
[redacted] /ENAV		09 March 2012
[redacted] /Thales		08 March 2012
[redacted] /Indra		08 March 2012
[redacted] /ECTL		08 March 2012

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Executive summary

The present document is the Validation Report for the CDM & Sector Team Operation project conducted under WP 04.03 by DSNA. It presents two validation exercises that took place between June and December 2011 in Brest ATCC.

Their objectives were to provide evidence about final usability and acceptability of the ERATO operational concept, integrated for that matter, into the CAUTRA legacy System, as well as to use these results to feed safety and HF cases, and to validate the training.

ERATO is an acronym of En-Route Air Traffic Organizer. It consists of a decision aid toolkit for conflicts detection and resolution on the one hand, and cooperative tools aiming at enhancing cooperation on a control suite on the other hand. Four main features are embedded in the ERATO concept:

- Filtering ;
- Task Scheduling ;
- Extrapolation ;
- Geographic Markers.

The two validation exercises involved licensed test ATCOs specifically trained to ERATO, and were respectively be based on:

- Shadow Mode Trials (plus Real Time Simulations): EXE-04.03-VP-032 ;
- Live Trials (plus Real Time Simulations): EXE-04.03-VP-237.

These trials have been conducted between June and December 2011 on DSNA legacy platform.

EXE-04.03-VP-032 allowed testing usability, situation awareness, and conflicts detection in a quasi-operational environment.

EXE-04.03-VP-237 was designated for ATCOs to work with the ERATO system in a fully realistic operational environment. This exercise merged all objectives already addressed in shadow mode; furthermore air traffic monitoring, teamwork and efficiency brought by ERATO tools have been evaluated.

Real Time Simulations have been used to fulfil validation needs which could not be addressed in shadow mode or live trials.

At the end of this validation phase, the ERATO concept has been validated.

In the French context, future work will deal with implementation of the ERATO tools in the french legacy system (correction of the identified defects and tuning of the tools, safety study, production of the operational and transition material (outside of SESAR scope))

It has been demonstrated that the concept can be applicable in certain environments other than the French one. However all the ERATO features might not be required in all environments. Furthermore, a total or partial implementation of the ERATO tools would require their adaptation to the specific environment of the foreseen control centre, taking into account the airspace and current legacy system characteristics, as well as associated working habits.

1 Introduction

1.1 Purpose and scope of the document

This document provides the Validation Report for the ERATO concept. It describes how operational needs, which have been defined and formalised as a set of requirements in document [8], have been validated, and provides a set of related conclusions and recommendations.

ERATO concept achieved its V2 phase in 2008 after intensive use of Real Time Simulations with licensed ATCOs from DSNA ATCCs (Aix-En-Provence, Bordeaux, Brest, Reims). These simulations took place in Enac, Toulouse in 2008. ERATO has been industrialized in a way to be used in the CAUTRA legacy platform to allow ATCOs to actually perform control in a full electronic environment.

Regarding its maturity level, it has achieved V3 status (ref. EOCVM), and ERATO is now part of the WP 4.3 quick-win projects to be integrated into Release 1.

The validation exercises conducted in the frame of this WP 4.3 activity have been described in D117, CDM Sector Team Operations Validation Plan. They took place in the Brest ACC with ATCOs from DSNA, ENAV and skyguide. These exercises are the following:

- EXE-04.03-VP-032 : Shadow Mode Trials (plus Real Time Simulations);
- EXE-04.03-VP-237: Live Trials (plus Real Time Simulations).

1.2 Intended audience

The stakeholders involved in this Validation Activity are people and organisation interested in the ERATO program.

This includes ATCOs and managers of DSNA (Direction des Services de la Navigation Aérienne), and their different sub-services, DO (Direction des Opérations) and DTI (Direction de la Technique et de l'Innovation), as well as ENAV and skyguide, as DSNA partners and associates within SESAR.

To those interested parties, this document aims at providing an assessment of the usability of the ERATO operational concept, including both functional aids and associated HMI concepts. For that purpose, implementation in the various appropriate operational contexts was considered.

Beside these SESAR validation activities, the usability of the specific DSNA ERATO set of tools integrated in the legacy system is being assessed, but will not be described in the present document.

Primary projects

- 04.03 - Integrated and Pre-operational validation& Cross Validation
- 04.7.8 - Controller Team Organisation, roles and responsibilities in a trajectory based operation within En-route airspace (including MSP Multi-Sector Planner)
- 05.09 - Usability Requirements and Human Factors Aspects for the Controller Working Position

Coordinating Federating Projects

- 04.02 Consolidation of operational concept definition and validation including operating mode and air-ground task sharing

Other Federating Projects for Consultation

- 05.02 - Consolidation of Operational Concept Definition and Validation

1.3 Structure of the document

The present document is structured as follows:

Chapter 1 – Introduction: describes the purpose and scope of the document, the intended audience, and provides the signification of the abbreviations and acronyms used throughout the document;

Chapter 2 – Context of the Validation: offers an overview of the ERATO concept, and a summary of the validation Exercises that have been described in the Validation Plan.

Chapter 3 – Conduct of validation exercises: reports on the way the exercises have been prepared and conducted, explains what deviations have been put in place or observed with respect to the planned activities and why those deviation occurred.

Chapter 4 – Exercises results: presents an overall summary of the exercises outcome

Chapter 5 – Conclusions and recommendations: draws the global conclusions of the exercises and the resulting recommendations.

Chapter 6 – Validation exercises reports: As a support to the preceding chapters, gives the detailed presentation and results analysis of each exercise.

Chapter 7 – References: lists the reference and applicable documents.

1.4 Acronyms and Terminology

Term	Definition
a/c	Aircraft
ACC	Area Control Center
ADD	Architecture Definition Document
Agenda	One of ERATO tools. Task scheduler: this feature provides a visual aid to the controllers (with conflict problems displayed as timely tasks to be done). It allows them to schedule the tasks attributed to the CWP, and so to plan their workload and to monitor the situation through time. It is also a support for the cooperation between the planning controller and the executive controller in order to help them to build a common view of the traffic on the CWP.
ANSP	Air Navigation Service Provider
ATCC	Air Traffic Control Centre
ATCO	Air Traffic Controller
ATM	Air Traffic Management
CAUTRA	Coordonateur automatisé du trafic aérien. French Legacy system
CDG	Charles de Gaulles
CENA	Centre d'Etudes de la Navigation Aérienne (now DSNA/DTI)
CLM	Concept Lifecycle Model
CWP	Control working position
DFS	German ANSP
DO	Direction des Operations, DSNA Operational Direction
DOD	Detailed Operational Description
DSNA	Direction des Services de la Navigation Aérienne. French ANSP
DTI	Direction de la Technique et de l'Innovation. DSNA's technical center
EC	Executive Controller
Effectiveness	Accuracy and completeness with which users achieve specified goals (ISO9241－11:1998)
Efficiency	Resources expended in relation to the accuracy and completeness with which users achieve goals (ISO9241－11:1998)
ENAC	Ecole Nationale de l'Aviation Civile
ENAV	Ente Nationale per l'Assistenza al Volo. Italian ANSP
E-ATMS	European Air Traffic Management System
E-OCVM	European Operational Concept Validation Methodology
ERATO	En Route Air Traffic Organizer
EUROCONTROL	European Organisation for the Safety of Air Navigation
Extrapolation	Extrapolation: on controller's request, this feature extrapolates on the radar image the predicted trajectory known by ERATO for a set of filtered flights (highly interactive view of a filtering allowing a faster graphical analysis of the situation). It provides an aid to diagnosis for the controller, to get him ahead of air traffic, and to speed up the building of his mental situation awareness.
FDP	Flight Data Processing
Filtering	Filtering: on controller's request, this feature shades flights which are irrelevant to the analysis of the situation. Linked to this feature, a monitoring process continuously checks that the aircraft are flying according to their flight plan. Based on the knowledge of controllers, this feature increases their ability to detect and

	solve conflicts but the choice of solutions and the responsibility for decisions are left to them.
FIR	Flight Information Region
HF	Human Factors
HMI	Human Machine Interface
IRS	Interface Requirements Specification
Interop	Interoperability Requirements
KPA	Key Performance Area
KPI	Key Performance Indicator
LT	Live Trial
MGA	Geographic Markers: this feature provides a way for the controller to record a task reminder for a flight at a specific location (point of the flight trajectory in the airspace of the CWP) and a monitoring aid to check for it to be overflown, raising then an alarm on the flight. It frees the controller from the stress related to forgetting something and eases to do the "right task at the right time" (without a substantial mental load consumed for this monitoring).
OFA	Operational Focus Areas
ORY	Orly
OSED	Operational Services Environment Description
PC	Planning Controller
Quick Win	Concepts already available for Sesar Integration
R&D	Research and Development
RTS	Real-Time Simulation
SESAR	Single European Sky ATM Research
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SJU	SESAR Joint Undertaking
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
skyguide	Swiss ANSP
SME	Subject Matter Expert
SMT	Shadow Mode Trials
SPR	Safety and Performance Requirements
SUT	System Under Test
Stripless	ATC environment designed without the use of paper or electronic strips
TC **ATCO**	Licensed Test Controllers Air Trafic COntroler
TMA	Terminal Manoeuvring Area
UIR	Upper information Region
Usability	Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use (ISO9241－11:1998)
VCS	Voice Communication System
V1, V2… V7	Concept Lifecycle Model Phases V1 to V7

2 Context of the Validation

This Validation takes place within the context of the Quick Wins which have been put forward by DSNA.

As the ERATO operational concept reached maturity level 3 over previous French Real Time Simulation, it's time now to really confront it to the real operational traffic, through Shadow mode and Live trial validations operated firstly at Brest ATCC within release 1 context and later at Bordeaux ATCC (presently not foreseen in any other release). The validation exercises covered by this validation phase were aimed at addressing human performance issues as described in the Validation Plan (see Ref [9]Section 2).

The ERATO OSED provides the description of the tasks the controllers will have to perform using the ERATO set of tools, and has been the basis for validation exercises definition and scenarios construction.

The results of these validations will directly be included in the state of the art of the WP 4.7.8, as an input to design and built the DSNA Sector Team Operation including the MSP concepts.

ERATO project is one of the step1 projects where foreign ATCOs were invited to actively participate into the validation process, not only as observers, but also in providing information for the validation report. Two ANSP have been involved in the process, ENAV and skyguide. Two controllers from each entity have been participating in a RTS process comprising a seven days training and three days of evaluation. For these RTS, the ERATO Tools were implemented in the French environment. Besides, the ENAV HF Team has been collaborating with DSNA in the preparation and conduction of the evaluation, with a more specific focus on global usability of the ERATO concept and concept applicability in the ENAV environment.

Due to obvious safety reasons, this foreign active participation could only be planned through RTS and shadow mode sessions.

2.1 Concept Overview

As described in the ERATO OSED (REF [10]), the ERATO (En-Route Air Traffic Organizer) operational concept relies on a decision aid toolkit for En-Route air traffic control in an electronic environment. Its objectives are:

- To provide an assistance to air traffic controllers for the detection and resolution of conflicts ;
- To facilitate the cooperation between the executive and the planning controller on a control suite[1]

ERATO is composed of four main features (functions) facilitating air traffic control and time management:

- Filtering: on the controller's request, this feature shades flights which are irrelevant to the analysis of the situation. Linked to this feature, a monitoring process continuously checks that the aircrafts are flying according to their flight plan. Based on the knowledge of controllers, this feature increases their ability to detect and solve conflicts but the choice of solutions and the responsibility for decisions are left to them.
- Task scheduler: this feature provides a visual aid to the controllers (conflict problems being displayed as timely tasks to be done). It allows them to schedule their tasks, and so to plan their workload and to monitor the situation through time. It is also a support for the cooperation between the planning controller and the executive controller in order to help them to build a common view of the traffic.
- Extrapolation: on the controller's request, this feature extrapolates on the radar image the predicted trajectory known by ERATO for a set of filtered flights (highly interactive view of a filtering allowing a faster graphical analysis of the situation). It provides an aid to diagnose for

[1] thus to some extent also contribute to CM-0301 although not addressed by this validation activity

the controller, to get him ahead of air traffic, and to speed up the building of his mental situation awareness.

- Geographic markers: this feature provides a way for the controller to record a task reminder for a flight at a specific location, i.e. a point of the flight trajectory in the airspace under responsibility, and a monitoring raising an alarm when this point is flown over. It frees the controller from the stress related to forgetting something and eases to do the "right task at the right time" (without a substantial mental load consumed for this monitoring).

EXE-04.03-VP-032 and EXE-04.03-VP-237 both address the four main functions of ERATO, with a particular focus on specific HP aspects, as described in the validation plan (See Ref [9] Section 4) and recalled in the tables hereafter:

Validation Exercise ID and Title	EXE-04.03-VP-032*: Shadow mode and RTS*
Leading organization	DSNA
Validation exercise objectives	Global usability assessment
Rationale	Usability will be assessed through the items of intelligibility, visibility and perceptibility, efficiency and comfort of use of the human machine interactions.
Supporting DOD / Operational Scenario / Use Case	“ERATO set of tools” services and scenarios tasks described in the 4.3 OSED
OI steps addressed	CM0201 Automated Assistance to Controller for Seamless Coordination, Transfer and Dialogue; CM0202 Automated Assistance to ATC Planning for Preventing Conflicts in En Route Airspace; CM0203 Automated Flight Conformance Monitoring (partially, limited to reminders); CM0204 Automated Support for Near Term Conflict Detection & Resolution and Trajectory Conformance Monitoring.(partially, no resolution advisory).
Enablers addressed	
Applicable Operational Context	Conflict management and support tools
Expected results per KPA	Capacity: + (CM0201, CM0203) to +++ (CM0202) Cost effectiveness: + (CM0201, CM0202) Efficiency: + (CM0202) to +++ (CM0201) Safety: + (CM0201, CM0202) to +++ (CM0203,CM0204)
Validation Technique	SM and RTS
Dependent Validation Exercises	

Table 1: EXE-04.03-VP-032

Validation Exercise ID and Title	EXE-04.03-VP-237*: Live Trial and RTS*
Leading organization	DSNA
Validation exercise objectives	i) assess ERATO tools effectiveness, ii) consolidate and assess working methods, iii) contribute to the safety case, iv) contribute to training needs identification, v) assess concept applicability into foreign stripless environments.
Rationale	Usability will be assessed through the items of intelligibility, visibility and perceptibility, efficiency and comfort of use of the human machine interactions.
Supporting DOD / Operational Scenario / Use Case	"ERATO set of tools" services and scenarios tasks described in the 4.3 OSED
OI steps addressed	CM0201 Automated Assistance to Controller for Seamless Coordination, Transfer and Dialogue; CM0202 Automated Assistance to ATC Planning for Preventing Conflicts in En Route Airspace; CM0203 Automated Flight Conformance Monitoring (partially, limited to reminders); CM0204 Automated Support for Near Term Conflict Detection & Resolution and Trajectory Conformance Monitoring.(partially, no resolution advisory).
Enablers addressed	
Applicable Operational Context	
Expected results per KPA	Capacity: + (CM0201, CM0203) to +++ (CM0202) Cost effectiveness: + (CM0201, CM0202) Efficiency: + (CM0202) to +++ (CM0201) Safety: + (CM0201, CM0202) to +++ (CM0203,CM0204)
Validation Technique	Live Trials and RTS
Dependent Validation Exercises	

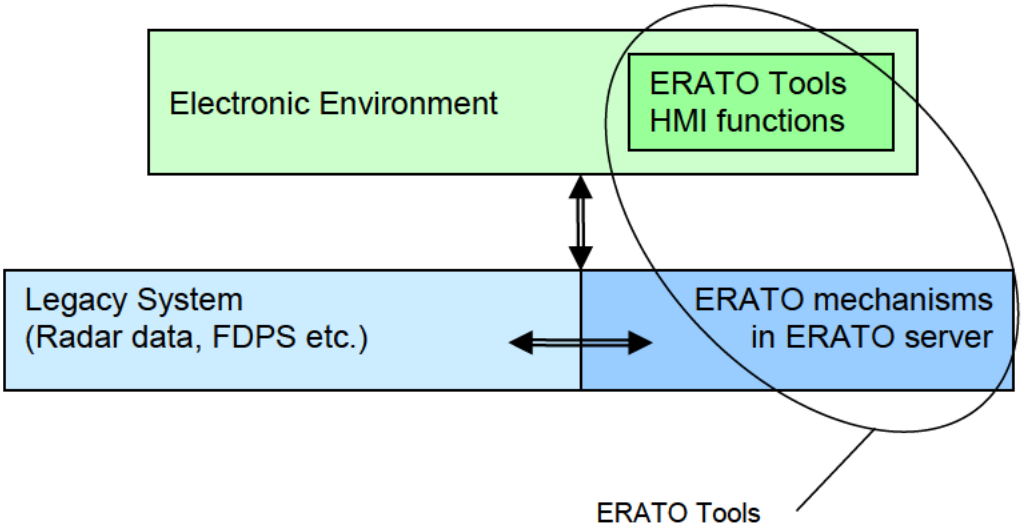
Table 1Bis: EXE-04.03-VP-237

Besides, regarding the EXE032 and EXE237 validation process, it has to be underlined that the ERATO concepts mechanisms are added to a global ATC system comprising all traditional capabilities such as radar tracking or FDPS, and aiming at allowing ATCOs to carry out their usual tasks.

More specifically, this system includes an Electronic Environment (EE), in which ERATO HMI functions, interfacing ERATO mechanisms with the ATCOs. Then, the term ERATO tools refers to ERATO mechanisms plus ERATO HMI functions.

Making the above distinction between the different sub-systems is needed to clearly identify what is being validated in these exercises :

- the EE is not actually under test in EXE032 and EXE237, as it relates to French implementation concerns; it can be addressed if appropriate throughout the global HMI assessment in EXE032 but only for French controllers;
- the ERATO HMI functions are in the scope of EXE032; they are manly addressed here on the concept level as implementations specifics are not to be dealt with;
- the integration of global ERATO tools, and therefore of the four ERATO conceptual functions, in the ATCO's work is addressed in EXE237.



2.2 Summary of Validation Exercises

2.2.1 Summary of Expected Exercises outcomes

The stakeholder identification, needs and involvement addressed are as follows:

Stakeholder	External / Internal	Involvement	Why it matters to stakeholder	Performance expectations
SESAR/SJU	External		Communication with partners	Obtain assurance that the concepts under consideration will be feasible and operable
Ground Industry	External	Thales ATM	Communication with partners	Ground system requirements validated
ANSP	Internal	DSNA skyguide ENAV	Obtain Air Traffic Controller's acceptance of the new concepts. Offering the possibility to share this acceptance with partners	Validated operational concept. This will speed up the deployment of the concepts.
ANSP	Internal	DSNA skyguide ENAV	No negative impact on operations derived from the use of new CWP/HMI	Working methods, tools and procedures acceptance by the human actors (ATCOs).
ANSP	Internal	DSNA skyguide ENAV	Enhance traffic handling by Air Traffic Controllers and safety due to the use of ERATO tools	Confirm the viability of the ERATO Concept of Operations Confirm its usability and applicability in several contexts

Table 2: Stakeholders' expectations

Compared to the information coming from the 04.03 PIR, the ANSP stakeholders for the exercises 032 and 237 are DSNA, ENAV and skyguide.

On the French side, the involved sub-services in DSNA (French Air Navigation Service Provider) are:

- DTI: Technical Support for DSNA
- DO: Operational services, including in particular Brest ATCC.

These sub-services are conducting a validation phase with the ERATO operational concept on their legacy. The needs for DSNA and both DO and DTI are to produce consolidated evidence about safety and final usability of this operational concept.

Concerning ENAV and skyguide, the expected outcomes are mainly related to the concept applicability in their own operational context.

2.2.2 Benefit mechanisms investigated

Benefits Mechanisms of the concept have been demonstrated within the FASTI program (see Ref. [11]).

However, in consistence with prescriptions in Project 16.6.5 (see Ref.[7]), the human performance (HP) issues to be dealt with in both EXE-04.03-VP-237 and EXE-04.03-VP-032 are described in as follows :

- **Procedures, roles and responsibilities**: assessment of the capacity of the tools to help the controllers to detect and solve conflicts and on the workload of the controllers, through an enhanced task sharing;
- **HMI**: assessment of the suitability of the HMI of the controller support tools (ERATO);
- **Training & regulation**: identification of training needs, impacts on licensing regulation.

The HP Regulation will not be addressed in the exercises, as the introduction of the ERATO tools does not imply any change on regulation aspects.

Furthermore, these HP issues will be investigated regarding their contribution to the KPAs described in the table below. This table lists the Operational Improvements Step that will be addressed and the associated expected benefits as defined in the SESAR ATM Masterplan (see Ref. [8]). In this table, the column “Magnitude” indicates whether the expected positive impact on a KPA is High (+++) or Low (+). Although not formally taken into account in this validation activity, the results of the validation exercise may also contribute to CM-0301 (work on the collaboration between EC and PC).

OI Step(s)	Description	Benefits	
		KPAs	Magnitude
CM02-01 Automated Assistance to Controller for Seamless Coordination, Transfer and Dialogue	This improvement relates to the dynamic management of airspace/route structure. The system provides support for decision making based on pre-defined sector sizing and constraint management in order to pre-deconflict traffic and optimise use of controller work force	**Capacity**	+
		Cost-effectiveness	+
		Efficiency	+++
		Safety	+
CM02-02 Automated Assistance to ATC Planning for Preventing Conflicts in En Route Airspace	The system assists the controller in conflict identification and planning tasks by providing automated early detection of potential conflicts; facilitating identification of flexible routing/conflict free trajectories; identifying aircraft constraining the resolution of a conflict or occupying a flight level requested by another aircraft	**Capacity**	+++
		Cost-effectiveness	+
		Efficiency	+
		Safety	+
CM02-03 Automated Flight Conformance Monitoring	The systems provides the controller with warnings if aircraft deviate from a clearance or plan, and reminders of instructions to be issued	**Capacity**	+
		Safety	+++
CM02-04 Automated Support for Near Term Conflict Detection & Resolution and Trajectory Conformance Monitoring	The system provides assistance to the Tactical Controller to manage traffic in his/her sector of responsibility and provides resolution advisory information based upon predicted short term conflict information within the tactical ATC environment	**Safety**	+++

Table 3: OI steps and associated KPAs

2.2.3 Summary of Validation Objectives and success criteria

In order to fulfil the stakeholders’ expectations, the objectives of the validation exercises are listed below:

- **Assess global usability**: this objective must allow determining the usability level of the pre-operational system functionalities, and more specifically to identify the remaining adjustments to be provided for deployment purposes. It will address both HMI ergonomics and functional issues. The topics will be: intelligibility, visibility and perceptibility aspects, efficiency and comfort of use for human machine interactions.
- **Assess ERATO tools effectiveness**: the tools dedicated to providing the controllers with assistance in conflict detection as well as in cooperation and planning tasks have been developed by the way of an iterative process. Their level of maturity is reckoned sufficient to

proceed to the present final validation exercise ; consequently, this objective consists in assessing the effectiveness of the service the controller is provided with ; remaining marginal adjustments will be determine through an opportunistic approach. The assessed ERATO tools are the filtering, the extrapolation, and the task scheduler including the MGA (geographic markers).

- **Consolidate and assess working methods**: preliminary to the trials, working methods have been defined; test controllers will be trained to these methods; then, the evaluation process will allow assessing the "fit-for-purposeness" of this working method in order to finally adjust them as needed.
- **Contribute to the safety case**: the exercises could allow various observations, identified as relevant data to feed the safety case. This objective consists in noticing and reporting the potential safety events occurring during the Live Trials or the RTS (provided such events would occur).
- **Assess concept applicability into foreign stripless environments**. ENAV and skyguide ATCOs will participate in the evaluation process. This participation will allow identifying the main potential operational benefits provided by the ERATO services if integrated in ENAV or skyguide environment. Moreover, it can participate in anticipating elements of "how to use" the ERATO services in the ENAV and skyguide environment if envisaged.
- **Contribute to training needs identification:** the exercises could allow various observations, identified as relevant regarding the training in working methods that will transform the ACC controller's skills. This objective consists in noticing and reporting the potential observations linked to difficulties in applying working methods, in the Live Trials or the RTS (provided such events would occur).

The table gives an overview of exercise 032 and exercise 237: Objectives, controllers and means that will be used (coloured cases).

		Live Trials		Shadow Mode		RTS	
	Objectives	French ATCO	Foreign ATCO	French ATCO	Foreign ATCO	French ATCO	Foreign ATCO
EXE 032	Usability	---	---		---		
EXE 237	Effectiveness		---	---	---		
	Working Method		---	---	---		
	Safety		---	---	---		
	Applicability	---	---	---	---	---	

Table 4: Overview of the exercises

Each validation objective is addressed by either EXE 032 or EXE 237 as described in the tables below and presented in part 4 of the Validation Plan.

Identifier	**OBJ-04.03-VALP-0032.0001**
Objective	Assess global usability

Identifier	Success Criterion
CRT-04.03-VALP-0XXX.0001	A HMI solution is identified as successful if no problem of use occurs.

Table 5: Validation objective - Global usability

Identifier	**OBJ-04.03-VALP-0237.0002**
Objective	Assess ERATO tools effectiveness

Identifier	Success Criterion

CRT-04.03-VALP-0XXX.0002	The ATCO achieves the control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method.

Table 6: Validation objective - ERATO tools effectiveness

Identifier	**OBJ-04.03-VALP-0237.0003**
Objective	Consolidate and assess working methods and related training

Identifier	Success Criterion
CRT-04.03-VALP-0XXX.0003	The ATCO achieves the control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method. The specified data analysis does not indicate any observation related to training leading to impossibility to put the ERATO tools into operation in Brest ACC.

Table 7: Validation objective – Working methods

Identifier	**OBJ-04.03-VALP-0237.0004**
Objective	Contribute to the safety case

Identifier	Success Criterion
CRT-04.03-VALP-0XXX.0004	The specified data analysis does not indicate any safety observation leading to impossibility to put the ERATO tools into operation in Brest ACC.

Table 8: Validation objective – Safety case contribution

Identifier	**OBJ-04.03-VALP-0237.0005**
Objective	Assess the concept applicability into foreign stripless environments

Identifier	Success Criterion
CRT-04.03-VALP-0XXX.0005	The specified data analysis does not indicate any impossibility to successfully integrate the concept into foreign stripless environments for ENAV and skyguide.

Table 9: Validation objective – Concept applicability into foreign stripless environments

2.2.3.1 Choice of metrics and indicators

For dealing with the previous objectives in exercises 032 and 237, qualitative indicators were used. Neither quantitative nor statistical analysis was performed.

The indicators associated with each of the validation objectives are listed in the table bellow.

Objective ID	Description	Indicator
OBJ-04.03-VALP-0032.0001	Global usability	Observing the easiness and difficulty when carrying out the HM interactions (for all controllers)
		Asking controllers participants to comment the observed difficulties and to answer questions about their points of no-satisfaction
OBJ-04.03-VALP-0032.0002	Tools effectiveness	Observing the easiness and difficulty when carrying out the operational tasks using the ERATO tools
		Interviewing controllers participants and comment the observed or perceived difficulties to successfully carry on the operational tasks
OBJ-04.03-VALP-0237.0003	Working methods	Observing the easiness and difficulty when carrying out the operational tasks applying the working methods
		Interviewing controllers participants and comment the observed or perceived difficulties to successfully carry on the operational tasks
	Training needs	Opportunistic observation of easiness and difficulties in applying the working methods for which controllers have been trained
		Asking controllers participants to comment the observed difficulties in response to adequate questions
OBJ-04.03-VALP-0237.0004	Safety	Opportunistic observation of safety event occurring during controllers' activity
		Asking controllers participants to comment the observed event (provided such event would occur) in response to adequate questions
OBJ-04.03-VALP-0237.0005	Applicability to foreign environments	Asking pairs of foreign controllers of the same nationality to mentally project the ERATO concept into their own environment and interviewing them about it

Table 10: Indicators per objective

2.2.4 Summary of Validation Scenarios

Validations scenarios included several situations on the widest possible scale, in order to reach a sufficient level of representativeness of the diverse ERATO use cases.

Those scenarios comprised standard traffic situations, on a representative range of sector types (simple or complex, departure or arrivals, nominal or high traffic load, etc.).

In each simulation run, controllers had to achieve the following tasks described in the OSED (see Ref. [10]):

- Identify groups of flights sorted according to operational criteria associated to flight trajectories;
- Materialize conflicts;
- Update of conflicts representation;
- Monitor the evolution of ongoing conflicts to act at the right time;
- Share management of conflicts on the CWP;
- Temporize or anticipate tasks presentation;
- Communicate in a synchronous and asynchronous mode on the CWP;
- Check the materialization of the detected conflicts;
- Organize tasks in the frame of conflicts management
- Optimize memory use;
- Anticipate clearance consequences on the traffic;
- Control task execution in order to check the actions efficiency or to correct them if needed.

For a detailed description of the scenarios, refer to the Validation Plan REF[9].

2.2.5 Summary of Assumptions

The following assumptions have been made to perform both exercises:

- Pseudo pilots carefully follow their dedicated instructions;
- Controllers are motivated in using the ERATO tools;
- Foreign controllers are motivated in using the French working methods;

The traffic load is high enough during the selected period (Shadow Mode Trials and Live Trials).

Besides, as the exercises take place in a V3 phase, addressing each of these objectives relies on the use of a global system integrating all the operational requirements listed in the OSED.

2.2.6 Choice of methods and techniques

The validation methods planned in exercises 032 and 237 were:

Shadow Mode trials (SM), which consists in placing controllers (Executive and planning controllers) in an operational-like environment, i.e. CWP under test supplied with live operational data by means of the connection to a test network that mirrors data received by the actual operational CWP. Some other features of the actual CWP are available on the position like VCS and phone listening. Controllers listen and manipulate the HMI as their operational counterparts do. In this quasi-operational environment, the validation objective which can be addressed is essentially global usability.

Live Trials (LT), which can occur when controllers are confident enough with the system. ERATO can be fully operational and rescued if any need by a conventional CWP. Assistance in teamwork and situation analysis for conflict detection brought by ERATO tools can be evaluated in this phase.

Real Time Simulation (RTS) has been used to make progress on some objectives that can be addressed neither during the live-trial nor during the shadow mode phases both for legal and technical reasons. The simulation tool used for this phase is a replication of the legacy system. Scenarios during this phase mainly concerned particular traffic situations, and usability and efficiency of ad hoc working methods.

As show in the following tables, they were applied depending on the objectives and the controllers involved.

Scope	French Controllers	Foreign Controllers
EE HMI Usability	Shadow Mode Trials and Real Time Simulations	N/A
ERATO HMI Usability		Real Time Simulations

Table 11: Exercise 032 usability scope and validation means

Objectives	French Controllers	Foreign Controllers
ERATO tools effectiveness	Live Trials Real Time Simulations	Real Time Simulations
ERATO working methods and related training	Live Trials Real Time Simulations	Real Time Simulations
Safety Contribution	Live Trials Real Time Simulations	Real Time Simulations
ERATO Concept applicability	N/A	Real Time Simulations

Table 12: Exercise 237 objectives and validation means

The data collection techniques were the following ones:

The same methodology will be used for each session of evaluation using a specific mean, implying several means of data collection.

For Shadow Mode trials, exercise 032:

- **Observation**: the observations are conducted during each Shadow Mode session. They allow collecting significant elements related to the HMI usability while controllers interacts with the EEE system;
- **Questions during the activity**: questions are asked during the simulation. They can initiate the verbal data collection on HMI usability. These data will be completed and studied more thoroughly during the individual interviews coming after the simulation;
- **Individual interview**: the interview is individually performed at the end of the exercise. It aims at collecting the controllers' verbalisations on their feeling about the observed difficulties and easiness they have experienced with the new environment. Further questions are related to the observations.

For Real Time Simulations, exercise 032:

- **Observation**: the observations are conducted during each Shadow Mode session. They allow collecting significant but opportunistic elements related to the HMI usability while controllers use the system and carry out their operational tasks;
- **Individual interview**: the interview is individually performed at the end of the exercise. It aims at collecting the controllers' verbalisations on their feeling about the observed difficulties and

easiness they have experienced with the new environment. Further questions are related to the observations.

Foreign controllers participated only to the RTS. For them, the scope of observations and verbal data to be collected in the post-simulation interview is limited to the ERATO tools and concept.

For Live trials, exercise 237:

A pair of controllers handles the real traffic with the ERATO tools. Both controllers alternate the EC function and the PC function. Observations are conducted, and individual interviews on operational tasks and cooperation follow the traffic control session.

For Real Time Simulations, exercise 237:

- **Observation**: the observations are conducted during each simulation exercise. They allow collecting significant elements related to the controller's activity. Specific attention will be pay to safety elements in case they would occur;
- **Operational tasks interview**: the post-simulation interview is individually performed at the end of the exercise. It aims at collecting the controllers' verbalisations on their feeling about carrying out the operational tasks of the simulation exercise. This interview focuses on EC and PC common operational tasks. It allows identifying the difficulties and easiness the controller participants have experienced with EEE environment. It is guided by questions related to these tasks.
- **Cooperation interview**: the cooperation debriefing is individually carried out at the end of each simulation exercise. It allows collecting the controllers' verbalisations on the carrying out of the cooperation tasks between EC and PC. It is guided by questions related to these tasks.
- **EC and PC specific operational tasks interview**: this interview is individually carried out at the end two simulations. It allows collecting the controllers' verbalisations on their carrying out of the operational tasks. This interview focuses on EC and PC specific operational tasks. It is guided by questions related to these tasks.
- **Final debriefing with the controllers**: a final debriefing is conducted with the expert controllers who carried out the training and who will have made observations during the simulations. The experts are asked to provide their observed items mainly related to working methods, cooperation and safety elements (if such events would occur).
- **ERATO Applicability debriefing**: It is expected to collect exploratory data on this point with foreign controllers.

All of the individual interviews integrate questions about safety elements, in case some difficulties would have been observed during the simulations and provided such events would have occurred.

Foreign controllers are only concerned with RTS. The scope of observations and debriefing for them is limited to the ERATO tools, the working method and the safety elements. Moreover, a particular debriefing is dedicated to the ERATO concept applicability.

2.2.7 Validation Exercises List and dependencies

As a summary to the preceding sections, the following figure shows how the two exercises were conducted, who participated in the simulations and trials, and which validation objectives they contributed to fulfil.

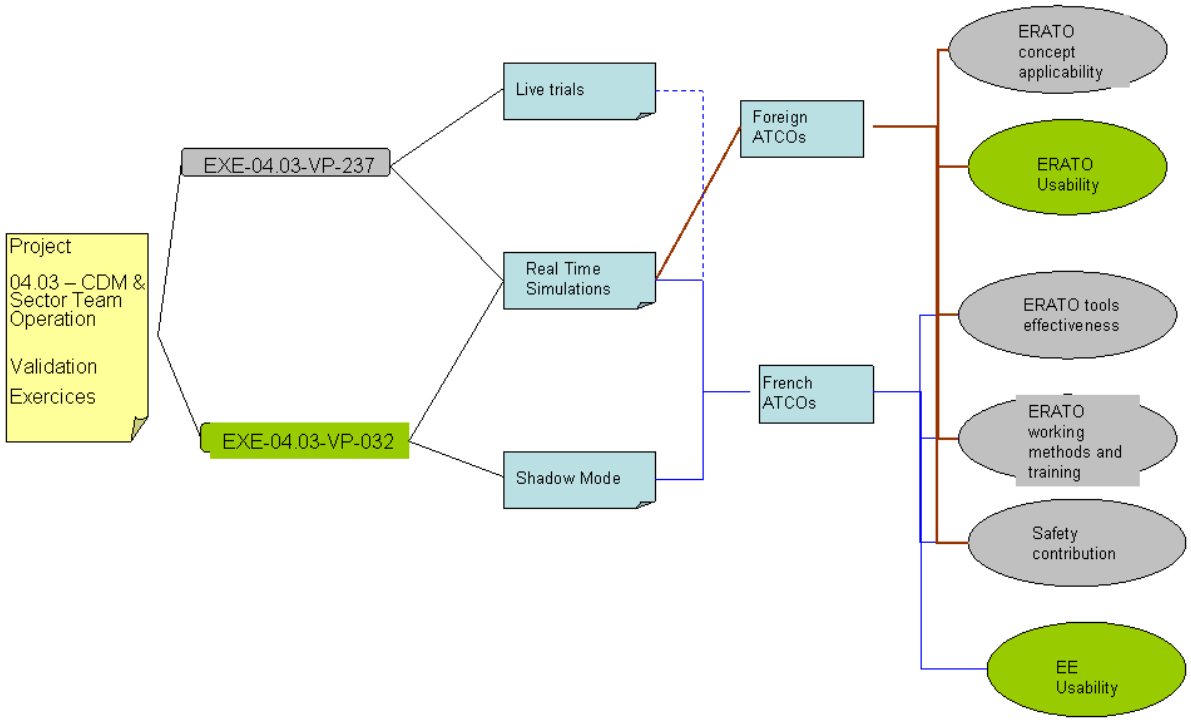


Figure 1: Validation Exercises List and dependencies

3 Conduct of Validation Exercises

3.1 Exercises Preparation

Concerning preparatory activities, exercises 32 and 237 were considered as a same integrated activity.

The table below indicates the realised scheduling for these preparatory activities (2010-2011).

Preparatory activities	Month					
	Until 01/11		01/11 to 03/11	03/11 to 05/11	06/11 to 10/11	11/11 to 12/11
Project management for preparation activities and coordination						
Set Validation Strategy						
Prepare the SUT and V&Vi						
Prepare the ATCOs' training						
Design the traffic samples with respect to simulation scenarios						
Prepare the supports for data collection						
Design exercise planning						

Table 13: Detailed Scheduling for preparatory activities in 2010-11

3.2 Exercises Execution

The table below indicates the realised scheduling for execution and post-exercises activities (years 2011-2012).

Preparatory activities	Month							
	06/11	07/11	08/11	09/11	10/11	11/11	12/11	01/12 to 02/12
Project management for execution activities and coordination								
Conduct Shadow Mode Trials								
Conduct Live Trials						Not done		
Conduct Real Time simulations								
Project management for post exercise activities and coordination								
Row data sorting and analysis								
Produce validation report								
Disseminate results information								

Table 14: Detailed Scheduling for execution and post exercise activities in 2011-2012

3.3 Deviations from the planned activities

3.3.1 Deviations with respect to the Validation Strategy

The VALS document from 4.02 wasn't available at the time this exercise was prepared.

3.3.2 Deviations with respect to the Validation Plan

Due to operational constraints in Brest ACC, the above schedules slightly differ from what was planned. Anyway, all preparatory activities could be carried out in time so as to execute the validation sessions in respect with the general deadlines.

The only exception to this is the preparation and conducting of live trials, which have been delayed, for the following reasons:

- Some unexpected technical drawbacks of live trials infrastructure on the operational systems were identified ;
- Complying with safety requirements in terms of operational procedures for the specific case of live trials needed more preparation time that initially forecast.

These two problems have been solved since then, and Live Trials sessions will be held soon. Anyway, it occurred that it was not really useful to postpone the data analysis and the validation report delivery, as these trials would not have an important added value for the validation process. Indeed, for safety reasons, live trials have to be in first phases carried out in low traffic periods, which are not appropriate to validate the ERATO operational concept aiming at enhancing capacity, efficiency and safety in heavy traffic situations.

For that reason, the present document only refers to shadow mode and RTS sessions.

Besides, some specific and isolated functions could not be tested because of malfunctioning. They will be pointed out in chapters 5 and 6. However, since these functions are not playing a central role in the ERATO tools, they are not an issue regarding the ERATO concepts validity.

All the foreseen validation scenarios have been addressed. However, “Anticipate clearance consequences on the traffic” could only be played with foreign controllers due to a late availability of the SIMFL function in the validation process.

4 Exercises Results

4.1 Summary of Exercises Results

Exercise ID	Exercise Title	Validation Objective ID	Validation Objective Title	Success Criterion	Exercise Results
EXE-04.03-VP-032	SM and RTS	OBJ-04.03-VALP-0032.0001	Assess global usability	A HMI solution is identified as successful if no problem of use occurs	(1) HMI concepts are validated. Functions were easily and efficiently used (2) Some specific improvements for implementation in the legacy system have to be made. Solutions already exist (3) Disturbance due to principles differences with their current systems were identified for foreign controllers, but easiness in use considering the quick training
OBJ-04.03-VALP-0237	Live trials and RTS	OBJ-04.03-VALP-0237.0002	Assess ERATO tools effectiveness	The ATCO achieves the control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method.	(1) ERATO concepts effectiveness is validated for French ATCOs (2) Effectiveness is lower for climbing and descending traffic. (3) Usefulness of simulated filtering and filtered flights table have to be further studied (4) Interesting results for foreign ATCOs (5) Still, effectiveness requires to be further investigated for foreign ATCOs: seems to depend on domestic specificities (see OBJ-04.03-VALP-0237.0005 results)
OBJ-04.03-VALP-0237	Live trials and RTS	OBJ-04.03-VALP-0237.0003	Consolidate and assess working methods and related training	The ATCO achieves the control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method. The specified data analysis does not indicate any observation related to training leading to impossibility to put the ERATO tools into operation in Brest ACC.	(1) Working methods and associated training are successful with French controllers (2) Some minor difficulties in new flight detection phases to deal with (3) Interesting results for foreign ATCOs (4) Further investigation required for foreign ATCOs: seems to depend on domestic specificities (see OBJ-04.03-VALP-0237.0005 results)
OBJ-04.03-VALP-0237	Live trials and RTS	OBJ-04.03-VALP-0237.0004	Contribute to the safety case	The specified data analysis does not indicate any safety observation leading to impossibility to put the ERATO tools into operation in Brest ACC.	No potential contributions to the safety case in the data collected.
OBJ-04.03-VALP-0237	Live trials and RTS	OBJ-04.03-VALP-	Assess the concept applicability into	The specified data analysis does not indicate any	(1) Very promising in ENAV environment

Exercise ID	Exercise Title	Validation Objective ID	Validation Objective Title	Success Criterion	Exercise Results
		0237.0005	foreign stripless environments	impossibility to successfully integrate the concept into foreign stripless environments for ENAV and skyguide.	(2) ENAV wish to test future automatic agenda concept (3) Low applicability into skyguide environment

Table 15: Summary of Validation Exercises Results

4.1.1 Results on concept clarification

As V3 Validation exercises, it was not expected from EXE-032 and EXE-237 to contribute dramatically to concept clarification. Indeed, the ERATO concepts tested in these exercises have been validated as such.

However, it has to be noted that the current Task Scheduling concept implemented in the Agenda function is a transitory concept. It has been proved to be very efficient regarding the KPAs it addresses, but a further step will be to validate an enhanced task scheduling concept, involving automatic aids to the controller. This enhanced Task scheduler could be implemented in later phases.

4.1.2 Results per KPA

The following table refers to KPAs as described in section 2.2.2. It establishes a link between the KPAs, the OIs, and level of success obtained for the validation criteria they are referring to.

KPas	OIs	Level of benefit	Validation Objectives	Level of success
Capacity	CM02-01 Automated Assistance to Controller for Seamless Coordination, Transfer and Dialogue	+	Global usability	+++
			ERATO tools effectiveness	++
			Working methods and training	+++
			Applicability into foreign environments	Promising in some contexts (see 6.2.3.2.8 and 6.2.3.2.9)
	CM02-02 Automated Assistance to ATC Planning for Preventing Conflicts in En Route Airspace	+++	Global usability	+++
			ERATO tools effectiveness	+++
			Working methods and training	+++
			Applicability into foreign environments	Promising in some contexts (see 6.2.3.2.8 and 6.2.3.2.9)
	CM02-03 Automated Flight Conformance Monitoring	+	Global usability	++
			ERATO tools effectiveness	++
Cost-	CM02-01 Automated Assistance to Controller for Seamless Coordination, Transfer and	+	Global usability	+++
			ERATO tools effectiveness	++

KPas	OIs	Level of benefit	Validation Objectives	Level of success
effectiveness	Dialogue		Working methods and training	+++
			Applicability into foreign environments	Promising in some contexts (see 6.2.3.2.8 and 6.2.3.2.9)
	CM02-02 Automated Assistance to ATC Planning for Preventing Conflicts in En Route Airspace	+	Global usability	+++
			ERATO tools effectiveness	+++
			Working methods and training	+++
			Applicability into foreign environments	Promising in some contexts (see 6.2.3.2.8 and 6.2.3.2.9)
Efficiency	CM02-01 Automated Assistance to Controller for Seamless Coordination, Transfer and Dialogue	+++	Global usability	+++
			ERATO tools effectiveness	++
			Working methods and training	+++
			Applicability into foreign environments	Promising in some contexts (see 6.2.3.2.8 and 6.2.3.2.9)
	CM02-02 Automated Assistance to ATC Planning for Preventing Conflicts in En Route Airspace	+	Global usability	+++
			ERATO tools effectiveness	+++
			Working methods and training	+++
			Applicability into foreign environments	Promising in some contexts (see 6.2.3.2.8 and 6.2.3.2.9)
Safety	CM02-01 Automated Assistance to Controller for Seamless Coordination, Transfer and Dialogue	+++	Contribute to the safety case	To be further studied (see 6.2.3.2.6, 6.2.3.2.7 and 6.2.4.1)
	CM02-02 Automated Assistance to ATC Planning for Preventing Conflicts in En Route Airspace	+++	Contribute to the safety case	To be further studied (see 6.2.3.2.6, 6.2.3.2.7 and 6.2.4.1)
	CM02-03 Automated Flight Conformance Monitoring	+++	Contribute to the safety case	To be further studied (see 6.2.3.2.6, 6.2.3.2.7 and

KPas	OIs	Level of benefit	Validation Objectives	Level of success
				6.2.4.1)
	CM02-04 Automated Support for Near Term Conflict Detection & Resolution and Trajectory Conformance Monitoring	+++	Contribute to the safety case	To be further studied (see 6.2.3.2.6, 6.2.3.2.7 and 6.2.4.1)

Table 16: Exercises Results per KPA

4.1.3 Results impacting regulation and standardisation initiatives

Regulation and standardisation issues were not addressed in the exercises, as the introduction of the ERATO tools does not imply any change on them.

4.2 Analysis of Exercises Results

In the following table, a synthetic view of the validation results regarding the objectives status is presented. For further information the results, the reader is invited to refer to appropriate sections in chapter 6.

In this table, the validation status will be described as:

- OK : validation objective achieves the expectations (exercise results achieve success criteria);
- NOK (not OK) : validation objective does not achieve the expectations (exercise results do not achieve success criteria);
- POK (partially OK): validation objective partially achieve the expectations (exercise results do not totally achieve success criteria).

Validation Objective ID	Validation Objective Title	Exercise ID	Exercise Title	Success Criteria	Exercise Results	Validation Objective Analysis Status
OBJ-04.03-VALP-0032.0001	Assess global usability	EXE-04.03-VP-032	SM and RTS	A HMI solution is identified as successful if no problem of use occurs	See section 6.1	French ATCOs : OK Foreign ATCOS: POK
OBJ-04.03-VALP-0237.0002	Assess ERATO tools effectiveness	EXE-04.03-VALP-0237	Live trials and RTS	The ATCO achieves the control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method.	See section 6.2	French ATCOs : POK Foreign ATCOS: POK
OBJ-04.03-VALP-	Consolidate and assess working	EXE-04.03-VALP-0237	Live trials and RTS	The ATCO achieves the	See section 6.2	French ATCOs : POK Foreign ATCOS: POK

Validation Objective ID	Validation Objective Title	Exercise ID	Exercise Title	Success Criteria	Exercise Results	Validation Objective Analysis Status
0237.0003	methods and related training			control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method. The specified data analysis does not indicate any observation related to training leading to impossibility to put the ERATO tools into operation in Brest ACC.		
OBJ-04.03-VALP-0237.0004	Contribute to the safety case	EXE-04.03-VALP-0237	Live trials and RTS	The specified data analysis does not indicate any safety observation leading to impossibility to put the ERATO tools into operation in Brest ACC.	See section 6.2	NOK, insufficient results
OBJ-04.03-VALP-0237.0005	Assess the concept applicability into foreign stripless environments	EXE-04.03-VALP-0237	Live trials and RTS	The specified data analysis does not indicate any impossibility to successfully integrate the concept into foreign stripless environments for ENAV and skyguide.	See section 6.2	POK, further studies required, enhanced validation process (training), very limited applicability for skyguide.

Table 17: Overview: Validation Objectives, Exercises Results and Validation Objectives Analysis Status

4.2.1 Unexpected Behaviours/Results

No noticeable unexpected behaviour was found during the exercises.

4.3 Confidence in Results of Validation Exercises

4.3.1 Quality of Validation Exercises Results

The confidence in the evaluation results presented is high, given that the interpretation of the analysed data was triangulated across multiple Human Factors experts, and given that there was always SME observers that systematically gave their operational outputs from the simulations.

However, certain assumptions concerning the length of training required for bringing foreign ATCOs to a sufficiently high level of expertise with the ERATO services was deemed lacking: it was assumed that the extensive experience of foreign ATCOs with their own electronic environments would flatten

the learning curve required for making expert use of the ERATO services. However, the assumption was faulty in that the a-priori experience of foreign ATCOs in their own electronic environment might have slowed-down the learning process of the new environment. In that case, the length of the training should have necessarily been longer as a means of allowing the unlearning of old working habits before learning new working practices.

4.3.2 Significance of Validation Exercises Results

The significance of validation exercises differ between the French ATCOs process and the foreign ATCOs process:

- The number of French ATCOs involved is quite important and the representativeness of operational realism of the exercise was excellent; consequently, the significance of the results is large;
- On the contrary, quite few foreign controllers were involved, and had to work in an unfamiliar operational environment; consequently, the significance of the results is much smaller; however, involving foreign controllers in a SESAR validation exercise is not very common and this experience revealed itself very promising, even if the results have now to be consolidated through an extensive process.

5 Conclusions and recommendations

5.1 Conclusions

Given the conclusions of each exercise (see 6.1.4 and 6.2.4), we may now consider that the ERATO concept has been validated:

- Its global usability has been assessed ;
- the ATCOs ability to achieve the control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method has been demonstrated;
- no noticeable safety issue related to the ERATO concept has been revealed during the exercises;
- the training performed with the French ATCOs is efficient, and can be used as a good training basis for transition purpose.

It has been demonstrated that the concept can be applicable in certain environments other than the French one. However, all of the ERATO features might not be required in all environments, depending on the characteristics of both the airspace and the current legacy system, as well as associated working habits.

5.2 Recommendations

In the French context, future work should now focus on the actual implementation of the ERATO tools in the French legacy system (correction of the identified defects and tuning of the tools, safety study, production of the operational and transition material including training… (outside of SESAR scope)) .

In a candidate foreign environment, the following activities should take place:

- A local implementation of ERATO should always take into account the characteristics of the candidate ACC (airspace structure e.g.) and associated legacy system (existing tools) in order to determine which of the ERATO features are needed;
- The transition steps between the legacy and new system should also be thoroughly assessed for each candidate centre, taking into account working methods, training needs, safety analysis;
- Implementation of the ERATO tools in the legacy system should take into account the tuning of the tools according to local needs (colour, additional information…), a safety study, production of the operational and transition material including training.

6 Validation Exercises reports

6.1 Validation Exercise EXE032 Report

6.1.1 Exercise Scope

In addition to elements provided in section 2 of the current document, the specificities of the scope of exercise 032 have been developed in the validation plan (see Ref. [9]).

As a reminder, major trends of this scope can be described here:

The objective related to this exercise is to assess **global usability** through the items of intelligibility, visibility and perceptibility, efficiency and comfort of use of the human machine interactions. Two aspects of the HMI are examined and linked together when it is relevant: the EE (Electronic Environment) HMI on one hand, and the E (ERATO) HMI on the other hand.

In order to assess these given low-level objectives, two means (Shadow Mode Trials & Real Time Human in the loop Simulations) and two methods are used depending on participants: French ATCOs or foreign ATCOs.

For French ATCOs, the global usability will encompass the EE (Electronic Environment) and the ERATO tools. Two validation means are used:

- **Shadow Mode Trials:** global usability is assessed by the means of Shadow Mode Trials. French controllers are asked to interact with the system in order to maintain the HMI updated in accordance with the ongoing situations: input data, display information, update the system. They are observed and individually interviewed about EE HMI usability and ERATO usability while they are acting on the system and afterwards. The Shadow Mode trials presents the advantage of using the system on real traffic, without any responsibility for the controller, so that he/she is able to comment as the same time about usability;
- **Real Time Simulations:** data gathered in Shadow Mode Trials is completed by those collected in RTS. In RTS, participants are asked to handle simulated traffic. They are not interrupted while controlling the traffic but any opportunistic observation related to any difficulty when interacting with the system is noticed. Then, every particular difficulty can be commented by the controller, in response to adequate questions.

For Foreign ATCOs, global usability is assessed in **Real Time Simulations**. The global usability scope is limited to ERATO tools. Participants are asked to handle simulated traffic. Similarly to French controllers, they are not interrupted while controlling the traffic but any opportunistic observation related to any difficulty when interacting with the ERATO tools is noticed. Then, every particular difficulty can be commented by the controller, in response to adequate questions.

Scope	French Controllers	Foreign Controllers
EE HMI Usability	Shadow Mode Trials and Real Time Simulations	N/A
ERATO HMI Usability		Real Time Simulations

Table 18: Exercise 032 usability scope and validation means

6.1.2 Conduct of Validation Exercise

6.1.2.1 Exercise Preparation

This exercise involved shadow mode trials and RTS.

Shadow relied on the integration of the SUT in the CAUTRA legacy system, while RTS relied on the ELECTRA RTS platform, also integrating the SUT in the CAUTRA legacy system, but simulating radar data by the use of a traffic generator.

Sectors and traffic characteristics chosen for each of them are detailed in the validation plan (cf. [9]).

6.1.2.2 Exercise execution

6.1.2.2.1 French ATCOs

Prior to the Evaluations (RTS and SM), the French ATCOs have been following a comprehensive training process. The training phase regarding the French controllers (phase 1) started in March 2011. It comprised several steps that spread over several months. These steps are as follows:

- Preliminary training (basic knowledge);
- Practical training (Real Time Simulations, Shadow Mode Sessions);
- Training evaluation;
- Authorization process to release the controllers on the CWP for Live Trials.

Concerning Shadow mode for EXE032, two one-week evaluation sessions took place as foreseen, in June (with 12 controllers) and October 2011 (with 14 controllers). Each run of the SM has been planned in conformance with the following scheme for each suite:

	Counterbalanced sequences		**Individual interviews**
Controller n°1	PC interactions on the EEE system	EC interactions on the EEE system	Interview on the EEE system interactions
Controller n°2	EC interactions on the EEE system	PC interactions on the EEE system	Interview on the EEE system interactions
Time duration	20 mn	20 mn	40 mn

Table 19: Exercise 032 shadow mode scheme – French ATCOs

The Shadow mode sessions have been completed by RTS sessions as depicted in the VALP. These RTS sessions have been common to EXE032 and EXE247.

Concerning the RTS, 2 one-week sessions took place in June (with 12 controllers) and October 2011 (with 13 controllers). Each run of the RTS (used both foe EXE032 and EXE247) has been planned in conformance with the following scheme:

A pair of controllers is involved in one session following the planning below (example for a given session).

The session is mainly organized according to the objectives to achieve in exercise 237. For the exercise 032 purpose, each interview integrates questions about EEE system interactions, in case some difficulties would have been observed during the simulation.

	Counterbalanced sequences		**Individual interviews**
Sector GA	**Controller n°1**	EC	Interview exercise 237 Comments about specific EEE interactions
	Controller n°2	PC	idem
Time duration		30 mn	15 mn
Sector N	**Controller n°2**	EC	idem
	Controller n°1	PC	idem
Time duration		30 mn	15 mn

Sector J Simulation 1	**Controller n°1**	EC	Interview exercise 237 Comments about specific EEE interactions
	Controller n°2	PC	idem
Time duration		30 mn	30 mn
Sector J Simulation 2	**Controller n°2**	EC	idem
	Controller n°1	PC	idem
Time duration		30 mn	30 mn

Table 20: Exercises 032 and 237 RTS scheme – French ATCOs

6.1.2.2.2 Foreign ATCOs

Prior to the Evaluations (RTS), the 4 ATCOs have been given a 5 days theoretical and practical training on the French environment and on the ERATO tools, as depicted in the following global planning:

Semaine		Matin		Après-midi
	Wednesday 16/11/2011	Welcome	Pa	EOE SESAR organisation (Logistique & administrative part)
		EEE programme and EOE presentation,		Debriefing
		EOE SESAR at BREST ACC presentation		

		WEEK 49		
		Morning		**Afternoon**
Week 49	**Monday 05/12/11**		Pause	Welcome, course introduction
				Theory: Operational environment presentation
				Operational room visit
	Tuesday 06/12/11	**Theory:** CWP presentation, Localization and interaction	Pause	**Practical:** CWP manipulation and sector Z initiation
		Practical: CWP manipulation and sector N initiation		**Theory** : ERATO Filtrage presentation
		Theory: Trajectory Monitoring		**Practical** : ERATO Filtrage manipulations
				Debriefing
	Wednesday 07/12/11	**Theory** : ERATO AGENDA presentation	Pause	**Practical:** ERATO AGENDA manipulations
		Practical: ERATO AGENDA manipulations		**Theory** : French controller working method presentation (end)
		Theory : French controller working methods presentation		**Practical:** French controller working method assimilation
				Debriefing
	Thursday 08/12/11	ERATO Training on ELECTRA	Pause	ERATO Training on ELECTRA
				Debriefing
	Friday 09/12/11	ERATO Training on ELECTRA	Pause	
		Week Debriefing		

Weekend

		WEEK 50		
		Morning		**Afternoon**
Week 50	**Monday 12/12/11**		Pause	Welcome, week planning
				SMP session (Group 1)
				SMP Session (Group 2)
	Tuesday 13/12/11	ERATO Training on ELECTRA	Pause	ERATO Training on ELECTRA
				SMP session in //
				Training debriefing
	Wednesay 14/12/11	ERATO Evaluations	Pause	ERATO Evaluations
				SMP session in //
	Thursday 15/12/11	ERATO Evaluations	Pause	ERATO Evaluations
				Debriefing
	Friday 16/12/11	Evaluations Questionnaires	Pause	
		First evaluations feedback presentation		
		General Debriefing		

Figure 2 : Exercises 032 and 237 Training – Foreign ATCOs

Concerning the Evaluation session (14th to 16th of December), the following planning has been prepared and followed for both exercises 032 and 237:

SESAR Validation Planning CRNA-O Week 50 - EXE-04.03-VP-032 & EXE-04.03-VP-237

		Wednesday 14 december				Thursday 15 december				Friday 16 december	
Starting	WP F3	WP E4		WP EL3		WP E4		WP EL3		Meeting Room	
08:30		EC	PC	EC	PC			EC	PC		
08:45		EVAL Briefing						EN2	SK1	Debriefing HF with SME	
09:00				SK2	EN2			SESAR_Eval_D1		Cooperation/ Safety	
09:15	SMP			SESAR_Eval_A		Interview by pairs				Working Method Applicability	
09:30	If available			SME Interview		Cooperation/Usability		EN1	SK2	Final Questionnaire	
09:45				Individual Interview Usability/				SESAR_Eval_D1			
10:00				Effectiveness/Working Method		Interview by pairs				Primary Results	
10:15		Coffee Break				Cooperation/Usability		SK1	EN2		
10:30		EN2/SME then SME/EN2						SESAR_Eval_E1			
10:45		SESAR_Eval_B		SK1	EN1	Interview by pairs				Final Debriefing	
11:00		Feed Back from SME		SESAR_Eval_A		Cooperation/Usability		SK2	EN1	Conclusion	
11:15				SME Interview				SESAR_Eval_E1			
11:30		SK2/SME then SME/SK2		Individual Interview Usability/		Interview by pairs					
11:45		SESAR_Eval_B		Effectiveness/Working Method		Cooperation/Usability					END of EVAL
12:00		Feed Back from SME									
12:15						Lunch Break					
12:30		Lunch Break									
12:45											
13:00				EN2	SK2	Foreseeing Applicability : Introduction & Instructions (All)					
13:15		EN1/SME then SME/EN1		SESAR_Eval_C				EN1 & EN2		Traffic sample	
13:30		SESAR_Eval_B		SME Interview		Meeting Room		Strcutured Brainstorming		A - D Sector N	
13:45		Feed Back from SME		Individual interview		SK1 & SK2				B - C - E Sector Z	
14:00				Effectiveness/Usability		Structured Brainstorming		EN1	EN2		
14:15		SK1/SME then SME/SK1		Working Method				SESAR_Eval_D2			
14:30		SESAR_Eval_B		Coffee Break		EN1 & EN2					
14:45		Feed Back from SME				Interview by pairs		SK2	SK1		
15:00		Coffee Break		EN1	SK1	Debrief & Struct. Brainstorming		SESAR_Eval_D2			
15:15				SESAR_Eval_C		SK1 & SK2					
15:30	SMP			SME Interview		Interview by pairs		EN2	EN1		
15:45	If available			Individual interview		Debrief & Struct. Brainstorming		SESAR_Eval_E2			
16:00				Effectiveness/Usability		EN1 & EN2					
16:15				Working Method		Interview by pairs		SK1	SK2		
16:30				END of EVAL DAY		*Conclusion*		SESAR_Eval_E2			
16:45		Debriefing HF with SME				SK1 & SK2					
17:00		Agenda as a cooperation support tool/Safety				Interview by pairs					
17:15						*Conclusion*					
17:30						Debriefing HF with SME					
17:45						Cooperation/Usability/Applicability/safety					
18:00											

Figure 3 : Exercises 032 and 237 Evaluation – Foreign ATCOs

As stated in the VALP (see REF.[9] for the simulation scenarios description), the same Real Time Simulation sessions have been used in exercise 032 and exercise 237. For foreign controllers, the RTS were based on two scenarios (N and Z), with 4 traffic samples each.

Validation exercise EXE-04.03-VP-032, focusing on the objective of assessing the global usability of the ERATO tools for foreign ATCOs was conducted mainly as part of EVAL A (2 exercise runs) and EVAL C (2 exercise runs). The execution of the exercise incurred: 4 ATCOs x 2 sectors (N and Z) x 2 roles (PC & EC).

Sector ID	Objectives	EC	PC
Sector N	Assess Global Usability & Tool Effectiveness	SK2	EN2
		EN1	SK1
Sector Z	Assess Global Usability & Working Methods	EN2	SK2
		SK1	EN1

Table 21: Assessment of Global Usability in EVAL A and EVAL C

The 4 exercise runs were conducted over a day. Each run consisted of the same sequence in time:

i) The simulation was executed where observations of usability-related problems were recorded using pen-and-paper,

ii) the French SME over-viewing the ATCOs was interviewed for 15 minutes and initial global usability issues were identified (when difficulties were observed) and recorded in audio as well as pen-and-paper, and

iii) Individual interviews were conducted by 2 HF experts for each ATCO-pair participating in each exercise run. For EVAL A, each individual interview lasted 30 minutes. For EVAL C, consisting of heavier objectives, each individual interview lasted 45 minutes.

The identification of opportunistic global usability issues was further integrated into the remaining exercise runs, through interview probes. Thus, each interview was introduced by a general question concerning the possible identification of usability issues by ATCOs and these questions were furthered in case an issue was formally identified by the HF or by the SME over-viewing the different exercise runs.

6.1.2.3 Deviation from the planned activities

No noticeable deviation occurred. Anyway, it must be reported that some biases inherent to Shadow Mode experimental situations, which had been foreseen during the elaboration of the validation plan, appeared to be even more significant. These biases are related to the fact that controllers working in shadow mode are often, as they themselves describe it, “behind the traffic”, dependent to analysis and decisions they don’t make, but which are carried out by the controller on the real operational work position. For that reason, all planning and problem solving activities cannot be reflected on the shadow mode work position.

This was the reason why Shadow Mode was restricted to dealing with the Global Usability objective. But even within the frame of this objective, it appeared that the use of some HMI functions is so intimately linked with planning and problem solving activities that it could not be performed in Shadow Mode. RTS were used instead and finally, all validation objectives have been addressed.

6.1.3 Exercise Results

6.1.3.1 Summary of Exercise Results

Validation Objective ID	Validation Objective Title	Success Criterion	Exercise Results
OBJ-04.03-VALP-0032.0001	Assess global usability	A HMI solution is identified as successful if no problem of use occurs	(1) HMI concepts are validated. Functions were easily and efficiently used (2) Some specific improvements for implementation in the legacy system have to be made. Solutions already exist (3) Disturbance due to principles differences with their current systems were identified for foreign controllers, but easiness in use considering the quick training

Table 22: EXE 032 - Validation Objectives and Exercises Results

6.1.3.1.1 Results on concept clarification

See 4.1.1

6.1.3.1.2 Results per KPA

See 4.1.2

6.1.3.1.3 Results impacting regulation and standardisation initiatives

See 4.1.3

6.1.3.2 Analysis of Exercise Results

Validation Objective ID	Validation Objective Title	Success Criterion	Validation Objective Analysis Status per Exercise
OBJ-04.03-VALP-0032.0001	Assess global usability	A HMI solution is identified as successful if no problem of use occurs	French ATCOs : OK Foreign ATCOS: POK

Table 23: EXE 032 - Validation Analysis Objectives Status in the Exercise

In this above table, the validation status is described as:

- OK : validation objective achieves the expectations (exercise results achieve success criteria);

- NOK (not OK) : validation objective does not achieve the expectations (exercise results do not achieve success criteria);
- POK (partially OK): validation objective partially achieve the expectations (exercise results do not totally achieve success criteria).

6.1.3.2.1 Unexpected Behaviours/Results

Issues during Preparation

There were no reportable issues encountered during the preparation phase.

Issues during Execution

During the exercises in RTS with Foreign ATCOs, there was a near-systematic usage of directs as a means of optimizing trajectories and as the same time de-conflicting traffic on Entry. The behaviour lead to a minimal usage of the Task Scheduler (Agenda) given that ATCOs also considered that once a Direct had been given, a potential conflict situation was resolved and did not justify the creation and monitoring of a Problem Label in the Agenda.

The behaviour was unexpected since different from that of French ATCOs for the same sectors and Entry conflict situations. Even though French controllers used to apply same strategy, their direct routes are shorter and not so frequent. A contextual factor which might have influenced the behaviour of ATCOs is the length of the training and experience of the operational sector assimilated during the validation, although not specifically probed during the validation exercise. More particularly Foreign ATCOs hadn't enough experience regarding coordination rules and habits between the Brest sectors and the nearby sectors.

Issues during Analysis

A special consideration for a type of data which was collected should be noted here. This concerns end-user design suggestions and conceptual propositions originating from controllers. Data concerning such literal expressions of needs were not treated or recorded as new needs or specifications. The reason is that controllers do not necessarily possess the global technical vision of the system nor a unified view of the HMI such that associated constraints, compromises and principles of logic for determining needs or specifications cannot be literally entertained.

We made use of controllers' propositions to understand the underlying needs at a conceptual level.

6.1.3.2.2 Global usability for French ATCOs

This section presents the analysis of Global Usability results, based on French ATCOs. Both the Electronic Environment and ERATO tools issues were dealt with. The data was collected in shadow mode and RTS sessions.

Electronic Environment

Labels: the principles of presentation and organisation of the labels were clear and usable:

- colour symbolization of R/T and coordination status is understood and no mix-up occurred, including for filtered traffic ;
- no difficulty was observed and reported concerning the finding of information in the labels; no information is missing ;
- inputs were easily done by controllers.

Some minor improvements can still be done for implementation, for example:

- the choice of colours could be improved to enhance perceptibility;
- optimization of the label size could help avoiding some remaining overlapping problems;
- some consistency issues concerning the presentation of information between labels and flight dyps could be dealt with;

- more adequate default values could be chosen in some menus.

Highlights: for each flight, many items can be highlighted and de-highlighted, which is used as a reminder or warning means. These functions were easily and efficiently used either in Shadow mode or in RTS, with no noticeable operating difficulty.

Flight table (dyps): the organisation and readability of flight dyps allowed controllers to easily and efficiently find the required information. Some minor implementation evolutions could yet be made (RFL presentation mainly).

Flight lists (on the radar display):

- entry flight lists (containing on-coming flights) were not often used in shadow mode sessions, for bias reasons (see 6.1.2.3); in RTS, they were used for new flights detection; no operating difficulty occurred;
- assumed flights lists appeared to be useful for controllers' checks and for some inputs, even if some sorting difficulties among sector flows were observed for some controllers; this issue will have to be dealt with in transition activities of the project.

"Info" dyps: as the "info" dyps are displayed on the radar screen, during RTS, they were very useful for the controllers to connect radar information and flight plan information, for example during integration activities.

Basic Filtering

HMI operations related to filtering were correctly, easily and efficiently carried out during Shadow Mode sessions. All associated presentation principles regarding flight status appeared to be relevant. The graphical route (graphical view of flight plan information) was often associated.

Extrapolation

The extrapolation function in itself is very useful.

Some implementation improvements should be done:

- HMI operations related to extrapolation were easily executed but not always efficient because of pointing problems, which have to be solved;
- Readability of extrapolation in filtering mode has also to be enhanced, due to the large amount of information to be displayed.

SIMFL

SIMFL was not used due to malfunctioning problems.

Agenda (Task Scheduler)

Problem Label: Problem labels were easily created, and manipulated by all controllers.

Problem Filtering and Problem Extrapolation: HMI operations related to problem filtering were correctly, easily and efficiently carried out. All associated presentation principles regarding flight status appeared to be relevant.

MGA: MGA were easily used.

Bin: the operation consisting in restoring a deleted label could be simplified; however the concept principle is understood.

6.1.3.2.3 Global usability for Foreign ATCOs

This section presents the analysis of Global Usability results, based on Foreign ATCOs. As a reminder, only the Global Usability of ERATO tools were validated in this exercise given the limited operating capabilities of foreign ATCOs in a French electronic environment (see VALR 4.1.1.4).

The breakdown of the analysis is presented in terms of 5 aspects of usability, namely:

- Intelligibility: Pertaining mainly to textual elements and interface symbols,

- Visibility: Pertaining to the occlusion of interface objects needed by ATCOs, by others,
- Perceptibility: Pertaining mainly to the choice of colours and sizes of interface elements,
- Efficiency: Pertaining mainly to the performance of an interaction with an interface elements,
- Comfort of Use: Pertaining to the accessibility and ease of interactions with interface elements, namely through mouse clicks.

Basic Filtering

Both PC and EC made use of the Basic Filtering without systematic issues and positively reviewed the straightforward access to the function through the left mouse button (Click Button 1). Controllers used Filtering in most of its modes of access, i.e. by clicking directly on radar labels, by clicking in the Entry lists and FREQ lists, and minimally through the head-down display.

Controllers (namely ENAV) experienced issues differentiating between Filtered and non-Filtered flights and specifically pertaining to the salmon colour. They reported that the salmon colour is not sufficiently salient with respect to the contextual, grey flights.

Figure 4 shows an example of the French HMI with Basic Filtering, showing: i) the Reference flight EZY2KF in a box, ii) interfering flight RAE253, FL 350 and in salmon, and iii) non-interfering flight PGL811 at FL370, in grey. Comparatively, Figure 5 shows an ENAV HMI although without a similar filtering: i) Assumed flights are in light green, ii) Tentative flights are in magenta. The two HMIs are shown comparatively here for illustrating the colour saliencies and lead to hypothesis that controllers having high colour saliencies in their own environment could be hampered with smoother colour differentiation in the Filtering.

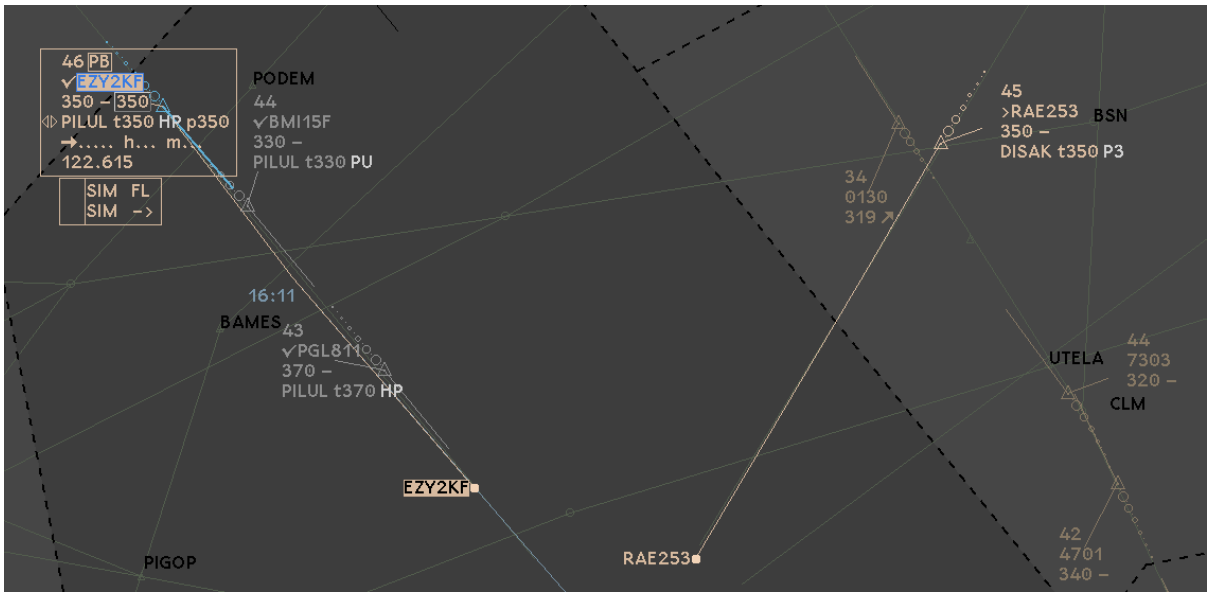


Figure 4: Basic Filtering and Extrapolation showing the reference flight (boxed), filtered flights (salmon) and Non-Filtered flights (grey) – extrapolation lines are also shown, terminating with a dot.

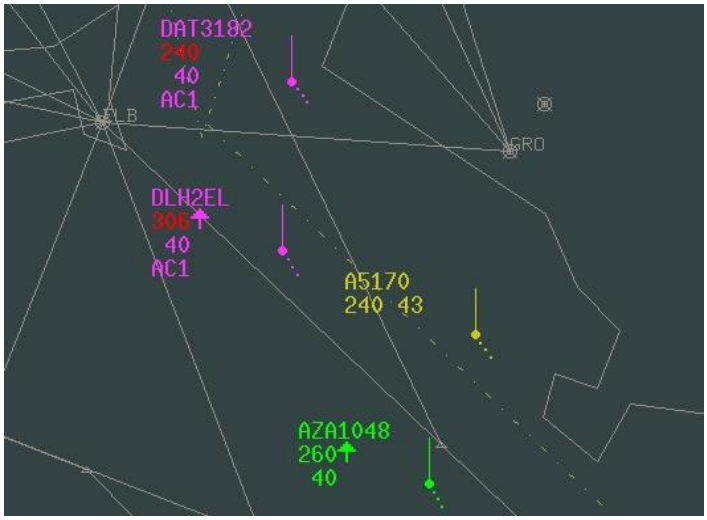


Figure 5: ENAV Radar Image and Colour Usage

Concerning the access to Basic Filtering, in certain cases, controllers attempted Filtering on flights where the ERATO service was not available yet or was not available at all. In other cases, it was observed that controllers perceived the delay as too long when accessing a Filtering on flight where the ERATO service was available. This is why, in case a Filtering was not immediately available, controllers attempted to click again on the same flight, thereby generating a click-Assume.

A minor issue concerning transfer of a flight pertaining to the Filtering leading to the creation of a Problem Label was apparent when controllers erroneously clicked on the [PB] button. The [PB] button only becomes visible upon mouse hover of the flight label, nearby the call sign, and might reasonably explain why controllers click on it instead of clicking on the call sign. Despite these one-off issues, controllers operated the Filtering with fewer problems after participating in a few exercises.

Extrapolation

The extrapolation service was used by all controllers on a frequent basis. Controllers could generally operate an Extrapolation from a Basic Filtering without major usability consideration.

Controllers performing extrapolation with many flights expressed difficulties in differentiating among flights from only the flight identifier present at the extremity of an extrapolation line. In other words, controllers found that at the closest crossing point where more than 3 flights were extrapolated on the screen, flight identifiers were not sufficient for discriminating the nature of conflicts. At that time, there was either a lack of information originating from a distant flight label, or a lack of preliminary integration of flights.

Other minor issues met by controllers with Extrapolation pertain to two known technical limitations:

- The extrapolation service could be lost intermittently and leaded to the incapacity to function during conflict detection (see, [3]). The indicated workaround was to exit the Filtrage and retry,
- The ERATO routes mismanaged the extrapolation between beacons (see, [3]). There were no indicated solutions to the limitation.

Due to the limitations, the extrapolation service was not available upon initial demand for certain flights even though the ERATO services were active on those flights.

SIMFL

Controllers made reasonable, although non-systematic use of the SIMFL for simulating FL changes. Similar to the usage of other tools at the beginning of exercises, some controllers attempted to perform SIMFL on non-assumed flights, although the behaviour rapidly disappeared with more experience.

Concerning the perceptibility of SIMFL, controllers were observed on a few occasions to attempt Basic Filtering on an alternate reference flight, while being in a SIMFL. When asked whether there

was a risk of being in a SIMFL and believing that it were a Basic Filtering, a surprising results was obtained. Controllers judged personally that there were not risks in confounding a SIMFL with a Basic Filtering. The contradiction in the observation and the interview output clearly denotes a problem with the differentiation and detection of modes of Filtering, although further hypotheses concerning the reason for this contradiction were not explored.

One of the main issues encountered by controllers was due to technical limitation FFT/333/IVS/11 [3]. Controllers experienced the loss of ERATO services following a SIMFL. The instructed workaround was to enter new flight control information and then retry the SIMFL. However, controllers preferred avoiding the usage of the service with its workaround during busy traffic situation given the combined delay it incurs.

Agenda (Task Scheduler)

Problem Label: the Problem Label within the Agenda was used by all controllers easily and consisted of relatively few usability issues.

Controllers managed to create Problem Labels with multiple flights by two techniques: either by using the [PB] button in the flight Radar Label or by creating multiple individual Problem Labels and merging those using the [&] button in the Problem Labels themselves. In both cases, controllers did not encounter difficulties in creating Problem Labels.

However, once the Working Area of the Agenda started containing at least 4 Problem Labels, the clutter bothered the controllers.

Controllers managed to delete Problem Labels systematically using right-click behaviour (Button 3) with a few exceptions of attempting to drag-and-drop Labels into the Bin. In both cases, controllers did not encounter difficulties in deleting Problem Labels.

Problem Filtering and Problem Extrapolation: controllers managed to perform Problem Filtering and Problem Extrapolation with a minimal number of usability issues.

Controllers sometimes confused the access to Extrapolation with that for re-Positioning Problem Labels. The issue was non-systematic but occurred a few times. In certain cases, controllers did not realise that they had erroneously changed the order of the Problem Label, due to that erroneous action.

MGA: controllers did not experience usability issues with the MGA tool, although usage was rare.

Bin: controllers found access to the Bin through the deletion of Problem Labels easy. However, PCs and ECs unanimously encountered issues attempting to retrieve Problem Labels from the Bin as a means of acknowledging the Blue acknowledgement (MGP). This happened when a Problem Label is in the storage area and not manually deleted before it automatically goes in the Bin. In several cases, controllers asked their pair to help them with the operation.

Cooperation indicators and manual transfer: controllers did not indicate systematic usage of the CO/CR indicator and sometimes preferred to directly inspect the screen of their pair in order to know if they were busy.

Controllers did not notice the CO/CR indicator of cooperation, whether in the Agenda or on the secondary screen.

Concerning the salmon indicator in the Agenda and denoting whether a Problem Label is being manipulated by one of the controllers, there was no evidence suggesting frequent usage.

The Manual Transfer was used almost systematically by controllers for sharing Problem Labels between Agendas and without detected usability issues.

Summary of findings

Table 24 provides a summary of the Global Usability results, all ERATO services combined.

Intelligibility	• CO/CR indicators of cooperation went unnoticed by controllers and were not used.
Visibility	• There were no visibility issues detected during the evaluation sessions for the ERATO services.

Perceptibility	• Colour discrimination issues between flights in Filtering and flights excluded from Filtering, • When a Filtering involved many flights, controllers hesitated in correctly matching the termination dot in the extrapolation with its associated call sign, • Mode of interaction (SIMFL) needs to be differentiated from a Basic Filtering to prevent mode confusions, • Cluttered when handling more than 4 Problem Labels,
Efficiency	• There is a feedback delay perceptible by controllers when accessing Filtering, • Controllers attempted to use Filtering on flights with no ERATO service available, • Extrapolation lines originating from certain flights lost continuity and were not coherent with the direction of flight (known bug, see, [3]), • Extrapolation is not possible on flights given headings, • Controllers were hampered in their work by a bug of SIMFL (FFT/333/IVS/11 [3])
Comfort of Use	• Positive returns on the 1-click interaction to access Filtering, • The interface does not systematically register the clicks to a flight for performing extrapolation, • Haptic confusion when accessing Problem Extrapolation and Problem Label Repositioning, • Awkward removal of Blue acknowledgement once a Problem Label is in the Bin.

Table 24: Summary of Global Usability issues

6.1.3.3 Confidence in Results of Validation Exercise

6.1.3.3.1 Quality of Validation Exercise Results

See .4.3.1.

6.1.3.3.2 Significance of Validation Exercise Results

See .4.3.2.

6.1.4 Conclusions and recommendations

6.1.4.1 Conclusions

6.1.4.1.1 French ATCOs

The validation results obtained with French ATCOs show a very good level of maturity of the EE and ERATO concepts regarding global usability in normal to high traffic load. As seen in section 6.1.3.2.2, there were very few findings, and most of them refer to specific implementation issues within the French legacy EE system (ODS). They are currently being solved and will be implemented in a future version of the ODS system (for V4 phase).

6.1.4.1.2 Foreign ATCOs

It has to be noted that most of the findings are related with EE HMI usability which was not in the scope of the validation objectives regarding foreign controllers. However, it was interesting to identify them as they are meaningful (see 6.1.3.3 and 6.1.4) and can be used for further activities of this type:

- HMI principles differences between their own environment and the tested environment were disturbing for foreign controllers;
- Training was not sufficient to avoid this (lack of time to maturate a different operational environment and different working habits additionally to the technical environment).

Furthermore, some difficulties of use which occurred are related to a lack of maturity in the understanding of the tools (e.g. controllers attempted to use Filtering on flights with no ERATO service available). Again, these difficulties can be explained by an insufficient time between the training and the RTS.

Beside these HMI and difficulties, controllers managed to use ERATO tools on a regular basis within the course of their work. No negative phenomenon as excessive workload or delay or loss of situation awareness occurred. This shows a good level of global usability in normal traffic load.

6.1.4.2 Recommendations

6.1.4.2.1 French ATCOs

EE HMI enhancements allowing overall usability of the system (supplementary to concept usability) have to be fulfilled.

6.1.4.2.2 Foreign ATCOs

When carrying out validation activities on a foreign system, specific attention has to be paid to the impact of HMI principles differences on the controllers' ability to accomplish their tasks; adequate training has to be performed to avoid the resulting evaluation biases.

6.2 Validation Exercise EXE237 Report

6.2.1 Exercise Scope

In addition to elements provided in section 2 of the current document, the specificities of the scope of exercise 237 have been developed in the validation plan (see [9]).

As a reminder, major trends of this scope can be described here:

The objectives related to this exercise are to **i) assess ERATO tools effectiveness, ii) consolidate and assess working methods, iii) contribute to the safety case, vi) Contribute to training needs identification, vii) assess concept applicability into foreign stripless environments.**

Tools effectiveness and working methods will be assessed in the same time, given that both dimensions are tightly linked. The way ATCOs will use the ERATO tools will partly determine the perceived benefits of the ERATO services. This objective consists in evaluating the effectiveness and fit-for-purposeness of working methods for filtering, extrapolation, task scheduler and MGA.

The contribution to the safety case consists in searching for any opportunistic event that could present any valuable information for safety analysis. Then, every particular relevant event (provided such event would occur) will be commented by the controller, in response to adequate questions.

The contribution to the training needs identification case consists in searching for any opportunistic observation that could feed the training content, particularly difficulties in applying the working methods.

The question of concept applicability into foreign stripless environments only concerns the foreign controllers coming from ENAV and skyguide.

In order to assess the given objectives, two means (Live Trials & Real Time Human in the loop Simulations) and two methods will be used depending on participants: French ATCOs or foreign ATCOs.

For French ATCOs, the objectives will be assessed through two validation means:

- **Live Trials:** participants will be asked to handle real traffic. They will be observed and individually interviewed about how easy or difficult it is to perform the operational tasks using the ERATO tools and the defined working method. Any event identified as relevant to safety case and to working methods training will be commented.

- **Real Time Simulations:** participants will be asked to handle simulated traffic. They will be observed and individually interviewed about how easy or difficult it is to perform the operational tasks using the ERATO tools and the defined working method. Any event identified as relevant to safety case and to working methods training will be commented.

For Foreign ATCOs, the objectives will be pursued in **Real Time Simulations**. Similarly to French controllers, participants will be observed and individually interviewed about how easy or difficult it is to perform the operational tasks using the ERATO tools and the defined working method. A specific working sequence (simulation and interview) will be dedicated to the topic of concept applicability. The ERATO concept applicability into foreign environments will be assessed by asking pairs of foreign controllers of the same nationality to mentally project the ERATO concept into their own stripless environment and interviewing them about it.

Both methods are necessary to acquire the relevant data considering that:

- Live Trials is essential to acquire data from the real environment in view to put the EEE system into operation in Brest ACC;
- It is impossible for foreign controllers to carry out Live Trials for legal and safety reasons.

Objectives	French Controllers	Foreign Controllers
ERATO tools effectiveness	Live Trials Real Time Simulations	Real Time Simulations
ERATO working methods and related training	Live Trials Real Time Simulations	Real Time Simulations
Safety Contribution	Live Trials Real Time Simulations	Real Time Simulations
ERATO Concept applicability	N/A	Real Time Simulations

Table 25: Exercise 237 objectives and validation means

The safety elements will be noticed provided such events occur during the simulations.

6.2.2 Conduct of Validation Exercise

6.2.2.1 Exercise Preparation

This exercise was supposed to involve both live trials and RTS. As said in § 3.3, live trials hasn't been carried out yet, only RTS are referred to here.

RTS relied on the ELECTRA RTS platform, also integrating the SUT in the CAUTRA legacy system, but simulating radar data by the use of a traffic generator.

Sectors and traffic characteristics chosen for each of them are detailed in the validation plan (cf. [9]).

6.2.2.2 Exercise execution

See 3.2 for a description of the exercise execution (RTS only for EXE247)

6.2.2.3 Deviation from the planned activities

See §3.3.

6.2.3 Exercise Results

6.2.3.1 Summary of Exercise Results

Validation Objective ID	Validation Objective Title	Success Criterion	Exercise Results
OBJ-04.03-VALP-0237.0002	Assess ERATO Tool Effectiveness	The ATCO achieves the control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method.	(1) ERATO concepts effectiveness is validated for French ATCOs (2) Effectiveness is lower for climbing and descending traffic (3) Usefulness of simulated filtering and filtered flights table have to be further studied (4) Interesting results for foreign ATCOs (5) Still, effectiveness requires to be further investigated for foreign ATCOs: seems to depend on domestic specificities (see OBJ-04.03-VALP-0237.0005 results)
OBJ-04.03-VALP-0237.0003	Consolidate and Assess Working Methods and Related Training	The ATCO achieves the control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method. The specified data analysis does not indicate any observation related to training leading to impossibility to put ERATO tools into operation at Brest ACC.	(1) Working methods and associated training are successful with French controllers (2) Some minor difficulties in new flight detection phases to deal with (3) Interesting results for foreign ATCOs (4) Further investigation required for foreign ATCOs: seems to depend on domestic specificities (see OBJ-04.03-VALP-0237.0005 results)
OBJ-04.03-VALP-0237.0004	Contribute to the Safety case	The specified data analysis does not indicate any safety observation leading to impossibility to put the ERATO tools into operation at Brest ACC.	No potential contributions to the safety case in the data collected.
OBJ-04.03-VALP-0237.0005	Assess the Concept Applicability into Foreign Stripless Environments	The specified data analysis does not indicate any impossibility to successfully integrate the concept into foreign stripless environments for ENAV and skyguide.	(1) Very promising in ENAV environment (2) ENAV wish to test future automatic agenda concept (3) Low applicability into skyguide environment

Table 26: EXE 237 - Validation Objectives and Exercises Results

6.2.3.1.1 Results on concept clarification

See 4.1.1

6.2.3.1.2 Results per KPA

See 4.1.2

6.2.3.1.3 Results impacting regulation and standardisation initiatives

See 4.1.3

6.2.3.2 Analysis of Exercise Results

Validation Objective ID	Validation Objective Title	Success Criterion	Validation Objective Analysis Status per Exercise
OBJ-04.03-VALP-0237.0002	Assess ERATO Tool Effectiveness	The ATCO achieves the control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method.	French ATCOs : POK Foreign ATCOS: POK
OBJ-04.03-VALP-0237.0003	Consolidate and Assess Working Methods and Related Training	The ATCO achieves the control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method. The specified data analysis does not indicate any observation related to training leading to impossibility to put ERATO tools into operation at Brest ACC.	French ATCOs : POK Foreign ATCOS: POK
OBJ-04.03-VALP-0237.0004	Contribute to the Safety case	The specified data analysis does not indicate any safety observation leading to impossibility to put the ERATO tools into operation at Brest ACC.	NOK, insufficient results
OBJ-04.03-VALP-0237.0005	Assess the Concept Applicability into Foreign Stripless Environments	The specified data analysis does not indicate any impossibility to successfully integrate the concept into foreign Stripless environments for ENAV and skyguide.	POK, further studies required, enhanced validation process (training), very limited applicability for skyguide.

Table 27: EXE 237 - Validation Analysis Objectives Status in the Exercise

In this above table, the validation status is described as:

- OK : validation objective achieves the expectations (exercise results achieve success criteria);
- NOK (not OK) : validation objective does not achieve the expectations (exercise results do not achieve success criteria);
- POK (partially OK): validation objective partially achieve the expectations (exercise results do not totally achieve success criteria).

6.2.3.2.1 Unexpected Behaviours/Results

Issues during Analysis

A special consideration for a type of data which was collected should be noted here. This concerns end-user design suggestions and conceptual propositions originating from controllers. Data concerning such literal expressions of needs were not treated or recorded as new needs or specifications. The reason is that controllers do not necessarily possess the global technical vision of the system or a unified view of the HMI such that associated constraints, compromises and principles of logic for determining needs or specifications cannot be literally entertained.

We made use of controllers' propositions to understand the underlying needs at a conceptual level.

6.2.3.2.2 Tool effectiveness for French ATCOs

The following results only deal with ERATO tools. The validation of the EE tools was not an objective of EXE 237. It has been performed on the global usability point of view in EXE 032.

Basic filtering and extrapolation

Basic filtering was used to detect conflicts, and was generally associated with extrapolation.

Its effectiveness was related to the characteristics of the traffic : with numerous climbing and descending flights, more potential conflicts remain, the help the controllers is provided with is not as high as with cruising traffic.

The complementarities of filtering and extrapolation helped the controllers build their mental image. It can be described as follows:

- Filtering performs a flights sorting on the radar display, allowing the controller to focus on relevant flights relatively to a specific flight; this was really appreciated in high workload situations;
- Filtering helps comparing information between flights via labels;
- Extrapolation added value is its visual and dynamic characteristics, which helps the controller to rapidly evaluate the future flights positions on the conflict point.

On the contrary, the filtered flights table, on the secondary display, was not often used. For transition purposes, the usefulness of this table will have to be assessed, but a result of EXE 237 is that its use or not is not an issue regarding the filtering concept validity.

Simulated Filtering

Simulated filtering was not used. This can be explained by malfunctioning of this tool during RTS. The usefulness of simulated filtering will have to be assessed in further studies.

Agenda (Task Scheduler)

Agenda and Problem Label

Problem labels were created by controllers in a relevant and reasonable way i.e. when actions were to be carried out later or to communicate between PC and EC (See “Conflict detection and management” in 6.2.3.2.4).

They totally fulfilled their purpose:

- The PC created problem labels to prepare the EC work and reduce his conflict detection workload; he rightfully used the appropriate part of the agenda for that; the temporal position chosen for the label was estimated regarding the moment the EC would have to solve the conflict plus a supplementary delay;
- On some occasions, the PC created problem labels for himself as reminders, and removed them very rapidly when they were not useful any more;
- The PC was transferring problems to EC when appropriate according to his own assessment;
- After transfer, labels updates were made by the EC when needed; in some specific situations, the EC would ask the PC to do it;
- Removing the obsolete problem labels was made via global checks and not necessarily at the exact end of the problem.

Problem Filtering & Extrapolation

The Problem Filtering, associated with extrapolation, showed its effectiveness when used to alleviate doubt and to follow the evolution of a potential conflict. Within this frame, different schemes of use can be described:

- The PC was systematically using problem filtering and extrapolation after having created a problem label, in order to confirm his diagnosis and to reposition the label accurately;
- The EC was using problem filtering and extrapolation on problem labels created by the PC only for conflicts for which his own analysis or basic filtering were not sufficient;
- Both of them used problem filtering and extrapolation iteratively for long term problems and complex problems.

Problem filtering and extrapolation were also used in conflicts solving to choose the appropriate actions.

MGA

MGA was mostly used by the EC as a reminder in exit conditions management to symbolise the moment to perform an action on a specific flight. It was not often used by the PC, which can be explained by the fact that the temporal estimates made by the PC are not as precise as those made by the EC. Then, this use of the MGA seems perfectly in accord with the characteristics of the controllers' activity.

6.2.3.2.3 Tool effectiveness for Foreign ATCOs

Each ERATO tool/function is presented below. The effectiveness of each tool is analysed in terms of the French working methods.

Basic Filtering

Basic Filtering was used by PC and EC for Flight Integration, Detection of Conflicts and Preparation of Exit Flights.

During Flight Integration, PC found it easier to use the Basic Filtering particularly at the beginning of the scenario. Later in the scenario, as workload increased, sufficient time was not available for analysing "loaded" Filtering results (i.e. Filtering results where there are many flights shown).

Moreover, controllers preferred creating a Problem Label and then performing a Problem Extrapolation rather than directly extrapolate using the Basic Filtering. The reason was to take advantage of a simplified traffic picture provided by the extrapolation only on the two or three flights of the problem.

EC made use of the Filtering at Flight Integration for checking when to descend flights to their X/TFL, and usually with a look-ahead of 5-10 minutes.

However, controllers met with several issues when Integrating Flights:

i) The computation of a Basic Filtering operation sometimes incurs a delay for presenting the results. The delay was sufficiently perceptible to be reported as being an annoyance by controllers,

ii) The look-ahead provided by the ERATO services and the ability to perform a Basic Filtering before a flight entered the sector was noted by PC as being insufficient,

iii) The results of a Basic Filtering performed on an evolving reference flight could provide a solution with too many filtered flights. Controllers reported that the Filtering included flights which were non-essential for them, and

iv) It was sometimes faster to visually filter flights according to their FL namely for stable flights, rather than performing a Filtering since the results could be easily anticipated.

For conflict detection inside the sector, the usage of Basic Filtering was less systematic than at Flight Integration. It was more opportunistic for PC and EC. For one exercise, a catching-up conflict (EVAL A: 10h26; MMGLP & DLH777 at FL350) was not detected for an extended amount of time by one of the PC.

As is the case usually in catching-up conflict situations, the adjacent sector places a coordination call to the PC of the sector to inform of the problem. In the current case, it was decided that the coordination call would be delayed to verify that the controllers correctly detected the catching-up by performing Filtering on incoming flights. Thus, the coordination call was delayed for two more minutes

than the moment it was previously planned. However, controllers did not perform Filtrage and the catching-up was still not detected by the PC. Debriefings with the concerned controller and with the SME confirmed that the use of Basic Filtering would have sped up conflict detection in this case.

Another instance concerning missed conflict detection is noted (EVAL A: 10h17; AFR501 & EZY341P). The EC checked the separation of the flights using speed vectors but did not detect the conflict. However, the PC performed a Basic Filtering and detected the conflict, before it was safely managed by the EC.

Note:

The Graphical Route tool which is displayed at Flight Filtering for the reference flight was used liberally by controllers to gain knowledge of flight trajectories. Controllers lacked expertise of the beacons present within the sectors they were managing and the Graphical Route tool provided a visual support which was deemed more practical than other display items requiring the reading of textual flight route points.

Concerning the usage of Basic Filtering along with flights which will be given direct routes (or directs), controllers encountered the issue of having such flights being taken into account by the Filtering. Hence, while controllers considered that flights being in a short time put on a Direct did not enter their conflicts of interest anymore, these flights would still appear in the Basic Filtering and were inherently "noise" during conflict detection.

Simulated FL (SIMFL)[2]

Generally, Simulated Filtering (SIMFL) was minimally used by both PCs and ECs for performing conflict resolution. For one of the PC, SIMFL was used for managing climbing flights opportunistically. The use of the function helped him to issue safe FL to climbing flights.

Controllers attempting to use the SIMFL at the beginning of the exercise were often interrupted by an intermittent loss of the service. The issue had been previously reported as a technical limitation (see. FFT 333/IVS111 [3])[3]. Considering the limitation, the time necessary for controllers to complete an exhaustive analysis was shortened and it is reasonable to assume that subsequently, a lack of adoption of the tool was present.

Further and as recommended by the working methods, controllers performed SIMFL in the following situations:

a. For conflict detection when a new FL was being requested by the pilot.

b. For existing flights, when PCs wanted to check if a flight could climb immediately to its XFL.

But at the time controllers used SIMFL, they spontaneously attempted to extrapolate filtered flights although the function is not present as part of the tool. Thus, controllers were not supported at all for measuring or judging the minimal distance present between several flights of interest and whether that distance was less than the minima required in case the SIMFL would be performed. Considering that controllers are provided with such a means of obtaining distance information in their own environment, they found it irrelevant to manually perform the operation notably in the unfamiliar Brest sector and traffic.

Finally, controllers gave up the usage of the SIMFL and preferred basing their decisions on the Extrapolation from Basic Filtering or Problem Label.

Extrapolation

The PC and EC made use of the Extrapolation for preparing Exit conditions and also as a means of confirming their diagnostic with conflicts and prepare a solution.

Both PC and EC used the extrapolation as a means of conflict confirmation. Using the dynamic characteristic of the function, they confirmed the conflict and the point of smallest crossing distance.

[2] The SIM Direct was not utilised.
[3] During a SIMFL, given that the number of flights in the computation changes, the SIMFL was aborted by the system at the next refresh cycle of the algorithm.

EC noted that the extrapolation also allowed them to determine which one, of 2 or more flights, they could place on a direct first as a means of simplifying or resolving a conflict.

Controllers (namely PCs) reported that although Extrapolation is a good means of identifying traffic without having to visually scan the radar for all of them, there was also an issue concerning the Extrapolation of "loaded" Filtering. The number of Extrapolation lines present in a "loaded" Filtrage can be reported as overwhelming for controllers, especially when not all the filtered flights are considered as being problematic. Overloaded Filtering and Extrapolation has been reported namely with evolving flights.

Controllers made use of the Speed Vector tool present in the Electronic Environment for attempting to measure the smallest crossing distance between conflicting flights. The Speed Vector tool projects a leading line from a flight with optional increments of 1, 3 and 6 minutes, and was either displayed by controllers for all of the flights, or automatically displayed when ECS put in the Warning on conflicting flights.

Sometimes, controllers preferred to use Speed Vectors instead of Extrapolation because Speed Vectors followed the issued heading while the Extrapolation did not take into account the heading.

Agenda (Task Scheduler)

Agenda and Problem Label

The creation of Problem Labels was performed relatively easily by controllers. It was mainly the PC who created most of the labels.

One of the controllers expressed the usage of the Agenda as pertaining to conflict cases which were sufficiently complicated to be materialised. For instance, a PC noted that if a flight being given a Direct will enter into a conflict, then he will enter that into the Agenda for the EC to see.

Controllers considered that simpler conflict situations which could be resolved in a short time (such as by mainly: giving a Direct, coordinating with the previous sector, giving a heading) were not to be materialised. Similarly, conflict situations which are moderately complicated were better communicated to the EC by the PC rather than materialised in the Agenda.

Generally, PCs systematically performed manual transfers of Problem Labels to the ECs. It was noted that due to sector geography, it might have been possible for controllers to systematically transfer Problem Labels since they are often within 10 minutes of the moment requiring resolution (and the Transfer Bar is set to 10 minutes by default for the EC).

It is to be noted that while manual transfers of Problem Labels were not always immediate after creation, they were almost always done before the Label crossed the Transfer Bar.

Further, controllers used the Agenda for providing a shared information concerning conflicts as and when needed. In other words, the ability to quickly perform a Problem Filtering and Extrapolation when a conflict was being communicated by the PC allowed ECs to identify immediately the concerned flights and understand the nature of the conflict. This was recurrent even when the EC detected conflicts before Problem Labels were communicated to him by the PC.

In general, the temporal scheduling feature of the Agenda was limitedly used by controllers. In other words they didn't take advantage of the possibility to re-order the conflict resolutions, quite never modified the initial ordering presentation and didn't follow it. EC reported that it was sufficient to have Problem Labels in the Agenda as memos of conflicts rather than determining an order for troubleshooting the conflicts.

Controllers made limited usage of the Agenda and Problem Labels as a means of planning for the treatment of conflicts. Observations showed that ECs rarely consulted the positioning of the labels as an indicator of priority or urgency for the actions to be performed. The main factor justifying the resulting usage of the Agenda is that controllers performed little long-term surveillance of conflicts through the Agenda.

Re-positioning Problem Labels (and MGAs) in the Agenda, posed issues to both the PC and EC:

- PC sometimes found that the default position where a Problem Label was created in the Agenda was suitable since it mostly followed the temporal logic of flights coming into the sector,

- When traffic was heavy and conflicts were complex (involving multiple flights), the PC attempted to re-order Problem Labels for the EC but finally decided to manually transfer them instead of creating a suitable order and waiting for the Label to pass the Transfer Bar automatically,
- ECs generally did not re-position their Problem Labels. Instead, Problem Labels were consulted as soon as they were identified and not necessarily bottom-up (as according to the Working Methods). The issue was explained by a controller as one where there is a difference in what the PC and the EC perceive as being priorities in the resolution of conflicts.
- One EC noted that the management of the Agenda was too demanding and could have a large impact on activities. Thus, instead of manually materialising the changing priorities of Problem Labels by re-positioning them, EC preferred to mentally re-prioritise the conflicts particularly when traffic was busy.

Controller pairs encountered issues for managing Problem Labels when there was a lack of verbal communication present between PC and EC. The factors entailing a breakdown in communication are twofold:

- EC have noted that during peaks of traffic, they were focusing on the radar and do not have time for the Agenda.
- Further, if a PC attempted to communicate a forthcoming conflict at that moment, they were likely to be disturbed by the interruption.

The observation is not unanimous for all controller pairs since the verbal communication was often efficient and reached the objective. The choice of a correct moment to communicate conflicts to the EC appeared to be crucial to improve cooperation.

Finally, controllers unanimously perceived that the efficiency of the Agenda during heavy traffic situations was sub-optimal. The main issue controllers noted concerned the constant delay it took to create and manage each Problem in the Agenda – with heavy traffic, controllers indicated that the compounded delay for managing multiple conflicts in the Agenda was not-acceptable.

Controllers mostly found the usage of the Agenda to be too time-consuming for in heavy traffic situations. The issue was observed during the exercises when the EC omitted the management of the Problem Labels for past conflicts and did not delete the Label. In another case, the EC was observed to create an MGA but did not notice that a Problem Label, created by the PC, was available for denoting the same flight action to be made – the Label remained in the Agenda. This illustrates that the content of the Agenda was not regularly checked by the EC.

One of the issues encountered was that controllers needed to complement the information from Problem Labels by checking the Dyps on or the radar labels. Controllers report that the Problem Labels lack AFL, X/TFL, aircraft type and Exit beacon information. Without this information, and given that the Brest sectors were unfamiliar to them, controllers seemed to have difficulties in building their mental picture of the on-going conflicts from the Agenda Labels.

Problem Filtering & Extrapolation

The Problem Filtering and Extrapolation was displayed by both ECs and PCs when analysing traffic situations for problems as well as resolving conflicts.

PCs made usage of the Problem Filtering and its Extrapolation after having completed a first analytical pass of the traffic by using Basic Filtering and its Extrapolation.

Most of the time, the ECs made use of Problem Filtering only as a means of gaining access to the Extrapolation function.

One EC also reported making use of the Problem Filtering as a means of checking the appropriateness of a Problem Label created by the PC. The usage is confirmed by a PC in noting that the effectiveness of a Problem Filtering and Extrapolation were directly dependent on the appropriateness of the Problem Label constructed.

However and in general, ECs agreed that the presence of a well-prepared Problem Label by the PC and the ability to rapidly perform a Problem Filtering and Extrapolation simplifies the issue of searching for certain specific conflicting flights on the radar.

Finally, controllers concur that large Problem Labels are not to be avoided. In the opposite case, controllers have indicated that a large problem can be reduced into multiple separate Problems, or even reduced immediately by providing a resolution measure (e.g. an instruction) to one of the flights.

MGA

The MGA was used mostly in two simulation runs by one controller pair during EVAL A as a means of materialising the location where Exit conditions of a flight needed to be managed. The other controller pair made no use of the MGA.

For the controller pair using MGA, the tool was used to mark the point along a flight's route where it had to be provided with descent instructions. More specifically, controllers started using the MGA when two conflicting flights had not crossed yet, and one needed to be descended afterwards. Thus, as long as a flight was not yet cleared for its X/TFL, the MGA was useful as a reminder.

However, PC and EC agreed unanimously that the MGA was a tool for individual usage, instead of cooperation (in contrast with the trained Working Methods where the PC is denoted as the one creating the MGA, while the EC re-positions and updates the MGA). In other words, controllers noted that the MGA needs to be created by the EC after being notified by the PC of the specific X/TFL requirements of a flight.

At least one case was recorded where controllers encountered an issue[4] with the MGA. The EC gave a Direct (EVAL A, 10h08, TAP5400) which aborted the MGA created previously (10h06). The EC did not observe the loss of the MGA and there was no communication in that sense to the PC. However, the PC correctly identified the loss and re-created the MGA on TAP5400.

Controllers made liberal use of the Particularisation tool for marking the X/TFL filed directly in the Flight Dyps on radar as a means of materialising actions to take on Exit flights. Thus, it became apparent that controllers preferred the usage of Particularisation instead of MGA (even though the Particularisation does not indicate the specific moment for taking actions on a flight, as opposed to the MGA).

Bin

Controllers made use of the Bin for deleting Problem Labels and MGAs.

The EC moved Problem Labels to the Bin as soon as a resolution measure for a conflict was taken, such as when giving a Direct to a flight.

During increased traffic situations, there were cases where the EC forgot to remove spent Problem Labels. The task was either performed by the PC, with a communication of the action to the EC or the Problem Label remained in the storage area until it was automatically put into the bin.

The main issue encountered by controllers with the Bin was the retrieval of a Problem Label which had not been acknowledged and which is showed in blue on the radar screen (call signs move into blue colour). ECs reported that a flight showing in blue on the screen even after the associated conflict had been resolved is disruptive to work and hampered him when a Problem Label had been sent to the Bin. Two ECs had to seek the help of the PC to remove the Blue stimulus from the Radar screen since the operation was taking too long while trying to remove it themselves.

Finally, controllers expected the automatic removal of conflicts stored in the Agenda after the concerned flights had crossed their point of smallest separation. The manual removal of each resolved conflict was considered a drawback.

6.2.3.2.4 Working methods and training for French ATCOs

Flight Integration

[4] When a Direct is given to a flight which had been tagged with an MGA, the MGA disappears without any warning. According to the working methods, the MGA should be re-created.

New flights detection was made by the use of both flight labels colour and ad hoc highlights in the entry flight lists. Mostly often, the first detection was based on the labels colour, and then supplemented by the ad hoc highlight detection in the entry list.

The exit flights table (dyps) was not often used for this purpose, except in an opportunistic way for the PC when using this table for exit conditions management.

In some cases, the detection by the EC was based on problem labels created by the PC.

New flights integration begins with establishing priorities among flights. This establishment was based on: (1) the flight position on the radar display; (2) the traffic flow it belongs to, according to the entry lists; (3) the fact that the flight is potentially in conflict, according to the basic filtering; (4) for the EC, the fact that the PC has already integrated the flight, according to diverse indirect indicators.

During integration, controllers carried out their analysis on the basis of radar information (track position, radar label) as well as flight plan information in the entry lists. Most of time, the “info” dyp was used.

In the specific case when the PC used the dyps table to detect new flights, their integration was based on information from this tool.

Another key task in flights integration is traffic sorting taking into account: (1) the position in airspace (flow, level, centre or periphery of the sector); (2) the flight status regarding the controller’s activity. The diverse information displays used by the controllers for this task are the entry lists (with flow highlights) and flight colours on the radar display.

The following entry and exit conditions analysis made by the PC was relying on radar labels and “Info” dyps. When made by the EC, it was also taking into account elements resulting from the previous EC integration, e.g. highlights, problem labels etc.

De-highlighting the ad hoc highlight of the new flights was a way to either acknowledge the detection of the flight or symbolize the end of integration activities. This depended on various strategies according to sectors and flows types. These variations demonstrate a good level of appropriation of the environment by the controller.

All the observed detection and integration methods are compliant with the controllers’ previous training.

However, some remaining difficulties were observed essentially concerning detection:

- forgetting an entry list, leading to a late detection;
- poor oncoming workload estimate, because of the flights spread among lists.

These difficulties will have to be dealt with in further studies.

Conflict Detection and management

In compliance with the recommended task sharing, the PC was detecting entry and exit conflicts while the EC was detecting conflicts inside the sector.

For conflict detection purpose, the filtering was used when necessary, i.e. it was not used systematically but depending on a conflict suspicion based on the sector knowledge and the situation awareness.

When used, basic filtering was associated with extrapolation.

After a first detection, problem filtering, here again associated with extrapolation, was used, eventually iteratively, to alleviate doubt and to follow the evolution of a potential conflict.

Other elements from the EE were used supplementary to ERATO tools during conflict detection and management: range rings, speed vectors, warning marks etc.

Problem filtering and extrapolation were also used to choose the appropriate actions in conflicts solving.

Problem labels in the Agenda were created by controllers only when useful. They were not created in the following cases:

- When resolution was immediately following detection;
- When resolution and detection were performed by the same controller;
- When resolution was occurring before the flight entered the sector;
- For climbing and descending flights;
- For linear conflicts on the same route.

As described above, the use of ERATO tools in conflict detection and management shows a good understanding of their purpose and the way they have to be integrated in the diverse controllers' tasks. This allows considering that the training performed for EXE 032 and 237 was successful.

Exit conditions management

For exit conditions management:

- The exit flights table was used by the PC to watch the correct evolution of flights towards their exit conditions;
- MGA was used by the EC to symbolise the moment to perform an action on a specific flight.

Highlights were used as supplements.

Here again these methods are compliant with recommendations and training.

Global checks

As recommended, global checks were performed on a regular basis using radar labels, highlights, flight lists, the flights table and the agenda.

PC/EC Cooperation

Agenda

One of the purposes of the Agenda is to help cooperation between PC and EC through asynchronous and non verbal communication.

This purpose was totally fulfilled during RTS (see "Agenda" in 6.2.3.2.1).

On a cooperation point of view, it has to be mentioned that when transferring a problem label he had created for the EC, the PC usually accompanied it with a verbal explanation, helping the EC to rapidly understand and memorise the problem.

Highlights and warning marks were also largely used to facilitate cooperation.

Filtering

In some complex situations, filtering was used simultaneously by both controllers to share a representation of the traffic situation.

6.2.3.2.5 Working methods for Foreign ATCOs

Prior to the simulation runs, foreign ATCOs have been trained to use the same working methods as the French ones. The results of the consolidation and assessment of French working methods are presented next. The fitness of purpose of the working methods are assessed with respect to Flight integration, Conflict resolution and follow-up, Management of Exit flights, Sector Scanning, and EC/PC cooperation and communication [4]. The Roles and Responsibilities are overviewed next.

Overview on Roles and Responsibilities

The roles and responsibilities presented to foreign controllers in the training were globally applied in the simulations, though there was a slight difference in cooperation. This is an important point to be considered because it is tightly linked to the way pairs of controllers shared the use of the ERATO tools.

The observed roles and responsibilities were consistent with the French working methods on the following items:

- PC established the overall plan for the entry and exit of the traffic, and for the flow of traffic through the sector, looking for potential loss of separation. Then the entry and exit conditions with adjacent sectors were coordinated. Finally, the PC communicated with EC.
- EC carried out the plans established by the PC and expedited the flow of traffic operating within his area of responsibility. EC separated and sequenced flights operating within his area of responsibility and issued instructions to pilots. Aircraft trajectory was monitored according to the clearance provided through PFL/TFL/XFL. Finally, EC assumed flights when they first called on frequency and handed-off the flight by transferring them to the next sector.

The observed roles and responsibilities in cooperation differed as follow:

- EC carried out the strategies and actions established by him or the plan established in cooperation with PC. In other words, the activity of the EC seemed less coupled to that of PC, than what was depicted in the content of the training. As will be explained afterwards, this flexibility was characterised by a different usage of the agenda.

Flight Integration and Entry Conflict Detection

Both PC and EC performed flight integration and conflict detection using Basic Filtering and Extrapolation.

At flight integration, the Basic Filtering provided controllers with the information of the flight route via the graphical display of its route.

For a new flight, controllers scanned the sector for conflict detection. They used Basic Filtering service for a reference flight in order to filter out the non-interfering flights and analyse the traffic context for that flight. They used the extrapolation to check potential loss of separation between the traffic. In case too many flights were issued from the Basic Filtering, they made their analysis only using speed vectors and the distance measuring tool from the electronic environment (for the ALIDADE tool, see [5]).

While integrating a new flight in using the Basic Filtering, controllers were observed to often forego the manual acknowledgement of the other flights engaged in the Filtering. At the time the reference flight was analysed within its traffic context, other new flights displayed in the Filtering were also taken into account by controllers and effectively considered as integrated too.

ECs also could perform an Entry Conflict Detection via the Agenda. In this case a Problem Label was created by the PC who verbally informed the EC about the conflict situation.

Conflict Detection Labelling and MGA

Problem labels creation

The analysis of traffic situations using conflicts materialised in the Agenda as Problem Labels was performed by PC, with variegated levels of proficiency.

PCs created Problem Labels to prepare the Agenda as a means of supporting information sharing with ECs.

As a note, all conflicts were not systematically materialised by PCs. If a conflict needed to be solved within the next 3 minutes, is was not materialised. The reason is that there was a compromise between the perceived importance of a conflict and the effort spent in managing the Agenda.

Generally, materialised conflicts reduced the need for communication between PC and EC and made the subject of cooperation more succinct. However and during busy periods, controllers also tended to a principle of having the least amount of Problem Labels in the Agenda as possible.

MGA creation

Controllers created a few MGAs as a reminder for a specific action for a flight. According to the trained working method, the creation of MGAs was assigned to the PC while the EC re-organised and updated MGAs only. However, controllers created MGAs mostly when operating as ECs.

The reason is that MGA refers to the location where an action has to be taken by the EC, so it was considered preferable that the EC materialised his own action. Complementarily, PCs indicated that the decision to materialise an action should preferably not be interfered with, by them.

The observed working method depended on the roles and responsibilities EC and PC assigned to them: PC did not impose an action to EC with the MGA.

However, a second mode of utilisation can co-exist. It is also possible for the PC to create an MGA for signifying the result of a coordination (for instance, with military controllers) such that the EC knows at which moment he could climb or descend a flight. Thus, depending on the situation, it is either the EC of PC who could create the MGA. The French working methods are not invalidated according to this dual mode of utilisation of the MGA.

Manage the Agenda and Treating Conflicts

PCs attempted to plan the treatment of conflicts by re-ordering Problem Labels in the Agenda. They re-positioned the Problem Labels differently:

- They either perceived that the default chronological placement of a Problem Label upon creation was satisfactory and did not require re-ordering. The reason stated was that the order was justified with respect to the flow order of inbound flights, or
- They tended to re-position the Problem Labels after manually transferring it to the EC. The PC then communicated the new priority of the Label to the EC.

In general, PCs understood that their re-positioning of Problem Labels was tentative and that it was the ECs' task to re-order the Labels, as and when they would see fit.

The ECs consulted the Problem Filtrage and Extrapolation for further analysis. When there were 3 flights as part of the same label, ECs correctly removed one of them from a Problem Label in the Agenda as soon as the instruction was given to the flight for a heading which de-conflicted it from other flights.

Controllers appropriately deleted Problem labels from the agenda when the materialised conflicts were solved. Controllers made use of a different strategy for conflict resolution based on very early decision for actions, limited long term surveillance of conflicts and a very early deletion of Problem Labels. It was observed that ECs could also delete Problem labels from the Agenda as an acknowledgement of the conflict situation.

The ECs did not systematically scan the agenda according to the bottom-up approach recommended by the working method.

Controllers did not update the Problem Labels systematically to reflect the real changing priorities on radar, although some opportunistic updating was performed (to demonstrate their knowledge of the tool functionalities). Generally, the agenda was only used as a memo (or storage space) while the temporal aspect of the label organisation was downplayed.

For all controllers, the Warning function was used to tag the conflicts under resolution.

Concerning the possibility for each controller pair to agree, a-priori, upon shared criteria for re-positioning Labels before working together, EC and PC noted that such consensus would come through the experience of working together rather than as a formal pre-requisite.

Resolving Conflicts using What-Ifs

The operational situations which exhibited the need to be resolved using SIMFL were not frequent. The simulation scenarios represented that reality. Moreover, controllers limited their utilisation of SIMFL due to the technical limitations mentioned.

However, due to the limited utilisation of the SIMFL, it should be noted that each case where the tool was justified and corresponded with the terms defined in the French working methods.

PC/EC Cooperation

Communication through the Agenda

With increased usage of the Agenda, PCs more systematically transferred Problem Labels to ECs, but also waited for opportunistic gaps in activity for transferring Problem Labels and communicating about the conflict. The Transfer Bar was generally not used according to its property for delineating the visibility of labels in time between PC and EC.

In case a conflict could be managed by the PC using coordination with the upstream sector, then the Problem Label was not transferred. PCs preferred to send as few Labels as possible to the EC as a means of keeping the number of labels in the Agenda as low as possible, and reduce the required management of the Agenda.

Generally, both PC and EC had a correct work-flow: the PC created, communicated and transferred Problem Labels, which the EC checked by performing a quick Problem Filtrage and Extrapolation to understand the conflict.

Verbal Communication

ECs needed to see a Label as soon as PCs had communicated about a related conflict situation. So, controllers made liberal usage of verbal communications to efficiently cooperate using the Agenda.

PCs differed in the way they communicated about the problem Labels to their respective ECs:

- Either the process of materialising conflicts, re-positioning the Problem Label, checking the consistency with a Problem Extrapolation and manually transferring the Problem Label to the EC while communicating the action verbally was performed without fail, or
- The PC had an excellent integration of traffic, detected the conflicts and materialised them properly, but was late in communicating the Problem Label creation to the EC. The EC was then observed to create a duplicate Problem Label, which was later deleted. In other words, efficient verbal communication was lacking and led to certain redundancies.

Concerning the value of correctly communicating a Problem Label during busy traffic analysis, controllers were observed to make use of an efficient strategy: upon conflict materialisation, the PC informed the EC that a new Problem Label had been created but did not go into details. Once the PC perceived the EC to be less busy, he detailed the conflict and the proposed solution if it was available.

Controllers made extensive usage of Warning and Particularisation (Electronic Environment) for cooperating and communicating their actions. Controllers made almost no use of the CO, CR saillance for gaining an appreciation of their teammate's activities.

6.2.3.2.6 Contribution to the safety case for French ATCOs

The data collected from French controllers does not indicate potential contributions to the safety case. Specific validation activities will have to be carried out in further phases of the project.

6.2.3.2.7 Contribution to the safety case for Foreign ATCOs

The data collected from foreign controllers does not indicate potential contributions to the safety case.

6.2.3.2.8 Concept applicability into Foreign Stripless Environment – skyguide

A number of factors led to the limited assessment of the concept applicability in the skyguide foreign electronic environment.

skyguide controllers' practices with the relatively few (2) sectors in Switzerland implied that both PC and EC had an excellent knowledge of their sectors and traffic patterns.

Considering controllers expertise leading to strong habits in traffic analysis and conflict detection, the usage of ERATO services for aiding work in the skyguide environment remain very limited. Several points of interest were extracted from data collected after analysis:

- skyguide controllers were satisfied with the possibility of filtering flights at the same FL, in their own environment, although this meant a simpler sorting logic. The concept of ERATO Filtrage remained well understood by controllers but it was considered as showing too many flights and therefore, appeared too complex compared to a per-FL filtering logic, The ERATO

Filtrage encompasses the traffic evolution for a flight during the entire crossing of the sector (before entering and until transfer) as a means of supporting anticipation. Further, it makes use of sorting criteria according to information about airspace structure and control expertise. Thus, the ERATO Filtering provides information which helps controllers analyse traffic situation while taking into account Exit conditions and potential pilots' requests for descent. Sorting flights per-FL answers a need which corresponds to a different concept.

- Extrapolation of flight trajectories was judged interesting by skyguide controllers, provided that the only flights of interest would be extrapolated. This is why the Problem Extrapolation from the Agenda was preferred to the basic Extrapolation. Controllers also judged that Extrapolation was of limited use within small-sized sectors.
- Considering the concept of the Agenda or Time Scheduler, skyguide controllers did not require the long-terms planning and ordering of conflict resolution actions, which are conducted very early in the skyguide operational context. The concept of the Agenda as a support for memorisation of conflicts was not used by controllers. The extensive experience of skyguide controllers with their own stripless environment has installed a means of building and updating their mental image of traffic by scanning the radar. It can be envisioned that the expertise in using radar data and an excellent knowledge of traffic patterns has an impact on the memorisation needs and strategies. This expertise renders of limited use, the aids and supports for planning and memorising conflicts.
- The new cooperation gradient prescribed by the usage of the Agenda implied that controllers judged the changed responsibilities for creating and managing Problem Labels between PC and EC to be unsatisfactory. The Agenda could be misinterpreted as a means for PC to prescribe actions to be done by the EC, while controllers mostly consider that the PC mostly assists the EC and should stay in that function, and
- Controllers judged the usage of MGA as tentatively interesting, although not really applicable in the skyguide environment given their ability for managing traffic through radar scanning.

The operational context of the skyguide environment is not sufficiently known (airspace, tools, procedures, etc.) for furthering this analysis. A familiarisation step is wanting and would be very interesting namely as a learning process for anticipating the potential future evolutions of the French working methods.

As a conclusion on applicability, skyguide controllers didn't refute the ERATO concept at its high level (controllers remain responsible for decision making, human cooperation is essential), however the ERATO tools could not be directly applicable in the skyguide environment.

6.2.3.2.9 Concept applicability into Foreign Stripless Environment – ENAV

Evaluating the applicability of an operational concept into an environment incurs the assessment of the *domain suitability* of that concept.

Domain suitability refers to the appropriateness of a concept with respect to the environment in which it is planned or envisaged, as in this specific case, to be introduced. Domain suitability is linked to aspects of user acceptability and technical usability discussed so far. However it also differs from them as it focuses also on the physical, cultural and organisational characteristics of the environment in which the concept is foreseeably introduced and on the compatibility of the concept. It may happen that one concept presents high levels of domain suitability with respect to a particular working environment, while it reveals itself to be inappropriate for another environment. It depends on the actual characteristics of the respective environments.

The assessment of domain suitability requires knowledge of the context of use of the new concept and of factors such as:

- the users' characteristics, their goals,
- their working methods (including roles allocation and tasks distribution),
- their subjective strategies in specific situations,
- their interactions with the working environment,
- their practices and procedures,

- the communication with others, and so on.

The assessment of concept applicability was performed at a very high level due to: i) the time constraint (i.e. only a half-day session was available), ii) the number of Italian controllers attending the validation exercise (two) and iii) the impossibility to test in a concrete way the concept in an Italian electronic environment (the French one was available and used).

The brainstorming exercises were treated as envisioning sessions, useful for collecting qualitative feedback about the concept and about any possible benefits and/or issues triggered by its implementation in a stripless and automated environment such as the Italian one.

The applicability of ERATO into Italian environment was evaluated and is reported with respect to the routine activities and operations performed regularly by Italian Executive and Planning controllers, and in other words with respect to the working methods. The rationale for this approach is twofold:

i) Working methods - as previously stated - represents a crucial factor able to affect the concept's domain suitability. The evaluation of the concept applicability with respect to this "dimension" represents an adequate basis for this study and for any eventual future ones. To maintain links and connections with working methods also allow the achievement of an adequate level of analysis of collected results that is coherent with the type of evaluation technique adopted (i.e. envisioning session), and

ii) the presentation of results according to the main steps which make up working methods allows a better readability of the results itself and their subsequent comparison with the French ones reported.

Working methods are made up of the following main activities:

i) *Integration of new flights*, further subdivided into analysis of traffic situation, problem detection, analysis of traffic situation of a problem, planning the treatment of problems;

ii) *Problem resolution and follow-up*;

iii) *Sector scanning*;

iv) *Controllers' cooperation and communication*.

Integration of new flights

To integrate new flights represents a crucial step in controllers' activities since it incurs having to successfully analyse the traffic (inbound traffic with respect to the other), detect any eventual interactions with other aircraft (already in the sector or planned to enter) and, in case of problem, define a strategy for the resolution of the problem itself.

Analysis of Traffic Situation

Analysis of traffic situation allows controllers to achieve and maintain a valid mental picture of the traffic, i.e. the inbound traffic on its own and the inbound traffic with respect to traffic already inside the concerned sector. This process means that an adequate level of mental representation of evolving traffic situations is maintained.

As a means of better comprehending the theoretical cognitive tasks performed by controllers during the analysis of a traffic situation, a cognitive model of situational awareness is considered. According to the cognitive model, controller's situational awareness results from two main sources:

- information about the actual traffic situation, and
- Controllers' knowledge of ATC and sector structures.

The situational conditions are integrated into controllers' mental model to form actual mental picture of the situation.

Due to their strategic role, Planning controllers always try to anticipate and predict how the traffic situation is going to develop by projecting the actual mental picture into the future. This anticipation is constantly checked against actual events. If the actual events match the controllers' anticipation, then the mental picture is confirmed.

If the mental picture and the actual situation do not fit beyond the controllers' mismatch tolerance, then an explanation (diagnosing activity) is attempted. Diagnosis of a mismatch normally includes the active check of external information that has to be integrated into the mental picture.

The availability of aids like Extrapolation could support Planning controllers in the anticipation and prediction of traffic situation. It could facilitate controllers' activity making more automatic this analysis that is currently mentally performed.

Based on the mental picture, controllers also plan their future actions for instance, by doing long-term anticipations. As long as controllers are successful in achieving these predictions and subsequent action plans, it is said that a suitable level of situational awareness has been achieved.

The checking action (executed with respect to actual events) is performed by directing attention to several information sources like the radar screen, the electronic flight progress strips, certain information displays, reminders which controllers have set in terms of speed vector activation, and so on. This information check is triggered when the controllers receive new or unexpected information, suspicions or presumptions that perhaps something is not going the expected way. After a deliberate check for information the mental picture is confirmed or updated.

Problem Detection

Detecting problems is another core cognitive task of controllers. A first conflict search was done by planner controller about 5-15 minutes before aircraft enters the sector, when it appeared quite far from the boundary of the concerned sector. The general information needed by controllers to detect a problem is:

- flight level,
- route,
- overflying time regarding certain points/beacons in the sector,
- speed/type of aircraft.

Controllers still had in mind the present traffic or they check this data against the traffic labels of other traffic they have on the radar screen. At this stage they knew where a potential conflict might arise. This “searching conflicts” process was also guided by the controllers' knowledge of the sector, and where conflicts were more likely to occur. For a more fine-grained assessment, radar tools like Range & Bearing and Speed Vector were used.

The availability of aids like Extrapolation and Filtering (combined together) could support controllers in the manually identification of problems and their location. But in case of high traffic load, the manual detection of conflict could be quite limiting for controllers and the activities they have to execute. Further studies could be addressed toward the evaluation of a system able to automatically propose to controllers' problems, keeping the controllers always in the loop of the decision.

Planner controllers generally performed pre-screening for conflicts. They either took action by themselves, e.g. they co-ordinated a solution with the previous sector (telling or showing the Executive controllers afterwards), or they informed Executive controllers of the problem. They discussed together to try to find a solution, suggesting ways, or the problem was left to the Executive controllers that decided what to do.

Depending on the workload and the assessment of how likely it is that a conflict will occur, they decided whether actions should be taken right away; for instance, co-ordinated early handing over of aircraft with the previous sector's controllers or asked them to do something with it. They might also wait and monitor the flight coming into their sector. Every time they checked, they automatically followed the same decision process: “Is the flight still a potential conflict?”, “Do I take action now or do I further monitor?” The advantage of taking action (i.e. the “safe conservative strategy”) is that they did not need to pay attention to this aircraft any longer. The disadvantage might be to have additional co-ordination and inconvenience for the aircraft in the future.

The availability of aid like Extrapolation could help controllers in assessing the priority of a problem and in deciding if they should immediately act on the flight or not.

The aircraft data were finally mentally integrated and the future development was anticipated or predicted: controllers estimated whether the traffic was going to constitute a conflict or not and where. This was followed by an update of the mental picture.

The availability of aid like Extrapolation could support controllers in assessing whether the flights are going to conflict or not and where with an adequate level of accuracy.

This whole "searching conflicts" process was guided by controllers' knowledge of the points/sector area where conflicts were more likely to occur.

Analysis of Traffic Situation of a Problem

Controllers manually evaluated the situation of traffic related to a problem directly looking for concerned information on the radar screen. Information evaluated were the same already quoted in the previous section, i.e. flight level, route, overflying time regarding certain points/beacons in the sector, speed/type of aircraft.

In general, the analysis was first performed by the Planning controller. His working horizon and the pre-screening activity already performed in the previous step (see previous section "Problem Detection") allowed the assessment of information quite in advance, in order to allow the definition of a strategy for the treatment of the problem.

Essential information deemed useful for the understanding of the problem and its assessing in term of gravity were shared with the Executive controller. The purpose is to speed up the tactical work limiting the information to analyse and facilitate the definition of a planning for the management of the problem.

The availability of aid like Filtering could support controllers in i) highlighting the concerned flights, ii) speeding up the detection and analysis of the situation, iii) communicating, iv) sharing the same mental picture (acting on filtering, the same flights are highlighted on EC and PC radar screen).

Planning the Treatment of Problems

Controllers knew about potential problems and had to decide whether to:

a) Monitor the potential conflicts for a while, or

b) Act on the problems right away.

Monitoring was applied when controllers were not completely sure that the potential problems would become conflicts (for instance due to the early time at which problem prediction has been performed) *and* controllers' workload allow coming back to the problem for a further evaluation refinement, without affecting the attentional resources. In addition, controllers' actions on surrounding aircraft (e.g. re-routing, level change, speed variation, etc.) could indirectly act on the concerned problem letting its natural resolution. If controllers decided on monitoring, they had to direct their attention to the problem from time to time, which implied a switching attention process. Controllers had to attend to them as long as aircraft did not pass each other or until they were sure that they would safely pass each other.

The availability of aid like Extrapolation could make the monitoring phase much shorter.

Acting right away – by planning the proper strategy/treatment - was the adopted solution when the severity of the problems was made certain or when controllers' workload was so high that a monitoring was not feasible, according to the attentional resources they had to spend. Arranging the treatment meant to co-decide (i.e. between Planner and Executive) a strategy that was safe and efficient, also considering different factors like: the characteristics of the problem (i.e. 3D position and visual properties of the concerned aircraft), the amount and spatial distribution of surrounding flights in the sector, the current workload of Executive controller, the availability of flexible coordination with neighbour sector in case of problem between inbound flights or a flight already in the sector and an inbound one).

The availability of aid like Filtering could support controllers in immediately catching and assessing relevant information. The addition of a what-if logic – combined with the Extrapolation aid – could facilitate controllers in evaluating the quality of the proposed strategy.

Problem Resolution & Follow-Up

The resolution starts when the problem becomes more concrete and assumes a high probability of occurring.

In case Executive controllers decided to act on the problem, they i) placed increased attention on the problem and ii) applied a strategy/solution from their experience-based episodic memory.

i) Attention to concerned problem depended on the time available to solve it (i.e. level of urgency), how complex the problem was and according to what the demand from the remaining traffic in the sector is. Safe traffic moved to the background and obtained very little attention. Non-urgent items moved back as well and were dealt with later on.

The availability of aid like agenda could help in assessing the level of urgency. Controllers could decide if the order has to be modified, considering the evolution of the traffic inside the sector and the instructions provided time by time to the aircraft. The availability of Problem Filtering could facilitate the evaluation of the problem complexity. Extrapolation could help in understanding the evolution of the problem time by time with respect to the surrounding traffic.

Considering the workload, in case of low traffic load these functions could be used both by Executive and Planner. In case of high traffic, the Executive controller would continue to work as in the current way, mainly focussing on the radar screen and on the information here displayed. The functions would be mainly used by the Planner controller.

The availability of aid like agenda could also support in keeping the Executive controller workload at proper level due to the considerable effort spent by the Planner controller in keeping attention and assessing the problem.

The criterion for choosing a *solution* was first of all safety, then efficiency. Efficiency is with regard to aircraft movements as well as the workload of controllers. Solutions had to meet these criteria, depending on the time the controllers can spend thinking about them. Since the most common and frequently used solutions are thought of first, they are also named routine solutions.

When controllers chose a solution, they co-ordinated with the adjacent sector (if necessary). Once they found an agreement they instructed aircraft according to defined plan. They carefully monitored traffic on radar screen to see whether it followed the instructions. The frequency of checking also depended on controllers' expectation which is based on their experience. If the problem was not solved by the applied action, controllers had to retrieve their backup plan. For almost every conflict controllers had a backup plan in mind in case their initial plan did not work. A backup plan was usually characterised by being safe but not very efficient. This explains why, if there is enough time available, controllers tried to find a new solution on top of their backup plan. So, if they neither have time nor capacity left, they could always implement their backup plan and instruct the aircraft accordingly.

As soon as the controllers were sure that the conflict was solved their mental picture was updated and they turned to the next problem, starting the "solving conflicts" activity again or switching to monitoring activity (see section "Sector Scanning").

The other problems displayed in the agenda could lead or at least provide a tendency regarding the solving conflict process.

In situations where different conflicts had to be solved or conflict resolution had to be alternated with routine high priority tasks (e.g. answer to radio call), attention was switched almost all the time. So, switching attention task became a crucial intrinsic element of conflict resolution. In general controllers tried to avoid too many pending tasks. Especially in high workload conditions, they followed a fixed sequence of tasks which allowed them to deliberately do one thing after the other.

Difficulties came up when this fixed sequence of standalone tasks could not be performed because unfinished tasks of higher priority were present at the same time. The "switching attention" process could not be left. This meant that controllers were caught in tasks with higher priority and there was a risk they might not come back to the unfinished previous task. In such a situation there could be a risk that controllers forgot something important. This risk increased the more controllers quit an unfinished task in favour of a task that seems to be of higher priority. A high risk of working memory overload arose from this situation. Currently controllers, especially Executive controllers, set mental or visible reminders (i.e. speed vector) to remember situations or tasks over which they had to come back.

Problems still placed in the agenda could help controllers during these continuous switching attention processes in not forgetting actions that must be executed for the specific concerned flights.

Sector Scanning

Controllers constantly monitored the traffic on the radar screen that represented the most important source of information. The scanning/monitoring process was closely related to routine traffic management and was repeated while controllers were working on position. It was made up of i) a

constant update of the mental picture and ii) a problem search. *Constantly* means that controllers usually did this whenever their attention was not required by other tasks such as instructing, co-ordinating, making an input or any mental problem solving. The scanning frequency also depended on the traffic load and the qualitative complexity of the situation.

The main purposes were to maintain an adequate level of situational awareness and to look for any eventual conflicts. Executive controllers were mainly focussed on scanning traffic inside the sector. Planner controllers were essentially devoted to the analysis of traffic inbound the sector or at the boundary (entry/exit flights).

When mental picture was confirmed, controllers updated their sector plan and, particularly under high workload conditions, they checked their action hierarchy, i.e. what the next most urgent things to do were. If it was necessary to take some action, the monitoring process lead to three alternative task processes:

- activation of the solving problems process, if a potential conflict was expected;
- management of pilots/neighbours controllers requests - if controllers received specific demands – that means assess certain information (e.g. CFL, route) and check the request feasibility from a safety point of view;
- management of routine traffic, otherwise.

The availability of an aid/system by which organise and handle detected problems could support controllers in deciding which of these alternative tasks has to be performed at first. In case of a "solving problem" process activation, the aid/system could provide support in easily understanding the order and the time (thanks to the time reference) of execution, reducing the allocated controller mental effort.

Further studies could be addressed toward the evaluation of a system able to automatically propose to controllers problems (keeping the controllers always in the loop of the decision). The purpose is to better understand if an automatic detection of problems could provide positive effect in the sector scanning activities (i.e. reduction of mental workload and of time devoted for the scanning process).

EC/PC Cooperation & Communication

Cooperation and information exchange between controllers of the team were supported by the adoption of the same working tool (i.e. the radar screen) where all the relevant data was placed and could be easily shared, verbally.

As anticipated, communication was basically performed in a verbal way and also assisted by direct indication of relevant information on the radar screen of the colleague. The latter was generally performed by the Planner controller on the CWP of the Executive controller, to highlight flights and relative data crucial for the tactical activity. The manual indication of relevant information sped up the identification of any eventual problem and/or inbound flight that had to be carefully assessed by Executive controllers.

The visualisation of problems in a dedicated area would improve the communication between Executive and Planner controllers in terms of i) reducing communication related to the problem identification and ii) improving the ones deemed crucial for the resolution of the problem itself.

The concept could also provide cooperation improvement, i.e. a better support from the Planner controller in preliminary handling the problem and trying to find a resolution strategy able to decrease the Executive workload.

The fact that Planner controllers also have the radar qualification as Executive controllers allowed a tacit understanding inside the team. They generally had the shared mental model and shared anticipations.

Personal reminders as the speed vector and the Range & Bearing were additional means able to guarantee a silent communication between controllers of the team.

6.2.3.3 Confidence in Results of Validation Exercise

6.2.3.3.1 Quality of Validation Exercise Results

See 4.3.1.

6.2.3.3.2 Significance of Validation Exercise Results

See 4.3.2.

6.2.4 Conclusions and recommendations

6.2.4.1 Conclusions

The validation results obtained with French and foreign ATCOs demonstrate a real ability to achieve the control tasks with effectiveness (i.e. with accuracy and completeness), while using the ERATO tools with the defined working method. However, some difficulties have been encountered due to implementation issues (SIMFL, simulated filtering) which should lead to assess those tools in further studies during the implementation phase. Some other difficulties are more specific to the foreign ATCOs participating to the exercise. The electronic environment has been easily taken into account by the ATCOs from ENAV and skyguide, thanks to their experience on electronic environment. But the lack of time to maturate the new functionalities and/or the French inter-sectors agreements after the training phase (difficulty of changing working habits in a very short timeframe, different type of sectors…) could explain some limitations to the validation.

For instance, the conflicts which were introduced in the traffic samples in order to observe ERATO tools use are representative of what is usually dealt within the sectors simulated for the tests. Sadly, in some runs, foreign ATCOs systematically solved conflicts by the way of actions in the previous sectors through coordination. This method was not realistic as it doesn't match with the actual constraints in the previous sectors. As it had not been anticipated, the operators playing the role of adjacent ATCOs had not been briefed. Consequently, they accepted all coordination requests which wouldn't have occurred in real. This had the consequence to largely simplify the traffic and lower the need for ERATO tools inside the sector. .

During the exercises, the opportunistic noting down of safety events did not reveal any noticeable safety issues. A complete safety analysis will be part of the implementation work to be done before operation.

The training performed with the French ATCOs is efficient, and can be used as a good training basis for transition purpose.

It has been demonstrated that the concept (see 2.1) can be applicable in certain environments other than the French one. However, concerning the implementation of tools, all of the ERATO features might not be required in all environments, depending on the characteristics of both the airspace and the current legacy system (which may already integrate part of the concept), as well as associated working habits.

For the foreign controllers, it has to be noted that most of the findings are related with EE HMI which was not in the scope of the validation objectives regarding foreign controllers. However, it was interesting to identify them as they are meaningful and can be used for further activities of this type:

- HMI principles differences between their own environment and the tested environment were disturbing for foreign controllers;
- Training was not sufficient to avoid this (lack of time to maturate a different operational environment and different working habits additionally to the technical environment).

Some other difficulties more linked with the ERATO tools may also be explained by a lack of maturity in the understanding of the implementation, which would probably necessitate to have more time between training and evaluation.

6.2.4.2 Recommendations

In the French context, future work should now focus on the actual implementation of the ERATO tools in the French legacy system (correction of the identified defects and tuning of the tools, safety study, production of the operational and transition material including training, (outside of SESAR scope)) .

In a candidate foreign environment, the following activities should take place:

- A local implementation of ERATO should always take into account the characteristics of the candidate ACC (airspace structure e.g.) and associated legacy system (existing tools) in order to determine which of the ERATO features are needed;
- The transition steps between the legacy and new system should also be thoroughly assessed for each candidate centre, taking into account definition of working methods, of training needs… ;
- Implementation of the ERATO tools in the legacy system should take into account the tuning of the tools according to local needs (colour, additional information…), a complete safety study, production of the operational and transition material including training.

In the frame of a SESAR validation activity implying ATCOs to work on a foreign environment, the training phase and planning should take into account the time necessary to maturate a different operational environment and different working habits additionally to the technical environment.

Finally, it should be valuable to study a concept of automatic agenda which was noted as potentially interesting in high traffic situation during the observations of foreign controllers handling of the manual agenda.

7 References

7.1 Applicable Documents

[1] V&V Plan Latest version

[2] D02-01-1-2 En Route Concept Validation Strategy document Step1- draft1

[3] Template Toolbox 02.00.00

[4] Requirements and V&V Guidelines 02.00.00

[5] Toolbox User Manual 02.00.00

[6] European Operational Concept Validation Methodology (E-OCVM) - 2.0 [March 2007]

[7] SESAR 16.06.05 HP input to the Cross-TA Plan of Assessments for Release 1 of Step 1, Edition 00.01.00, dated 2010/11/30

[8] Operational Improvement Steps (SESAR European ATM Master Plan Portal https://www.atmmasterplan.eu)

7.2 Reference Documents

The following documents provide input/guidance/further information/other:

[9] 04.03-D117-CDM Sector Team Operations Validation Plan.doc

[10] 04.03-D27-CDM & Sector Team Ops OSED & Requirements

[11] FASTI Business Case Report D4 - Making change in En-Route Air Traffic control V2.0 – EUROCONTROL - dated 2008/02/11

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