Operational evaluation of industrial Short Term Conflict Alert (STCA) prototype for Terminal control area (TMA) specific operations

Document information	
Project title	Ground based safety nets
Project N°	04.08.01
Project Manager	DSNA
Deliverable Name	Operational evaluation of industrial STCA prototype for TMA specific operations
Deliverable ID	D05
Edition	01.00.00
Template Version	02.00.00
Task contributors	
EUROCONTROL, DSNA	

Abstract

The aim of this exercise is to operationally validate (V3) enhanced Short Term Conflict Alert (STCA) for Terminal control area (TMA) based on an industrial prototype developed in the scope of SESAR. Validation objectives derived from operational requirements and EUROCONTROL guidance material for STCA are evaluated. The prototype is configured for one TMA (i.e. Lyon in France), run in fast-time with recordings of real radar tracks, and alerting performance compared with a state-of-the-art STCA already operational in Lyon TMA. Results indicate that the prototype, parameterised and tuned over a period of weeks, operates within acceptable limits of alerting performance. However, compared to the state-of-the-art STCA in operation for years, the prototype increases the proportion of undesirable alerts from 21% to 29% i.e. safety levels are maintained with a potentially negative impact on human performance. Recommended improvements include reducing undesirable alert rate between aircraft flying under visual flight rules in uncontrolled class G airspace.

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Document History

Edition	Date	Status	Author	Justification
00.01.00	13th January 2012	Draft	EUROCONTROL/ DSNA	Initial draft
00.02.00	1st February 2012	Draft	EUROCONTROL/ DSNA	Updated after comments from 4.8.1/10.4.3
0.03.00	15th February 2012	For approval	EUROCONTROL/ DSNA	Updated after comments from 4.8.1/10.4.3/16.6.5/16.6/4.2
01.00.00	17th February 2012	Final	EUROCONTROL/ DSNA	Approved by SESAR 4.8.1 partners for delivery to SJU as part of Release 1

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Executive summary

The goal of the Single European Sky Air Traffic Management Research (SESAR) Project 4.8.1 “Evolution of ground-based safety nets” is to conduct an appropriate evolution of ground-based safety nets to ensure that they will continue to play an important role as a last Air Traffic Control safety layer against the risk of collision (and other hazards) during managed trajectory and separation operations.

Under the Operational Focus Area 03.04.01 Enhanced STCA, it is expected to adapt in a stepwise approach STCA to the changes brought by the SESAR Concept of Operations. The first Operational Improvement CM-0811 "Enhanced STCA for specific TMA operations" is evaluated by the exercise EXE04.08.01-VP140 conducted in the Release 1 plan.

This report is the result of task 5.2 “Conduct operational validation of enhanced STCA for TMA specific operations at industrial site”. The enhanced STCA is an industrial prototype developed by Project 10.4.3. The intended European Operational Concept Validation Methodology (E-OCVM) maturity level is V3 ‘Pre-industrial development and integration’.

Validation objectives are derived for from operational requirements and EUROCONTROL guidance material for STCA. Eleven days of recordings from 2010 of real radar tracks from Lyon TMA in France are used for the validation. Corresponding alerts from the state of the art multi-hypothesis algorithm based STCA operational in Lyon TMA are taken as a benchmark for enhanced STCA in TMA, and used as a baseline for comparison. The prototype is configured for Lyon TMA and run in fast-time with the corresponding recorded radar tracks. Alerts from the prototype and the baseline system are classified by an air traffic controller, and alert start times noted.

Results indicate that the prototype, parameterised and tuned over a period of weeks, operates within acceptable limits of performance. It is expected to be operationally acceptable for relatively complex medium sized TMAs, comparable with Lyon TMA, with the order of 100,000 movements per year. However, compared to the state-of-the-art STCA in operation for years at Lyon TMA, the prototype increased the proportion of undesirable alerts from 21% to 29% i.e. similar safety levels are maintained with a potentially negative impact on human performance.[1]

Compared to the baseline, the following differences were noted for possible further investigation and improvement:

- (1) Over 10% of necessary alerts and over 30% of desirable alerts are not common to both systems, and each of those alerts involved at least one IFR aircraft.[2]
- (2) Significantly more undesirable alerts are raised by the prototype between VFR aircraft in class G airspace.
- (3) Duration of alert is not computed due to inconsistencies between baseline and prototype way of handling surveillance tracks and synchronisation messages

Specific areas identified for potentially improving prototype functionality include: inhibiting alerts based on airspace classes, processing invalid mode A codes, and correction of area levels using QNH[3].[4]

[1] The prototype was configured differently to the baseline for some processing e.g. invalid mode A and QNH correction, and regarded some situations as desirable alerts when the baseline considered them to be undesirable or unnecessary.

[2] This may result in improvements to the baseline as well, although it should be remembered that classification of alerts may differ between air traffic controllers. Human factors and local circumstances determine what constitutes an operationally relevant conflict and an effective minimum of undesirable/void alerts.)

[3] Outside of scope of this validation THALES claims slight adaptations were made shortly after the end of the validation exercise to adopt similar alerting criteria as the baseline; a further run conducted with the adapted prototype showed a level of unnecessary and nuisance alerts that dropped to levels similar to or better than the baseline. These results are documented in 10.04.03-D36-Validation support Report*

[4] DSNA provided radar tracks based on a clockwise distribution, whereas the prototype processes surveillance tracks in a strip mode. This creates latencies in the prototype on alert detection, up to

Undesirable and void alerts exclusively raised by the prototype as well as undesirable and void alerts exclusively raised by the baseline should be further investigated.

New functionality developed in the scope of SESAR either were out of scope of this validation (e.g. traffic in parallel runways and cleared flight level input) or could not be tested due to lack of adequate situations in the data (e.g. traffic in stacks). Future validation might address this functionality. Analysing multiple alert occurrences for the same encounter may give more insight into STCA enhancements due to multi-hypothesis algorithms.

approximately 4s. THALES suggests investigating the same radar tracks with a strip mode distribution (ARTAS output) in step 2.

1 Introduction

1.1 Purpose and scope of the document

This document reports on the operational validation (V3) of an enhanced STCA for TMA specific operations as expected for Step 1 of the SESAR story board. This is part of operational sub-package Air Safety Nets and Operational Focus Area (OFA): 03.04.01 – Enhanced ground based safety nets. It describes the conduct and results of a validation exercise (EXE04.08.01-VP140 in the Release 1 plan) and defined in the related validation plan (VP-TMA-STCA-V3) of project 4.8.1 [8].

The scope is to evaluate an enhanced STCA for TMA supplied by SESAR project 10.4.3 by:

- ensuring appropriate operational requirements are fulfilled, and
- comparing alerting performance with the state-of-the art.

The 10.4.3 industrial STCA prototype is based on an operational STCA with an improved multi-hypothesis algorithm. This validation exercise is focussed on demonstrating acceptable operational performance of the STCA multi-hypothesis algorithm functionality. Validation objectives are derived from corresponding operational requirements [7] and EUROCONTROL guidance material for STCA [19]. Requirements related to inhibition zones/flights are included since they are considered important in the adaption to TMA. Only requirements related to STCA alerting performance (including zone/flight inhibition) are covered. Requirements related to: HMI, policy, organisational clarity, training and procedures are considered out of scope.

Due to the low alert rate of safety nets like STCA (of the order of one an hour), real-time simulation is usually considered impractical to collect statistically significant amounts of data. In this exercise, fast-time simulations based on real recorded data are used to generate several days worth of alerts that are then analysed off-line with a controller in the loop.

This study was led by EUROCONTROL as part of project 4.8.1 task 5.2 "Conduct operational validation of enhanced STCA for TMA specific operations at industrial site". The task was performed by DSNA and EUROCONTROL (as 4.8.1 partners) with the assistance of Thales (as 10.4.3 partner). DSNA, as ANSP, provided the state of the art operational baseline data and analysis expertise. Thales, on behalf of 10.4.3 and as industrial partner, hosted the validation exercise by providing the platform and running the exercise at its site in Rungis near Paris. All task partners were involved during the planning, preparation, execution and documentation phases of this task.

The corresponding SESAR 4.8.1 planning task 5.1 "Develop validation plan (V3) for enhanced STCA for TMA specific operations" was also led by EUROCONTROL. SESAR 4.8.1 project partner SELEX and Project 16.6.1 "Safety support and coordination function" and 16.6.5 "Human performance support and coordination function" contributed to the validation plan [8].

1.2 Intended audience

This document is intended for members of 4.8.1 "Evolution of ground-based safety nets" and 10.4.3 "Safety nets adaptation to new modes of separation". The document is also intended for 4.2 "Consolidation of operational concept definition and validation including operating mode and air-ground task sharing", 16.6.1 "Safety support and coordination function", 16.6.5 "Human Performance support and coordination function", and those interested in results of Release 1 exercises.

1.3 Structure of the document

Section 2 gives an overview of the concept and summary of validation exercises.

Section 3 describes preparation and execution of validation exercise, and deviations from the plan.

Section 4 is a summary and analysis of the exercise results including confidence in the results.

Section 5 gives conclusions and recommendations

Section 6 contains the validation exercise reports.

1.4 Acronyms and Terminology

Term	Definition
ATM	Air Traffic Management
Conflict	Conflict is any situation involving an aircraft and hazard in which the applicable separation minima may be compromised. Hazards are the objects or elements that an aircraft can be separated from. These are: other aircraft, terrain, weather, wake turbulence, incompatible airspace activity and, when the aircraft is on the ground, surface vehicles and other obstructions on the apron and manoeuvring area. Source: ICAO Doc. 9854 – Global Air Traffic Management Operational Concept Converging of aircraft in space and time which constitutes a predicted violation of a given set of separation minima. (SPIN definition).
Desirable alert	Although there was no serious loss of separation, the situation was such that an alert would have been useful in drawing the attention of the controller to a potential conflict.
DOD	Detailed Operational Description
E-OCVM	European Operational Concept Validation Methodology
Ground-based safety net	A ground-based safety net is functionality within the ATM system that is assigned by the ANSP with the sole purpose of monitoring the environment of operations in order to provide timely alerts of an increased risk to flight safety which may include resolution advice. (SPIN definition).
False alert	Alert which does not correspond to a situation requiring particular attention or action (e.g. caused by split tracks and radar reflections). (EUROCONTROL SPIN definition). False alert was used in the validation plan but void is used throughout this report to be consistent with EUROCONTROL SPIN definition
Genuine alert	Necessary or desirable alert
IFR	Instrument Flight Rules
IRS	Interface Requirements Specification
INTEROP	Interoperability Requirements
Missed Alert	A lack of indication to an actual or potential hazardous situation that requires particular attention or action.
Necessary alert	Situation involved a serious loss of separation or avoided such a loss by a late manoeuvre.
Nuisance alert	Alert which is correctly generated according to the rule set but is considered operationally inappropriate. (SPIN definition). Nuisance was used in the validation plan but undesirable is used in this

Term	Definition
	report to be consistent with EUROCONTROL SPIN categories
OFA	Operational Focus Areas
OSED	Operational Service and Environment Definition
PASS	Performance and safety Aspects of Short term conflict alert – full Study
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SPIN	Safety net Performance Improvement Network
SPR	Safety and Performance Requirements
Undesirable alert	Situation presented little threat of separation loss and an alert would be distracting or unhelpful.
Unnecessary alert	An alert was unnecessary for the satisfactory resolution of the situation but would be “predictable” or understandable by the controller.
VFR	Visual Flight Rules
Void alert	This situation is not to be used for optimisation. For example. It may be a false situation caused by erroneous track data, or it may occur in a region of airspace not covered by STCA.
VP	Validation Plan
Warning time	The amount of time between the first indication of an alert to the controller and the predicted hazardous situation. Note – The achieved warning time depends on the geometry of the situation. Note – The maximum warning time may be constrained in order to keep the number of undesirable alerts below an acceptable threshold.

2 Context of the Validation

2.1 Concept Overview

2.1.1 Safety nets in Europe

In accordance with the European Single Sky Implementation (ESSIP) objectives (ATC02.2, ATC02.5, ATC02.6 and ATC02.7) for ECAC-wide standardisation by 2008/2013 [12], ground-based safety nets have already started to be implemented all across Europe. These safety nets encompass:

- Short Term Conflict Alert (STCA)
- Area Proximity Warning (APW)
- Minimum Safe Altitude Warning (MSAW)
- Approach Path Monitor (APM)

At present, it is however recognised that some safety nets are not yet implemented or not operationally useable in some ATC control operations e.g. dense TMA operations as well as complex relief or hazardous configurations, because the safety nets undesirable alert rate is evaluated to be too high; controllers do not trust those particular safety nets and therefore do not use those functions.

2.1.2 Short Term Conflict Alert

2.1.2.1 Evaluation framework

Within the context of SESAR Step 1 "Time-based operations", Project 4.8.1 "Ground based safety nets" has produced a "Consolidated baseline framework for safety and performance evaluation of STCA" [7]. This contains a set of safety and performance requirements with an appendix of operational requirements taken from external sources: EUROCONTROL SPIN (Safety net Performance Improvement Network) [18] and PASS (Performance and safety Aspects of STCA: full Study) [20]. Using these requirements, an enhanced STCA has been developed as part of Phase 1 of the technical mirror project 10.4.3 [9] [10] [11]. This is in accordance with Operational Improvement CM-0811 "Enhanced STCA for specific TMA operations".

2.1.2.2 Enhanced STCA for TMA: multi-hypothesis

Most STCAs in operation today use only a single hypothesis when probing ahead for conflicting encounters. That is only one estimated future trajectory is considered per aircraft. In state of the art (referred to as 'enhanced' in this document) STCAs, such as that operational at Lyon TMA and the prototype assessed in this study, more than one predicted trajectory per aircraft is considered. For example in the 10.4.3 enhanced STCA, depending on airspace parameter settings, up to two extrapolations are computed when surveillance tracks are processed by the STCA [11]:

- The main hypothesis – the trajectory expected to be followed which can be a straight line, or curved taking into account things like: Cleared Flight Level (CFL), Standard Arrival Routes (STAR), Holding pattern etc.
- The backup hypothesis – a straight line extrapolation (computed only if the main hypothesis is not a straight line)

Note: CFL information was not available as DSNA policy is not to use it (for independence purposes), especially in TMA where the information is less reliable. Therefore, assessing potential improvements brought by taking into account the CFL was out of the scope of this validation exercise.

A conflict is detected if:

- Both tracks have only one main hypothesis
  - A conflict situation is detected using main hypotheses and standard parameters
- Both tracks have one main and one backup hypothesis
  - A conflict situation is detected using main hypotheses and standard parameters, or
  - A conflict situation is detected using backup hypotheses and reduced parameters
- Only one track have both hypothesis
  - A conflict situation is detected using main hypotheses and standard parameters, or
  - A conflict situation is detected using main hypothesis versus backup hypothesis and reduced parameters

When a conflict is detected, it is internally monitored, and a conflict quality is determined. An alert is generated as soon as the conflict status requires controllers to be warned.

STCA conflicts are handled in two ways:

- By means of a conflict quality.
- By comparison between the time to conflict and the warning time (minimum time to solve the conflict: it includes the sum of reactions times of controller, pilot, aircraft)

Conflict quality is determined using the number of conflict detections against the age of the conflict:

The multi-hypothesis algorithm based STCA operational at Lyon TMA is taken as a benchmark for 'enhanced' STCA in TMA. It is used to compare alerting performance of the industrial prototype.

2.1.2.3 Release 1 exercise

In spring 2011, a validation plan was produced by project 4.8.1 in collaboration with project 10.4.3. Since comments were received on the validation plan from SJU reviewers [21] and as the execution phase progressed there has been a shift in emphasis from: checking that the industrial prototype gives better alerting performance than the operational system; to validating that enhanced STCA for TMA on an industrial prototype would be operationally acceptable. This involves using Lyon TMA to compare alerting performance of the prototype with EUROCONTROL guidance material for STCA (Table 5). The STCA operational in Lyon TMA is used as a benchmark for enhanced STCA in TMA to identifiy potential areas where the prototype could be improved. Some validation objectives have been refined accordingly (Table 3)

Validation Exercise ID and Title	EXE-04.08.01-VP-140 Enhanced STCA for TMA specific operations
Leading organization	EUROCONTROL
Validation exercise objectives	To operationally validate (v3) enhanced STCA for TMA specific operations at an industrial site as expected for Step 1.
Rationale	Technical Project 10.4.3 has built a prototype STCA according to 4.8.1 Operational Requirements for Step 1. The prototype is based on an operational system, built by industry, with enhancements to the multi-hypothesis algorithm for better alerting performance in a TMA environment. This is an opportunity for operational project 4.8.1 to validate the enhanced STCA of technical project 10.4.3.
Supporting DOD / Operational Scenario / Use Case	4.2 Enroute operations Detailed Operational Description, Step 1 “Time-based operations”, D06 Draft Edition 00.00.11, 3rd March 2011 [13] and 5.2 WP 5 TMA Step 1 Detailed Operational Description, D101 Draft Edition 00.01, 13th October 2011.
OI steps addressed	CM-0801 Ground based safety nets (TMA, Enroute) CM-811 Enhanced STCA for TMA
Enablers addressed	ER APP ATC 136 “STCA adapted to new separation modes in order to avoid false alerts”
Applicable Operational Context	Step 1 “Time based operations” in TMA
Expected results per KPA	Safety: Reduced undesirable alert rate while maintaining or increasing necessary or desirable alert rate and increasing alert warning times. No negative impact on human performance.
Validation Technique	Running prototype STCA in fast-time using real recorded encounters (radar tracks). Off-line controller in the loop analysis of alerts and comparison with recordings of alerts from real STCA with same set of encounters.
Dependent Validation Exercises	This is a stand-alone exercise

Table 1 Concept overview

2.2 Summary of Validation Exercise/s

2.2.1 Summary of Expected Exercise outcomes

At the end of 2010 a survey of SPIN sub-group members was conducted to establish the main operational issues with safety nets including STCA [15]. Responses were received from the following ANSPs:

- ANS, Czech Republic
- ENAV, Italy
- NATS, UK
- NAV Portugal, Portugal
- General Directorate of State Authority (DHMI), Turkey
- DSNA, France

The highest priority issues with STCA were judged to be:

- undesirable alert rates too high and
- warning times too short.

These priorities were confirmed by DSNA as being the priorities particularly in busy TMA airspace like Lyon TMA. In light of this information, the validation expectations from the stakeholders identified in section 2 are as follows:

- Controllers: expect an improvement of the alerting performance of STCA, particularly in TMA airspace, with:
  - a reduction of undesirable STCA alerts;
  - a warning time increase for necessary and desirable STCA alerts;
  - an improvement, or at least no impact, on the ability of STCA to detect and alert operationally relevant conflicts.
- ANSPs: expect an improvement in the effectiveness of STCA to assist TMA controllers in preventing collision between aircraft by generating, in a timely manner, operationally relevant alerts.
- Industry: expect to demonstrate the improved alerting performance of a prototype STCA compared to an existing operational STCA system.

On 7-8th April 2011 a meeting was held between SESAR WP 16.6.x/4.8.1/10.4.3 at DSNA in Toulouse, France to discuss expectations of validation. As a consequence, SESAR WP16.6.1 produced an “Enhanced STCA (OFA) Safety Plan” [16] Another consequence was that a preliminary human performance assessment on Release 1 scope was performed resulting in [17]. Human performance related assessment needs from [17] are used in section 2.2.5 “Summary of assumptions”.

2.2.2 Benefit mechanisms investigated

Table 2 gives an indication of the expected benefits and relates them to the key performance area of safety and transversal area of human performance. Reducing the number of undesirable alerts is expected to increase controller confidence in the STCA and therefore increase the human aspect of system performance. Increasing the number of necessary or desirable alerts should increase safety of TMA operations and therefore system safety overall. Increasing warning time of necessary or desirable alerts should also increase safety of TMA operations and system safety. It should be noted that these indicators tend to be strongly coupled therefore care should be taken that a beneficial impact of one should not be at the expense of a detrimental impact of another.

Feature	Impact Area	Indicators		Benefit or negative Impacts		Key Performance Area / Transversal Area
Enhanced STCA for TMA specific operations	Alerting performance of STCA	Number of undesirable alerts	↓	Controller confidence in safety nets	↑	Human performance
		Number of necessary and desirable alerts	↑	Safety of TMA operations	↑	Safety
		Warning time of necessary alerts	↑	Safety of TMA operations	↑	Safety

Table 2: Benefit mechanisms for enhanced STCA

2.2.3 Summary of Validation Objectives and success criteria

Table 3 provides summaries of the validation objectives as defined in the validation plan [8] with quantitative updates (see 3.3.2). Each objective is derived from a subset of requirements from the corresponding Safety and Performance Requirements (SPR) [7]. Each objective has at least one criterion to measure the success of the validation.

Exercise ID	Exercise Title	Validation Objective ID	Validation Objective Title	Success Criterion from validation plan (with refinements)
EXE-04.08.01-VP-140	Operational validation of TMA with prototype STCA	OBJ-04.08.01-VP-0010.0010		1/ Percentage of all alerts that are necessary or desirable > 25%
				2/ Percentage of all alerts that are undesirable or void, should be within 10% of that of baseline
		OBJ-04.08.01-VP-0010.0020		1/ Adaptable to the procedures in use in distinct volumes of airspace inside the TMA
				2/ Different parameters or trajectory predictions depending on specific volume of airspace.
		OBJ-04.08.01-VP-0010.0030		1/ Percentage of all alerts, except void, that are undesirable should be within 10% of baseline
				2/ Average start time of necessary alerts should be same or earlier
				3/ Early-terminated alert rate (i.e. is same or reduced.
		OBJ-04.08.01-VP-0010.0040		1/ Acceptable number of alerts for airspace not relevant to the local TMA controllers.
				2/ Acceptable number of alerts involving flights which are not relevant to the local TMA controllers
		OBJ-04.08.01-VP-0010.0050		All data pertinent to this validation available for off-line analysis

Table 3 Summary of validation objectives

Note: In the validation plan the terminology genuine, nuisance and false alert is used. In this report, the more detailed EUROCONTROL SPIN classification (Table 4) is used where genuine is replaced by necessary and desirable; nuisance is replaced by undesirable; and false is replaced by void.

2.2.3.1 Choice of metrics and indicators

Alerts are classified according to EUROCONTROL (SPIN) recommended categories [19]:

Alert encounter category	Encounter description
Necessary	Situation involved a serious loss of separation or avoided such a loss by a late manoeuvre.
Desirable	Although there was no serious loss of separation, the situation was such that an alert would have been useful in drawing the attention of the controller to a potential conflict.
Unnecessary	An alert was unnecessary for the satisfactory resolution of the situation but would be “predictable” or understandable by the controller.
Undesirable	Situation presented little threat of separation loss and an alert would be distracting or unhelpful.
Void	This situation is not to be used for optimisation. For example. It may be a false situation caused by erroneous track data, or it may occur in a region of airspace not covered by STCA.

Table 4 EUROCONTROL alert categories

For each alert set the numbers of each type are counted. The necessary alerts are also sub-classified into timely and late. The start time of Necessary alerts are also required.

Other metrics used in the analysis are:

- Air traffic control type = {IFR/IFR, IFR/VFR, VFR/VFR, IFR/Military}
- Airspace class = {C, D…} See Appendix A Table 16
- Encounter geometry type {Approach capture…}

Although there are no commonly agreed, absolute, performance requirements for STCA yet, Table 5 from [19] is used as a guideline.

Performance Indicator	**Maximise / Minimise**	**Required Performance**	**Preferred Performance**
% of necessary category encounters alerted	Maximise	≥95%	100%
% of desirable category encounters alerted	Maximise	≥80%	≥90%
% of alerted encounters which are in categories: unnecessary, undesirable and void	Minimise	≤75%	≤50%
% of unnecessary category encounters alerted	Minimise	-	≤30%
% of undesirable category encounters alerted	Minimise	-	≤1%
% of void category encounters alerted	Minimise	-	-
% of necessary and desirable category encounters where adequate warning time exists which give less than adequate warning time	Minimise	≤45%	≤35%
Mean warning time achieved for necessary and desirable category encounters where adequate warning time exists	Maximise	≥90% of adequate	≥95% of adequate
Mean achieved warning time for necessary and desirable category encounters where adequate warning time does not exist	Maximise	≥70% of mean objective warning time	≥75% of mean objective warning time

Table 5 Possible STCA performance requirements (EUROCONTROL)

2.2.4 Summary of Validation Scenarios

The validation scenario selected was Lyon TMA according to the following criteria:

- Medium size representative of many TMAs in Europe where traffic growth is expected;
- Complex and busy to expose the STCA to a challenging TMA with a relatively wide variety of alerting conditions
- State of the art STCA using multi-hypothesis algorithm already installed and operational to act as baseline.
- Operated by SESAR 4.8.1 and 10.4.3 partner DSNA giving access to sensitive operational data and relevant operational expertise.

The Lyon TMA includes one major airport, i.e. Lyon-Saint Exupéry Airport (LFLL), some secondary airports, e.g. Lyon-Bron Airport (LFLY), Grenoble-Isère Airport (LFLS) and several general aviation aerodromes like Saint-Yan (LFLN) and Valence-Chabeuil (LFLU).

More than 50 airlines operate from Lyon-Saint Exupéry Airport to more than 120 direct destinations. It is ranked fourth in France in terms of commercial (IFR) movements. The airport is notably used as a secondary hub by Air France (AFR).

According to the TMA characterisation proposed by TMA 2010+ and used as a baseline by SWP5.2, the Lyon TMA is to a certain extent:

- An “Environmentally Constrained TMA” with operating restrictions aimed at reducing noise nuisances in the vicinity of Lyon-Saint Exupéry Airport;
- An “Airspace Constrained TMA” due notably to the proximity of the Geneva TMA and the delegation of French airspace to the Swiss ANSP to facilitate the management of this neighbouring TMA;
- A “Traffic Volume and Variation Constrained TMA” in which traffic patterns are being exacerbated by the volume of traffic inbound/outbound to Lyon-Saint Exupéry Airport, the peaks of arrival/departure traffic flows towards the airport (hub operations), the seasonal variations in the VFR traffic inside the TMA, as well as temporary peaks of traffic due IFR training activity at some local airfields;
- An “Airfield Interaction Constrained TMA” due to the various airfields in the airspace providing a mix of IFR/VFR aircraft types being provided different air navigation services (with a mix of Class C, D, and to a lesser extent E, airspace inside the TMA).

2.2.5 Summary of Assumptions

It is assumed that the roles and responsibilities of any ATM actor involved in collision avoidance service SVC02.02 will not change for step 1.

Only changes to alerting performance are validated in this exercise. Although there is no controller in the loop during the simulation run, the metrics are assumed to be directly related to human performance.

Another key assumption is that the 10.4.3 prototype STCA will comply with the baseline requirements from EUROCONTROL SPIN sub-group and consolidated into the 4.8.1- Baseline framework for Safety and Performance Evaluation of STCA [7].

2.2.5.1 Safety and performance assessment

The following assumptions are derived from the 4.8.1 ‘Consolidated baseline framework for safety & performance evaluation of STCA’:

- Ground-based safety nets (i.e., STCA) will continue to play a major role in achieving an acceptable level of safety in ATM. Nevertheless no quantitative safety objectives for STCA are defined yet for Step 1(to be addressed by 16.6.1 for next steps).
- Safety benefits expected from the use of STCA are highly influenced by the alerting performance of the system and the behaviour of the ATM actors to the alerts (see above)
- The alerting performance of STCA is highly dependent on its capability to detect and alert operationally relevant conflicts with sufficient warning time, while achieving an effective minimum of undesirable alerts.
- Human factors and local circumstances determine what constitutes an operationally relevant conflict to be alerted by STCA and an effective minimum of undesirable/void alerts.

As a consequence, the validation exercise focussed on a comparative analysis of the alerting performance between a baseline STCA currently in operation and the prototype STCA to demonstrate relative safety benefits that can be expected.

2.2.5.2 Human performance assessment

The following assumptions were derived from the 'Screening and scoping' checklist of 'Human Performance Assessment of 4.8.1 Evolution of ground based safety nets (Release 1 scope)'.

The prototype STCA is assumed to:

- not change the roles and responsibilities of any ATM actor.
- not increase the complexity of the controller's task for a given level of traffic.
- not change the allocation of tasks between different ATM actors
- not negatively impact the task relevant information to an ATM actor
- not change the allocation of tasks between human and machine
- require a small amount of training for air traffic controller regarding update to enhanced ATC functionality (REQ 04.08.01-OSED-0010.0030)
- not require changes in team structure
- change the nature of human system interaction. Confidence in alert system directly affects human-system interaction and has to be ensured. ATC's decision making is strongly dependent on reliability of alerts. For example, there is high probability to ignore or even switch-off the system if number of undesirable or void alerts is too high.

2.2.6 Choice of methods and techniques

Because of the relatively low rate of safety net alerts in real-time (~1 Necessary or desirable alert / 3 hours in Lyon TMA) it is good practice to use off-line analysis of alerts to evaluate safety nets. Lyon TMA was simulated with the prototype STCA. The emulated alerts were then compared to the baseline STCA alerts from Lyon recordings. Both baseline and prototype alerts were classified by an air traffic controller using a tool to replay and analyse encounters.

Supported Metric / Indicator	Platform / Tool	Method or Technique
Number of alerts (compared to baseline STCA system)	10.4.3 prototype and analysis tool	Fast-time simulation of Safety-Net Server (using radar data recordings)
Operational classification of STCA alerts (by controller)	ELVIRA	Controller judgement (assisted by air situation replay and analysis tool)

Table 6 Methods and Techniques

See 6.1.2.2 for further details on the platform and tools used during the exercise execution.

2.2.7 Validation Exercises List and dependencies

There was only one standalone validation exercise planned and executed. The exercise consisted of running 11 days of recorded traffic on the prototype STCA so that alerts could be compared with the recorded alerts. Each day is run independently but as a set they are complementary in representing diverse conditions possible throughout a typical year.

3 Conduct of Validation Exercises

3.1 Exercises Preparation

Recordings of real radar tracks and corresponding alerts from the STCA operational in Lyon TMA in France are used as a baseline for comparison. Alerts are classified by an air traffic controller into categories (Table 4). The industrial STCA prototype is configured for Lyon TMA using parameters from the operational Lyon system (Table 15).

For details see section 6.1.2.1 Exercise preparation

3.2 Exercises Execution

Table 4 summarises the exercise

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end analysis date
EXE-04.08.01-VP-140	Operational validation of TMA with prototype STCA	15/10/2011	5/12/2011	8/11/2011	17/2/2012

Table 7 Exercises execution/analysis dates

The industrial STCA prototype is run in fast-time with the baseline radar tracks. Alerts from the industrial STCA prototype are classified by an air traffic controller into categories (Table 4), Alert types and start times of STCA prototype and baseline are compared encounter by encounter.
For details see section 6.1.2.2 Exercise execution

3.3 Deviations from the planned activities

3.3.1 Deviations with respect to the Validation Strategy

There were no significant deviations except perhaps for lack of real-time simulation. However, given the exceptional nature of safety nets, it is worth noting that the validation activity conducted during the exercise is the one typically conducted (at V4 level) prior to any STCA implementation by many ANSPs (including DSNA).

3.3.2 Deviations with respect to the Validation Plan

The deviations from the validation plan are:

- See 2.1.2.3
- Requirements involving generic performance parameters (REQ-04.08.01-SPR-0010.0050 to REQ-04.08.01-SPR-0010.0090) that were included in the validation plan were subsequently found to be out of scope and hence omitted from this validation report.
- There was a problem collecting end time of alerts therefore alert duration was not analysed as planned.
- Time originally allocated for surveillance input data preparation and platform configuration turned out not to be enough to achieve acceptable minimum level of performance. Therefore the schedule was adjusted to cope with the planned results being three weeks earlier than they were actually obtained.

4 Exercises Results

4.1 Summary of Exercises Results

Table 8 summarises the results of the validation exercises. Results are compared to the success criteria identified within the Validation Plan per validation objectives. All validation objectives embedded in the validation exercises are covered as per the corresponding validation plan.

Exercise ID	Exercise Title	Validation Objective ID	Validation Objective Title	Refined success criterion	Exercise Results
EXE-04.08.01-VP-140	Operational validation of TMA with prototype STCA	OBJ-04.08.01-VP-0010.0010		Percentage of all alerts that are necessary or desirable > 25%	Percentage of all alerts that are necessary or desirable decreased by 3% from 48% with the baseline to 45% with the prototype. Judged to be maintained well above EUROCONTROL guidance material minimum of 25%.
				Percentage of all alerts that are undesirable or void, should be within 10% of that of baseline	Percentage of all alerts that were undesirable or void increased slightly by 1% from 47% to48%. Judged to be acceptable compared to baseline.
		OBJ-04.08.01-VP-0010.0020		1/ Adaptable to the procedures in use in distinct volumes of airspace inside the TMA	STCA parameter set is a function of airspace volumes defined by 5 different polygons. Multi-hypothesis algorithm adapted to procedures in use for IFR flights in various volumes of airspace (like 1,000 feet level-off for separation during arrival and departure flights, radar vectoring of IFR flights on approach at local airport, No airspace class distinction implemented in prototype therefore no IFR/VFR separation procedures distinction depending on the class of airspace (Note: no specific operational requirement)
				2/ Different parameters or trajectory predictions depending on specific volume of airspace.	Use of multi-hypothesis algorithm for IFR flights (with targeted altitude / FL for vertical transitioning aircraft or curve trajectory prediction in turning areas associated with radar vectoring on approach) No airspace class distinction implemented in prototype therefore no IFR/VFR separation procedures distinction depending on the class of airspace (Note: no specific operational requirement)
		OBJ-04.08.01-VP-0010.0030		1/ Percentage of all alerts, except void, that are undesirable should be within 10 points of baseline	Percentage of all alerts, except void, that are undesirable, increased from 21% to 29% mainly due to VFR/VFR flights during track initialization.
				2/ Average start time of necessary alerts should be same or earlier	No significant difference with 95% confidence level.

Exercise ID	Exercise Title	Validation Objective ID	Validation Objective Title	Refined success criterion	Exercise Results
				3/ Early-terminated alert rate (i.e. is same or reduced.	Not assessed explicitly
		OBJ-04.08.01-VP-0010.0040		1/ Acceptable number of alerts for airspace not relevant to the local TMA controllers	27 VFR/VFR alerts and 1 VFR/Military in class G airspace compared with 10 and 1 respectfully for baseline (Acceptable)
				2/ Acceptable number of alerts involving flights which are not relevant to the local TMA controllers	Increase of undesirable alerts between VFR/VFR flights during track initialization (from 10 to 29 – acceptable) Slight decrease of void alerts (notably in case of false track) from 92 to 78.
		OBJ-04.08.01-VP-0010.0050		All data pertinent to this validation available for off-line analysis	Alert end time is not computed due to inconsistencies between baseline and prototype way of handling surveillance tracks and synchonisation messages

Table 8 Summary of Validation Exercises Results

4.1.1 Results on concept clarification

Not applicable

4.1.2 Results per KPA

Table 9 summarises main results for safety KPA by comparing alerting performance with EUROCONTROL guidance material for STCA. Both baseline and prototype are within the suggested acceptable operating limits.

Performance Indicator	Maximise / Minimise	Required Performance	Preferred Performance	Baseline	Prototype
% of necessary category encounters alerted	Maximise	≥95%	100%	93.8	95.3
% of desirable category encounters alerted	Maximise	≥80%	≥90%	87.5	81.8
% of alerted encounters which are in categories: unnecessary, undesirable and void	Minimise	≤75%	≤50%	51.6	54.6
% of unnecessary category encounters alerted	Minimise	-	≤30%	4.6	6.8

Table 9 Baseline and prototype alerting performance compared with EUROCONTROL guidance material for STCA

See section 6.1.3.1 for details

4.1.3 Results impacting regulation and standardisation initiatives

Prototype would benefit from improvements before transition to V4.

4.2 Analysis of Exercises Results

Table 10 summarises exercises results showing traceability with validation objectives, the exercise, and success criteria. Results have been assessed against the success criteria and the validation objective analysis status is set to OK or NOK:

- OK: Validation objective achieves the expectations (exercise results achieve success criteria).
- NOK: Validation objective does not achieve the expectations (exercise results do not achieve success criteria).

Exercise ID	Exercise Title	Validation Objective ID	Validation Objective Title	Refined success criterion	Exercise Results	Validation Objective Analysis Status
EXE-04.08.01-VP-140	Operational validation of TMA with prototype STCA	OBJ-04.08.01-VP-0010.0010		Percentage of all alerts that are necessary or desirable > 25%	Percentage of all alerts that are necessary or desirable decreased by 3 points from 48% with the baseline to 45% with the prototype. Judged to be maintained well above EUROCONTROL guidance material minimum of 25%.	OK
				Percentage of all alerts that are undesirable or void, should be within 10 points of that of baseline	Percentage of all alerts that were undesirable or void increased slightly by 1 point from 47% to 48%. Judged to be acceptable compared to baseline.	OK
		OBJ-04.08.01-VP-0010.0020		1/ Adaptable to the procedures in use in distinct volumes of airspace inside the TMA	STCA parameter set is a function of airspace volumes defined by 5 different polygons. Multi-hypothesis algorithm adapted to procedures in use for IFR flights in various volumes of airspace (like 1,000 feet level-off for separation during arrival and departure flights, radar vectoring of IFR flights on approach at local airport, No airspace class distinction implemented in prototype therefore no IFR/VFR separation procedures distinction depending on the class of airspace (Note: no specific operational requirement)	OK for procedures in use for IFR flights OK for procedures in use for VFR flights
				2/ Different parameters or trajectory predictions depending on	Use of multi-hypothesis algorithm for IFR flights (with targeted altitude / FL for vertical transitioning aircraft or	OK for IFR flights / OK for VFR flights

Exercise ID	Exercise Title	Validation Objective ID	Validation Objective Title	Refined success criterion	Exercise Results	Validation Objective Analysis Status
				specific volume of airspace.	curve trajectory prediction in turning areas associated with radar vectoring on approach) No airspace class distinction implemented in prototype therefore no IFR/VFR separation procedures distinction depending on the class of airspace (Note: no specific operational requirement)	
		OBJ-04.08.01-VP-0010.0030		1/ Percentage of all alerts, except void, that are undesirable should be within 10 points of baseline	Percentage of all alerts, except void, that are undesirable, increased from 21% to 29% mainly due to VFR/VFR flights during track initialization.	OK (yet possible area of improvement)
				2/ Average start time of necessary alerts should be same or earlier	No significant difference with 95% confidence level.	OK
				3/ Early-terminated alert rate (i.e. is same or reduced.	Not assessed explicitly	NA
		OBJ-04.08.01-VP-0010.0040		1/ Acceptable number of alerts for airspace not relevant to the local TMA controllers	27 VFR/VFR alerts and 1 VFR/Military in class G airspace compared with 10 and 1 respectfully for baseline (Acceptable)	OK
				2/ Acceptable number of alerts involving flights which are not relevant to the local TMA controllers	Increase of undesirable alerts between VFR/VFR flights during track initialization (from 10 to 29 – acceptable) Slight decrease of void alerts (notably in case of false track) from 92 to 78.	OK (yet possible area of improvement
		OBJ-04.08.01-VP-0010.0050		All data pertinent to this validation available for off-line analysis	Alert end time is not computed due to inconsistencies between baseline and prototype way of handling surveillance tracks and synchonisation messages	OK (yet possible area of improvement)

Table 10 Overview: Validation Objectives, Exercises Results and Analysis Status

Table 11 shows for each operational requirement relevant to the validation, whether it is covered or not by the validation objectives and results. A final V&V status is given to each requirement OK or NOK:

- NOT COVERED: operational requirements are not covered by a validation objective.

- OK: operational requirement is covered by a validation objective (as per validation plan) and achieves the expectations (validation objectives analysis status is OK).
- NOK: Operational requirement is covered by a validation objective (as per validation plan) but does not achieve the expectations (validation objectives analysis status is NOK).

Ops. Req ID	Ops. Req Title	OI	Exercise ID	Exercise Title	Validation Objective ID	Validation Objective Title	Validation Objective Analysis Status per exercise	Validation Objective Analysis Status	Req. V&V Status
Req-04.08.01-OSED-0010.0070	Detection capability of STCA		1	- Fast-time simulation of Lyon TMA with prototype STCA	OBJ-04.08.01-VP-0010.0010	Detecting and alerting conflicts in TMA	OK	OK	OK
Req-04.08.01-OSED-0010.0080	Alerting capability of STCA		1	‘’	OBJ-04.08.01-VP-0010.0010	Detecting and alerting conflicts in TMA	OK	OK	OK
Req-04.08.01-OSED-0010.0100	Effective minimum of undesirable STCA alerts		1	‘’	OBJ-04.08.01-VP-0010.0030	Alerting performance in TMA	OK	OK	OK
Req-04.08.01-OSED-0010.0120	Warning time of STCA alerts		1	‘’	OBJ-04.08.01-VP-0010.0030	Alerting performance in TMA	OK	OK	OK
Req-04.08.01-OSED-0010.0130	Continuity of STCA alerts		**1**	”	OBJ-04.08.01-VP-0010.0030	Alerting performance in TMA	NA (due to inconsistent alert end time)	NA	NA
Req-04.08.01-OSED-0010.0141	STCA alert inhibition capability (volumes)		**1**	‘’	OBJ-04.08.01-VP-0010.0040	Alert inhibition in TMA	OK	OK	OK
Req-04.08.01-OSED-0010.0142	STCA alert inhibition capability (flights)		**1**	‘’	OBJ-04.08.01-VP-0010.0040	Alert inhibition in TMA	OK	OK	OK
Req-04.08.01-OSED-0010.0170	STCA data recording for off-line analysis		**1**	‘’	OBJ-04.08.01-VP-0010.0050		NA (due to inconsistent alert end time)	NA	NA
Req-04.08.01-OSED-0010.0181	STCA adaptability to procedures in airspace		**1**	‘’	OBJ-04.08.01-VP-0010.0020	Adaptability to TMA	OK	OK	OK
Req-04.08.01-OSED-0010.0182	STCA adaptability to airspace volumes		**1**	‘’	OBJ-04.08.01-VP-0010.0020	Adaptability to TMA	OK	OK	OK
Req-04.08.01-OSED-0010.0194	Reduction of undesirable alerts through use		**1**	‘’	OBJ-04.08.01-VP-0010.0030	Alerting performance in TMA	OK	OK	OK

	of known/possible intents								
Req-04.08.01-OSED-0010.0195	Alerting performance of STCA in terms of alert duration		1	‘’	OBJ-04.08.01-VP-0010.0030	Alerting performance in TMA	NA	NA	NA
REQ-04.08.01-SPR-0010.0040	Validation of data sets		1	‘’	OBJ-04.08.01-VP-0010.0030	Alerting performance in TMA	OK	OK	OK

Table 11 Requirements Coverage

4.2.1 Unexpected Behaviours/Results

Regarding the STCAs, there was a significant number (15) of necessary and desirable alerts raised by the industrial STCA prototype that were not raised by the baseline Figure 12.

Regarding the platform, reliable alert end times were not available for analysis of alert duration due to discrepancies in way baseline and prototype handled surveillance track and synchronisation messages. Fortunately this was not critical for the evaluation.

4.3 Confidence in Results of Validation Exercises

4.3.1 Quality of Validation Exercises Results

Despite the lack of alert end times, the exercise results are judged to be of good quality because alert start times were sufficient for comparing warning times. Real data is used to configure and run the exercise. The actual industrial algorithm is used as the system under test and a real operational algorithm is used as the baseline. An air traffic controller is used for the critical classification of alerts into discrete categories.

4.3.2 Significance of Validation Exercises Results

The exercise results are judged to be operationally and statistically significant. There was only one independent variable, STCA type which took two values either baseline or prototype. All other conditions were kept the same: airspace configuration, STCA parameterisation, traffic radar tracks and therefore same encounters were used for both, and the same DSNA air traffic controller was used to classify both sets of alerts.

Care was taken to ensure the 11 days of traffic exhibited the variety in types of encounter typical in a year. The number of alerts obtained is physically equivalent to 11 full days of real-time Lyon TMA operations. The added advantage of fast-time simulation over real-time human-in-the loop simulation is that the effects of air traffic control are the same as the baseline.

Lyon TMA was chosen for its high traffic and complex airspace both spatially and in terms of wide variety of airspace users, and therefore representative of other TMAs in Europe up to a similar medium size and capacity. TMA features not addressed by this validation include traffic in stacks and parallel runways.

Results indicate that the prototype, parameterised and tuned over a period of weeks, operates within acceptable limits of performance. It is expected to be operationally acceptable for relatively complex medium sized TMAs, comparable with Lyon TMA, with the order of 100,000 movements per year. However, compared to the state-of-the-art STCA in operation for years at Lyon TMA, the prototype increased the proportion of undesirable alerts from 21% to 29% i.e. similar safety levels are maintained with a potentially negative impact on human performance.

5 Conclusions and recommendations

5.1 Conclusions

An operational evaluation is conducted on enhanced STCA for TMA specific operations based on an industrial prototype developed by 10.4.3 project in accordance with 4.8.1 operational requirements. Within the scope of this validation, results indicate that the prototype, parameterised and tuned over a period of weeks, operates within acceptable limits of performance in Lyon TMA. It is expected to be operationally acceptable for relatively complex medium sized TMAs, comparable with Lyon TMA, with the order of 100,000 movements per year. However, compared to the state-of-the-art STCA in operation for years at Lyon TMA, the prototype increased the proportion of undesirable alerts from 21% to 29% i.e. similar safety levels are maintained with a potentially negative impact on human performance.

5.2 Recommendations

Compared to the baseline, the following differences were noted for possible further investigation and improvement:

- (1) Over 10% of necessary alerts and over 30% of desirable alerts are not common to both systems, and each of those alerts involved at least one IFR aircraft.[5]
- (2) Significantly more undesirable alerts are raised by the prototype between VFR aircraft in class G airspace.
- (3) Duration of alert is not computed due to inconsistencies between baseline and prototype way of handling surveillance tracks and synchronisation messages

Specific areas identified for potentially improving prototype functionality include: inhibiting alerts based on airspace classes, processing invalid mode A codes, and correction of area levels using QNH[6].[7]

Undesirable and void alerts exclusively raised by the prototype as well as undesirable and void alerts exclusively raised by the baseline should be further investigated.

New functionality developed in the scope of SESAR was not simulated e.g. traffic in stacks, parallel runways and cleared flight level input. Future validation might address this functionality. Analysing multiple alert occurrences for the same encounter may give more insight into STCA enhancements due to multi-hypothesis algorithms.

[5] This may result in improvements to the baseline as well, although it should be remembered that classification of alerts may differ between air traffic controllers. Human factors and local circumstances determine what constitutes an operationally relevant conflict and an effective minimum of undesirable/void alerts.)

[6] Outside of scope of this validation THALES claims slight adaptations were made shortly after the end of the validation exercise to adopt similar alerting criteria as the baseline; a further run conducted with the adapted prototype showed a level of unnecessary and nuisance alerts that dropped to levels similar to or better than the baseline. These results are documented in 10.04.03-D36-Validation support Report*

[7] DSNA provided radar tracks based on a clockwise distribution, whereas the prototype processes surveillance tracks in a strip mode. This creates latencies in the prototype on alert detection, up to approximately 4s. THALES suggests investigating the same radar tracks with a strip mode distribution (ARTAS output) in step 2.

6 Validation Exercises reports

6.1 Validation Exercise #1 Report

6.1.1 Exercise Scope

6.1.1.1 Introduction

Sections 2 to 5 describe the exercise at a high-level. The following sections describe the exercise in more detail beginning with details of the Lyon TMA.

6.1.1.2 Airport information

Lyon-Saint Exupéry Airport (IATA: LYS, ICAO: LFLL) is one of the two airports located in the agglomeration of Lyon, France (see Table 12). Lyon-Bron Airport (IATA: LYN, ICAO: LFLY), the former international airport of Lyon, is now essentially used for general aviation and IFR training.

The other main airports in the vicinity include: Chambéry Aix-les-Bains Airport (IATA: CMF, ICAO: LFLB), which is a small international airport near Chambéry; and Grenoble-Isère Airport (IATA: GNB, ICAO: LFLS), which is a low cost airport of the Rhone-Alpes region. Both airports are also regularly used for IFR training.

2010 (variation 2010/2009)	Lyon-Saint Exupéry	Lyon-Bron	Chambery	Grenoble	Saint-Yan	Valence-Chabeuil	Saint-Etienne-Bouthéon
Commercial movements	116 121 (-3.3 %)	6 750 (1.2 %)	3 579 (-4 %)	3 266 (-21.6 %)	44 (+633.3 %)	303 (-33.7 %)	9 510 (1217.2 %)
Non-commercial movements	4 090 (+21.9 %)	60 484 (-3.3 %)	31 226 (+3.3 %)	35 892 (+2.9 %)	23 451 (+13.2 %)	25 090 (-18.5 %)	102 (0%)
Local flights (from/to a single airport)	0	40 849 (-6.2 %)	19 771 (+8.7 %)	35 892 (+2.9 %)	23 451 (43.9 %)	18 337 (-9.8 %)	102 (0%)
Travel flights (from/to distinct airports)	4 090 (21.9 %)	19 635 (+3.3 %)	11 455 (-4.9 %)	0	0	6 753 (-35.5 %)	0
TOTAL	120 211 (-2.6 %)	67 234 -2.9 %)	34 805 (+2.5 %)	39 158 (+0.3 %)	23 495 (+13.4 %)	25 393 (-18.7 %)	9 612 (+1066.5 %)

Table 12 Traffic statistics for airports in vicinity of Lyon

Source: Union of French airports

Lyon-Saint Exupéry Airport has two north-south closely-spaced parallel runways equipped with ILS category III. The outer runway (36R/18L) is preferred for arrivals, whereas the inner runway (36L/18R) is preferred for departures.

6.1.1.3 Airspace information

The Lyon TMA airspace is managed by Lyon Approach (APP) and Marseille Area Control Centre (ACC).

Lyon Approach control centre provides air traffic services within the Lyon TMA up to FL145 (or FL115 in some parts of the TMA) except for airspaces assigned to Grenoble Approach (up to 3000 feet AMSL) and Geneva Approach (in the eastern part of the TMA from FL75 to FL145). It also provides air traffic services outside the Lyon TMA from FL85 or FL115 up to FL145 within the boundaries of the Lyon Flight Information Sector.

Marseille ACC provides air traffic services within the remaining airspaces inside the Lyon TMA from FL85/FL115 to FL145/FL195 including the TMA parts around the Saint-Yan (LFLN) and Valence (LFLU) airports.

The core Lyon TMA is of Class C airspace. Some external parts of the TMA are of Class D (or in odd occasions Class E) airspace. The Control Regions (CTR) around Lyon-Saint-Exupéry (up to 2500 feet), Lyon-Bron (up to 2500 feet), Grenoble (up to 2800 feet), and Chambery (up to 3500 feet) are of class D airspace.

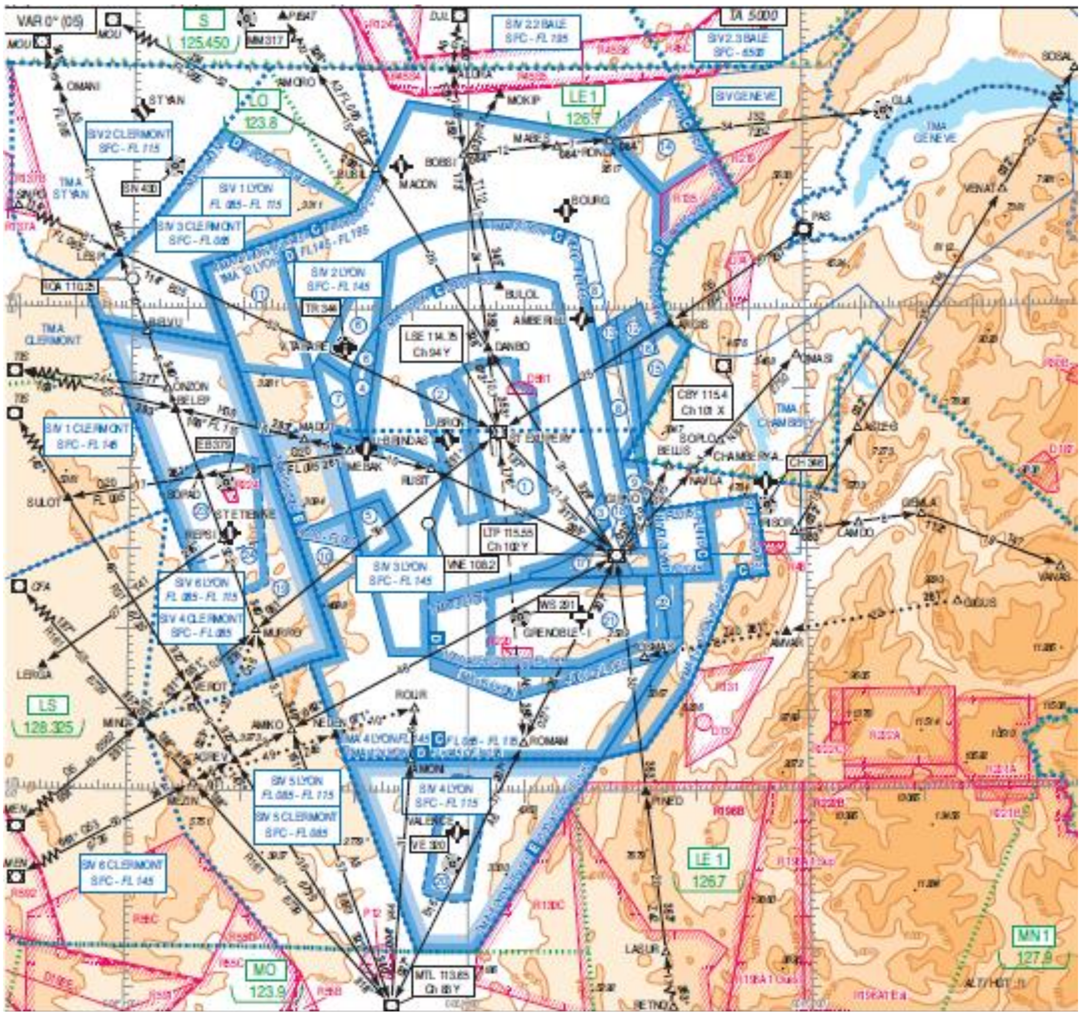

Figure 1 Map of Lyon airspace

Source: French "*Service d'Information Aéronautique*"

The Lyon TMA has four main entry points respectively for the northeast; the northwest, the southeast and the southwest traffic inbound to Lyon-Saint-Exupéry airport. The published Standard Arrival Routes (STAR) end at four main distinct Initial Approach Fixes (IAF) with associated holding procedures used when required by the traffic conditions (Figure 1).

A series of ILS, VOR/DME and LLZ/DME approach procedures are defined from these IAFs towards Lyon-Saint-Exupéry airport for use in southerly or northerly landing configuration depending on the wind direction as well as other conditions. For ILS approaches, in order to reduce noise nuisances, pilots must fly their approach so as to maintain the last altitude assigned by ATC services until intercepting the ILS glide slope. After intercepting the ILS glide slope, the final approach must be carried out so as not to fly below this glide slope.

The published Standard Instrument Departures (SID) include both conventional and RNAV departure procedures for use by aircraft depending on their equipment (i.e. P/RNAV, B/RNAV complying with the specifications about navigation in terminal area or non-RNAV). For all aircraft, SIDs have been defined in order to reduce noise nuisances, and must be observed by pilots.

In order to further reduce noise nuisances, the visual approaches are also prohibited except for safety or medical emergency reason, standard noise abatement procedures must be applied when going around, and low altitude circuit patterns are prohibited.

6.1.1.4 Traffic information

The monthly distribution of IFR controlled movements at the airport over the year 2010 is shown in Figure 2:

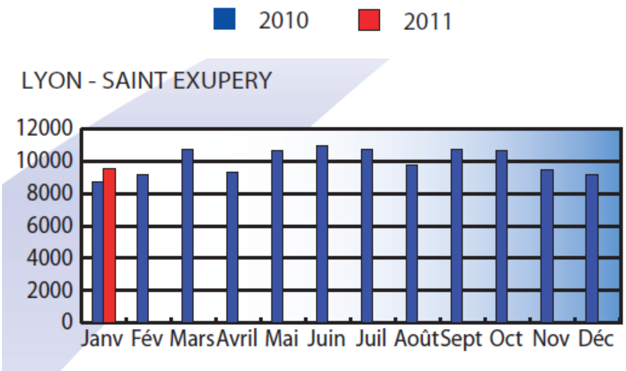

Figure 2: Monthly IFR controlled movements at Lyon Saint Exupery airport

Source "*Bilan mensuel Direction des Opérations DSNA/DO/1QP (January 2011)*"

6.1.1.5 Operational STCA system (baseline)

In France, STCA has been implemented in en-route airspace for more than 20 years. More recently, a new STCA adapted to TMA environment has been implemented in the main French Approach centres equipped with local tracker (metropolitan centres). The new STCA system has been in operational service in Lyon Approach centre since December 2008.

Since that date, a series of STCA optimisation initiatives have been performed to adapt the STCA parameters to airspace changes and to improve the alerting performances taking into account operational feedback from local controllers. Although operationally accepted, the existing STCA service could be further improved by the use of an enhanced STCA with increased warning time, reduced undesirable alerts, for operationally relevant conflicts in general and for IFR/VFR conflicts in particular (depending on the airspace classification).

The Domain Of Interest (DOI) of the baseline operational STCA used by Lyon Approach includes the Lyon TMA and the Lyon Flight Information Sector (see figure below).

To focus the generation of STCA alerts on conflicts that are operationally relevant for the local controllers, a series of STCA inhibition zones are also defined. These inhibition zones correspond to areas inside the STCA Domain of Interest in which the aircraft are not expected to be in contact with Lyon Approach.

Legend: The boundaries of the STCA DOI are indicated by the dashed blue line; the various STCA inhibition zones are outlined by the red lines; the standard arrival routes (for a southerly landing configuration) are shown by the purple lines, and the standard departure routes (for a southerly landing configuration) are shown by the dark green lines.

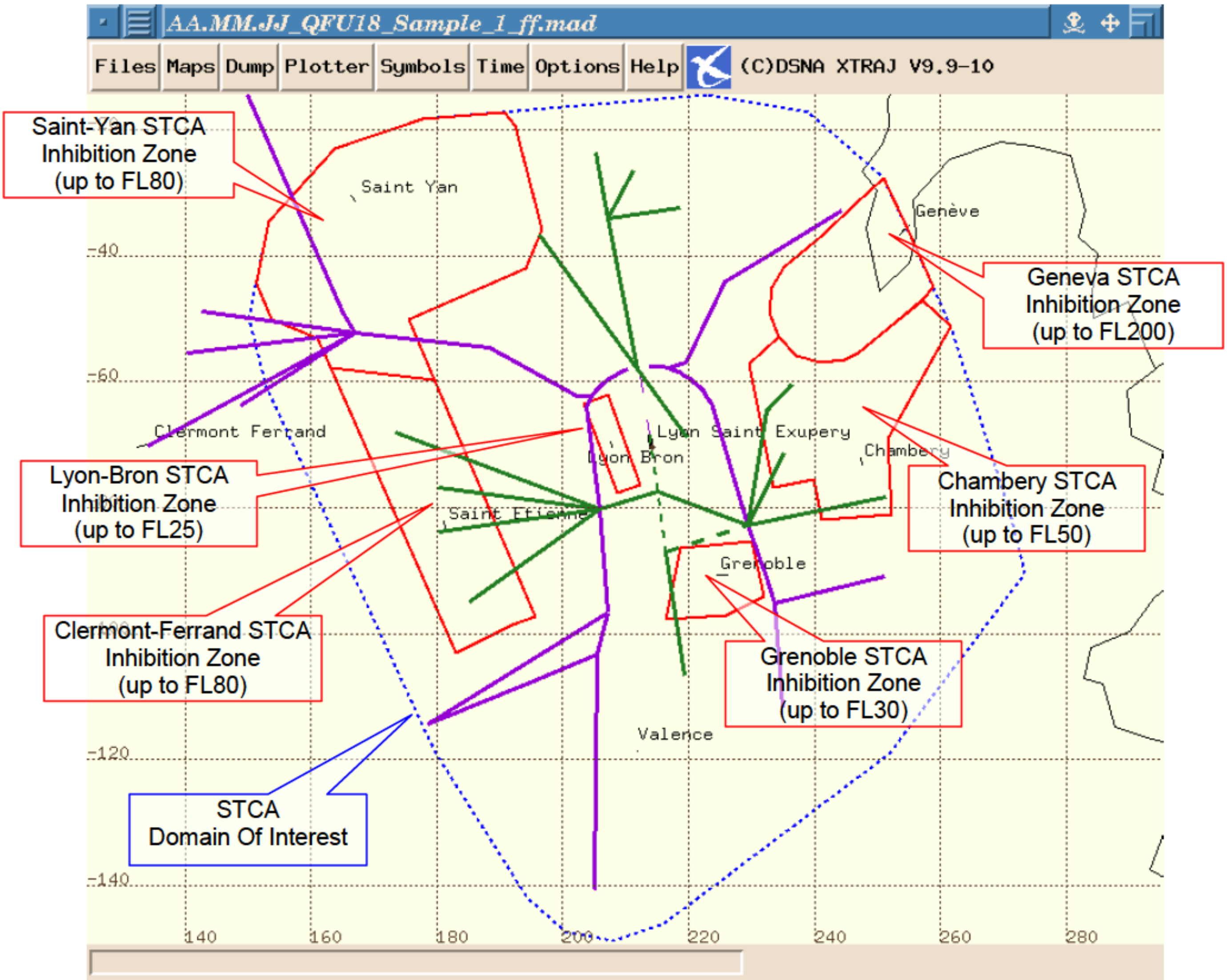

Figure 3: Context map of Lyon airspace

It is worthwhile noting that the baseline STCA system currently in operation in the Lyon Approach centre already includes some of the features of the prototype STCA system under development by Project 10.04.03 [10][11]. In particular, it includes a multi-hypothesis algorithm which uses different trajectory predictions and STCA alert parameters depending on the airspace where the aircraft are flying. The default prediction is a linear trajectory extrapolation based on the current state vector; turning trajectory predictions and level-off trajectory predictions are also used in some part of the airspace to detect relevant conflicts with sufficient warning time. To reduce the number of undesirable alerts, the alerting mechanism based on linear predictions typically uses reduced separation and warning time parameter values, whereas alerting mechanism based on trajectory predictions adapted to the airspace uses increased separation and warning time parameter values.

Hypothesis	Horizontal separation parameter	Vertical separation parameter	Warning time parameter
Curved or level-off predictions	2.9 NM	740 feet	50 seconds
Default linear predictions	2 NM	500 feet	45 seconds

Table 13 STCA parameters for predictions

6.1.2 Conduct of Validation Exercise

6.1.2.1 Exercise Preparation

Radar tracks and corresponding STCA alerts were recorded over eleven days in 2010. The eleven days were specially selected from different times of the year to reflect variation in traffic (Table 14).

Day	Month	Day of week	Scenario	Runway	Pressure setting (hPa)
1	January	Friday	Typical traffic density with close encounter on short final at Lyon.	QFU36	1012 to 1024
2	January	Tuesday	Typical traffic density with close encounter on short final at Lyon	QFU36	1024 to 1029
3	January	Saturday	Typical traffic density with IFR/VFR at Grenoble	QFU36	993 to 1003
4	February	Wednesday	Typical traffic density with close encounter on short final at Lyon	QFU18	1016 to 1019
5	February	Thursday	Typical traffic density on short final (and departure) at Lyon	QFU18	1010 to 1016
6	February	Friday	Typical traffic density with IFR/VFR at Bron	QFU36	1006 to 1013
7	February	Tuesday	Typical traffic density with IFR/VFR at Grenoble	QFU18 (except before 05h QFU36 (after 14h)	995to 1005
8	May	Friday	High density traffic (IFR/VFR)	QFU36 (except before 04h)	1022 to 1026
9	May	Saturday	High density traffic (IFR/VFR) and two abnormal close encounters IFR/VFR (Class C and D airspace)	QFU36	1022 to 1019
10	May	Sunday	High density traffic (IFR/VFR)	QFU36	1017 to 1019
11	May	Monday	High density traffic (IFR/VFR)	QFU18 (except some flights before 04h)	1013 to 1017

Table 14 Baseline recorded traffic data characteristics

The baseline STCA in operation in Lyon corresponds to version V4R1. Days 1 to 7 were selected in coordination with operational staff from Lyon to support the development of an enhanced version V5R1 (eventually, not deployed). These days are representative of typical traffic in the Lyon TMA (for the two QFU in use, different days of the week and different weather conditions). They also include specific scenarios of interest for which STCA behaviour could be improved.

Days 8 to 11 complement the above data set with days of high traffic density during spring (with increased volumes of VFR flights and high QNH values).

These eleven days hence included a sufficient number of conflict situations to allow for a meaningful comparative assessment between the baseline STCA system and the Enhanced STCA system developed by 10.4.3. The specific scenarios covered by the traffic samples (and with the potential to raise necessary, desirable, unnecessary or undesirable STCA alerts) include the following:

- A variety of aircraft convergence or proximity situations (i.e. encounter situations) involving two IFR flights:
  - IFR catching up IFR during departure (from same or close airports);
  - IFR catching up IFR during final approach (at same airport);
  - IFR/IFR convergence on approach towards same (or distinct) airport;(s);
  - IFR/IFR level-off at 1000' separated Flight Levels;
  - IFR/IFR crossing between arrival and/or departure flights;
  - Abnormal IFR/IFR proximity in controlled airspace (Class C);
- A variety of encounter situations involving IFR and VFR flights in various classes of airspace (which are not all operationally relevant conflicts to be alerted by STCA):
  - IFR/VFR encounters in airspace volumes where separation is provided by ATC (Class C);
  - IFR/VFR encounters in airspace volumes where separation is ensured by the application of 'see and avoid' (Class G) possibly assisted by traffic information from ATC (Class D and E);
  - VFR/VFR encounters in various classes of airspace; and
- a few other situations (like IFR/MIL encounters or MIL/MIL encounters).

The following Figure 4 to Figure 7 show the daily (and total) proportion of the baseline STCA alerts in the analysed recordings, respectively for IFR/IFR scenarios and scenarios other than IFR/IFR.

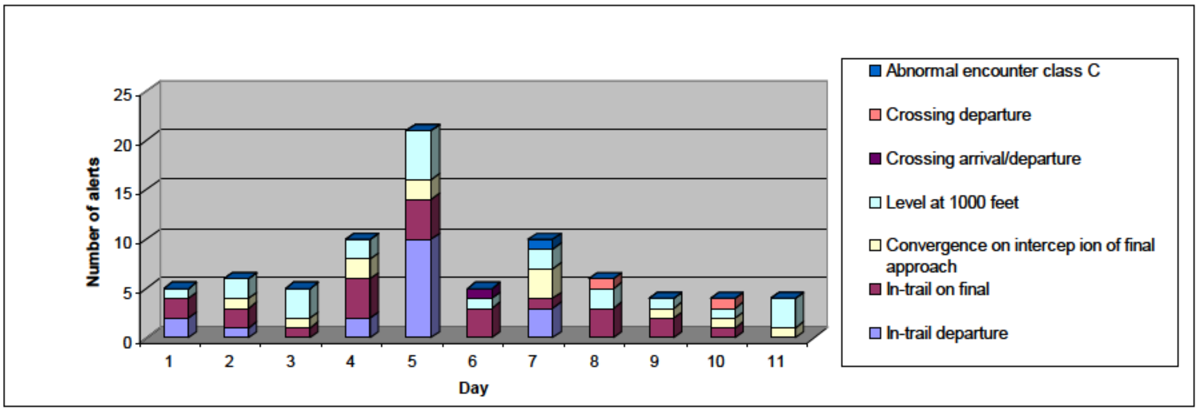

Figure 4 Baseline STCA alerts – proportion of IFR/IFR scenarios per day

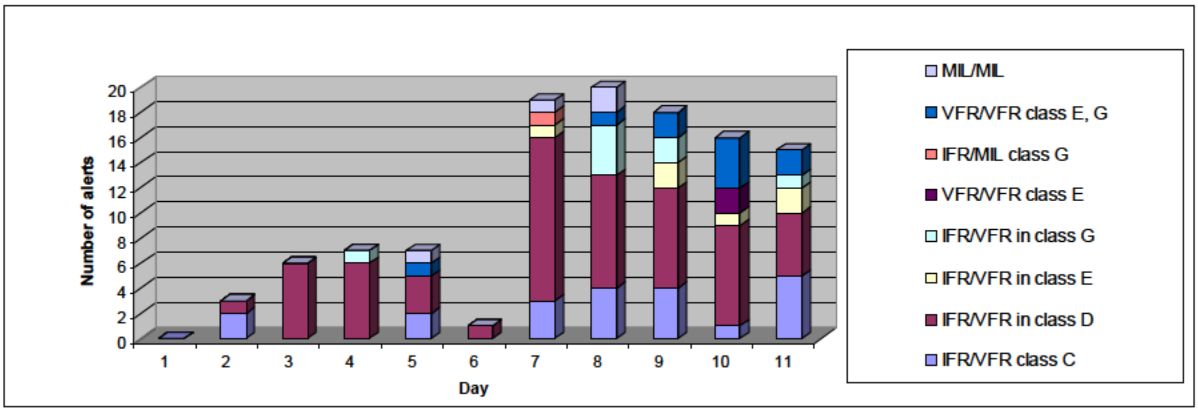

Figure 5 Baseline STCA alerts – proportion of scenarios other than IFR/IFR per day

The radar tracks and corresponding baseline STCA alerts were analysed by DSNA experts using DSNA's radar data recording-reading system (ELVIRA). The alerts were classified according to EUROCONTROL (SPIN) recommended categories. Figure 6 to Figure 7 show the distribution of alert types per day and ATC type. Note, as recommended by EUROCONTROL guidance material for STCA, void alerts are excluded from most of the following analysis because they are associated more with problems of surveillance rather than STCA.

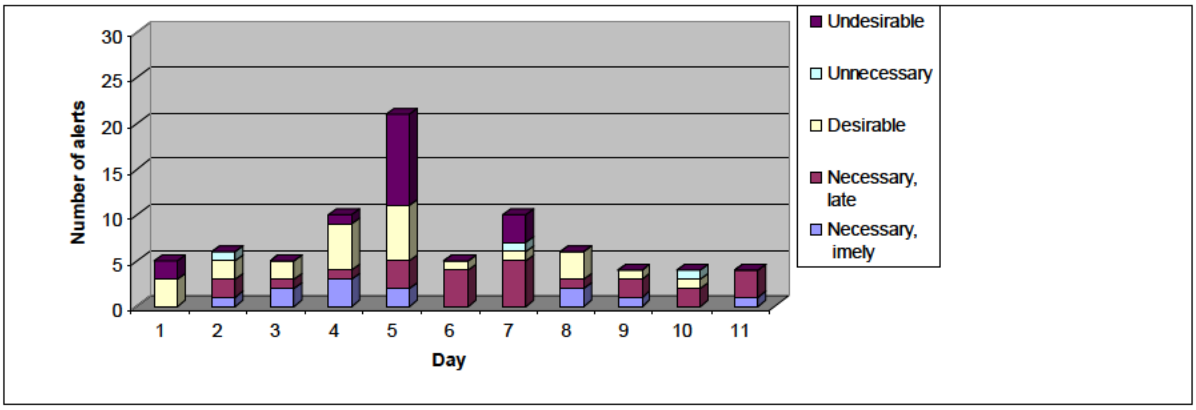

Figure 6 Baseline IFR/IFR alerts – proportion of alert types per day

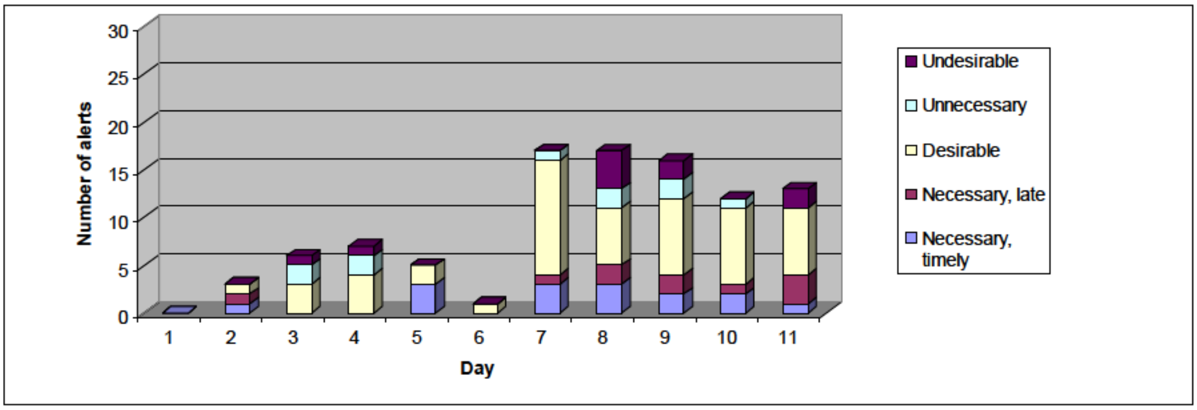

Figure 7 Baseline alerts other than IFR/IFR

6.1.2.2 Exercise execution

The exercise execution took place at the THALES premises in Rungis, France.

The verification and validation platform is based on a stand-alone PC with a suit of Unix based software developed by THALES Air Systems. The main components are:

- System under test, 10.4.3 prototype STCA and display and analysis tool
- SESAR 10.4.3 display and analysis tool developed by THALES Air Systems to assist users working with surveillance software. It displays recorded air situations statically and dynamically including: track updates and the content of safety net alert messages generated by the safety nets server (Figure 8).

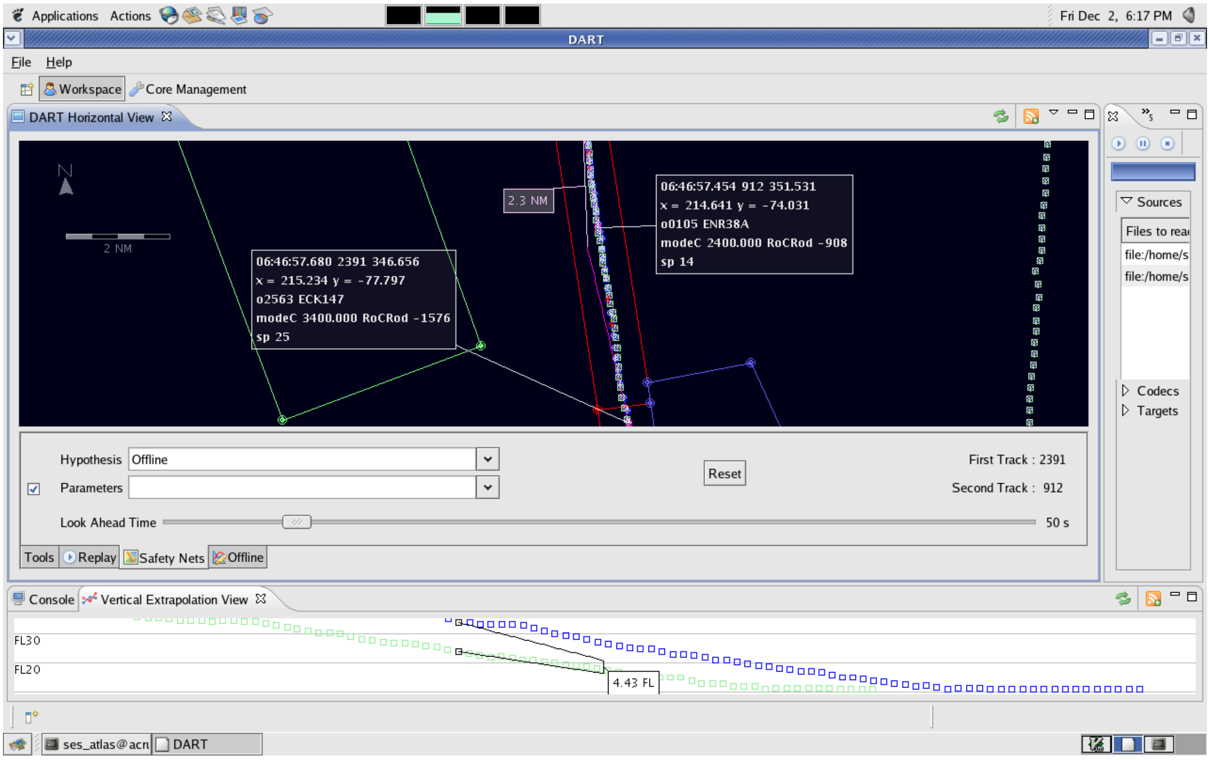

Figure 8 Horizontal and vertical view of THALES display and analysis tool

The platform was configured by THALES Air Systems. DSNA provided a parameter set used by the baseline STCA. This parameter set was a function of airspace volumes defined by 5 different polygons. These parameters were used to configure the prototype STCA. Several intermediate runs were performed to verify semantics and syntax of surveillance data recordings against prototype, and test the platform configuration. Each iteration involved running the prototype STCA with all 11 days of recorded radar track data, to finalyse parameter settings and to reduce the number of missed alerts while increasing the warning time. At least two iterations involved analysis of alerts by DSNA. Table 15 summarises some of the main parameters common to the prototype STCA and baseline.

STCA parameter	**Values**
Look ahead time main hypothesis	80s
Look ahead time backup hypothesis	70s
Warning time main hypothesis	50s
Warning time backup hypothesis	45s

Imminent time main hypothesis	20s
Imminent time backup hypothesis	20s
Horizontal separation main hypothesis	[2.2, 2.5, 2.6, 2.8, 2.9] NM
Horizontal separation backup hypothesis	2 NM
Horizontal separation diverging	1.5 NM
Horizontal separation direct conflict	[2.2, 2.5, 2.6, 2.8, 2.9] NM
Horizontal separation coarse	10 NM

Table 15 Main configuration parameters common to both systems

(Note: Call signs in recordings were scrambled by DSNA to protect sensitive data and avoid traceability issues.)

After the platform was configured and tested, the prototype STCA was run in fast-time with all 11 days of recorded radar data. Data corresponding to each metric was recorded (The duration of alert is not computed due to inconsistencies between baseline and prototype way of handling surveillance tracks and synchonisation messages). DSNA operational staff analysed the set of alerts and categorised them according to the same EUROCONTROL (SPIN) classification used in the baseline.

The validation platform used at this stage was the DSNA in-house tool ELVIRA which allows the acquisition, replay and analysis of radar tracks and safety-net alerts. The tool has a configurable HMI (similar to the radar scope on Controllers Working Position) which can either be used for dynamic replay of air situations or static trajectory display. It also include a trajectory analysis mode assisted by a specific display of the horizontal and vertical trajectories of selected tracks (Figure 9 and Figure 10).

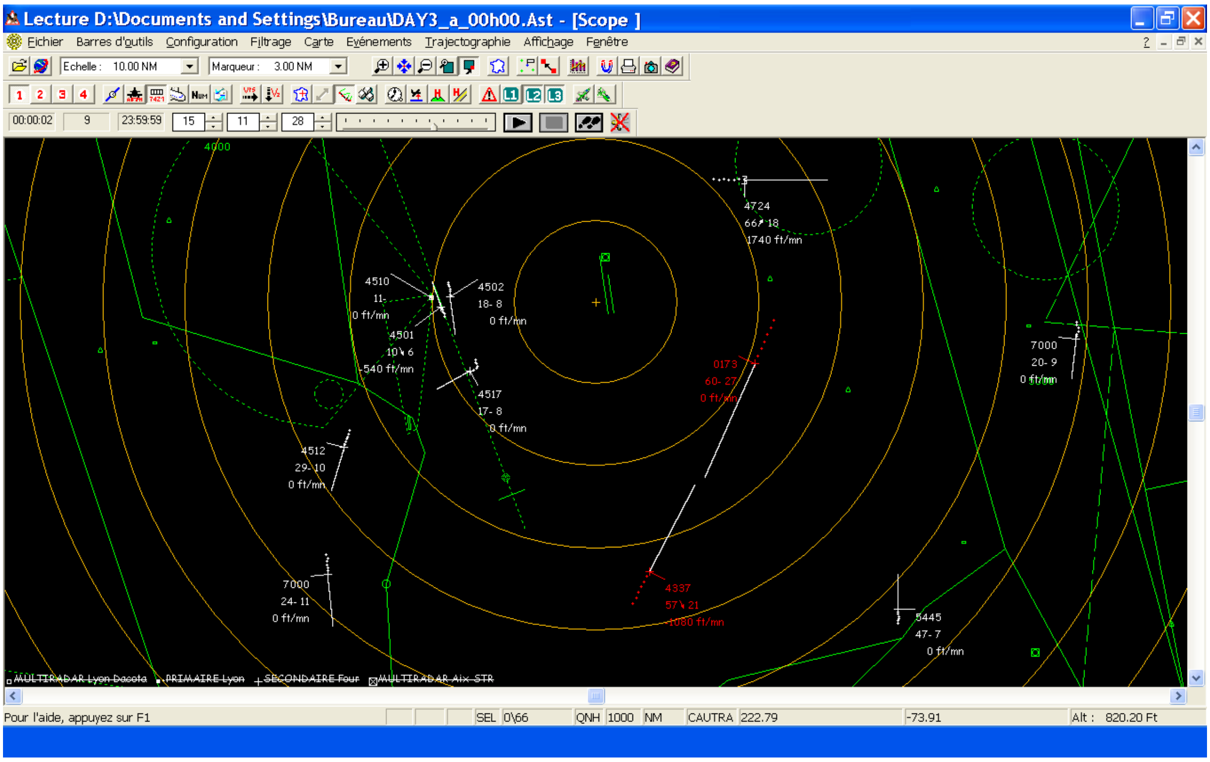

Figure 9 Scope view of ELVIRA in dynamic replay mode

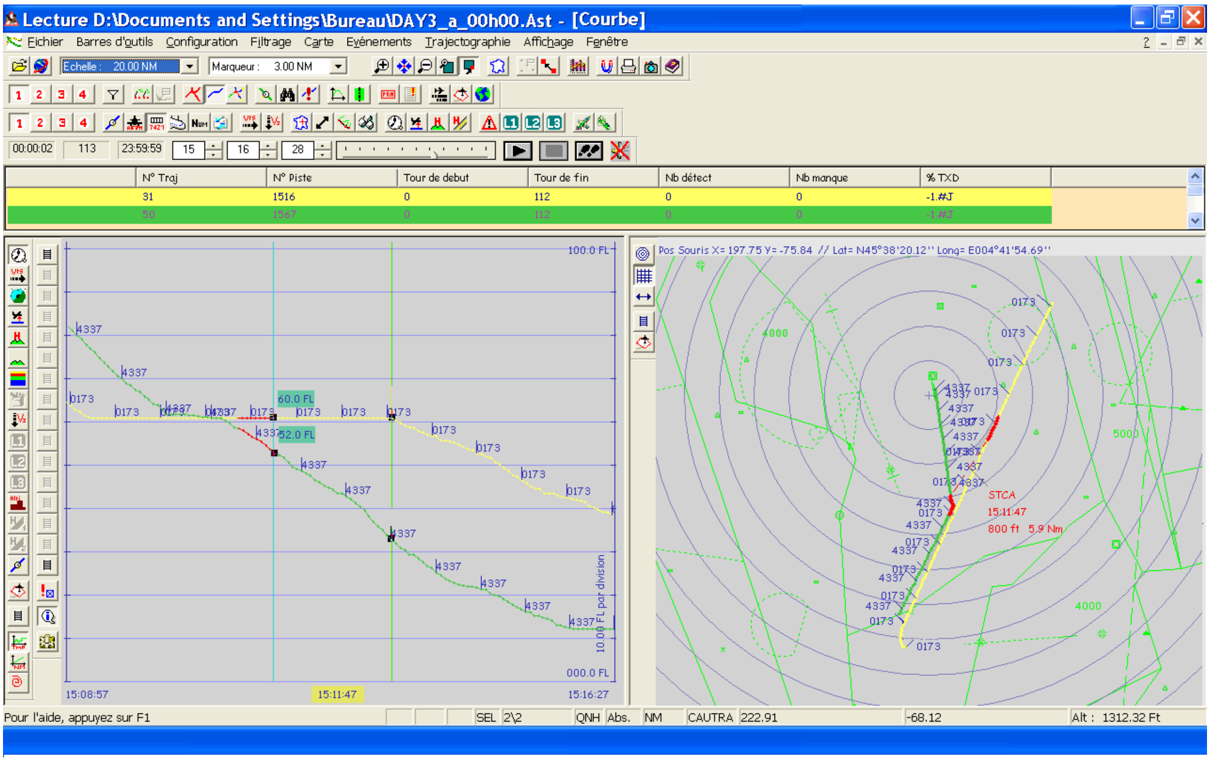

Figure 10 Trajectory analysis view of ELVIRA

6.1.2.3 Deviation from the planned activities

See section 3.3.

6.1.3 Exercise Results

6.1.3.1 Summary of exercise results

6.1.3.1.1 Results on concept clarification

See 4.1.1

6.1.3.1.2 Results per KPA

6.1.3.1.2.1 Operational performance assessment

STCA is intended to improve safety only therefore the following results are concerned with the safety key point indicator. Figure 11 indicates that alert rates are comparable overall for both systems (totals within 4% of each other). The percentages of alerted encounters which are necessary or desirable are 45% for the prototype and 48% for the baseline which are both considerably above the minimum guideline of 25% (derived from “≤75% of alerted encounters which are in categories: unnecessary, undesirable and void” in Table 5), and approaching the preferred minimum performance of 50% (Table 5). It is noted that the prototype raises significantly more undesirable alerts than the baseline. This is analysed in more detail later.

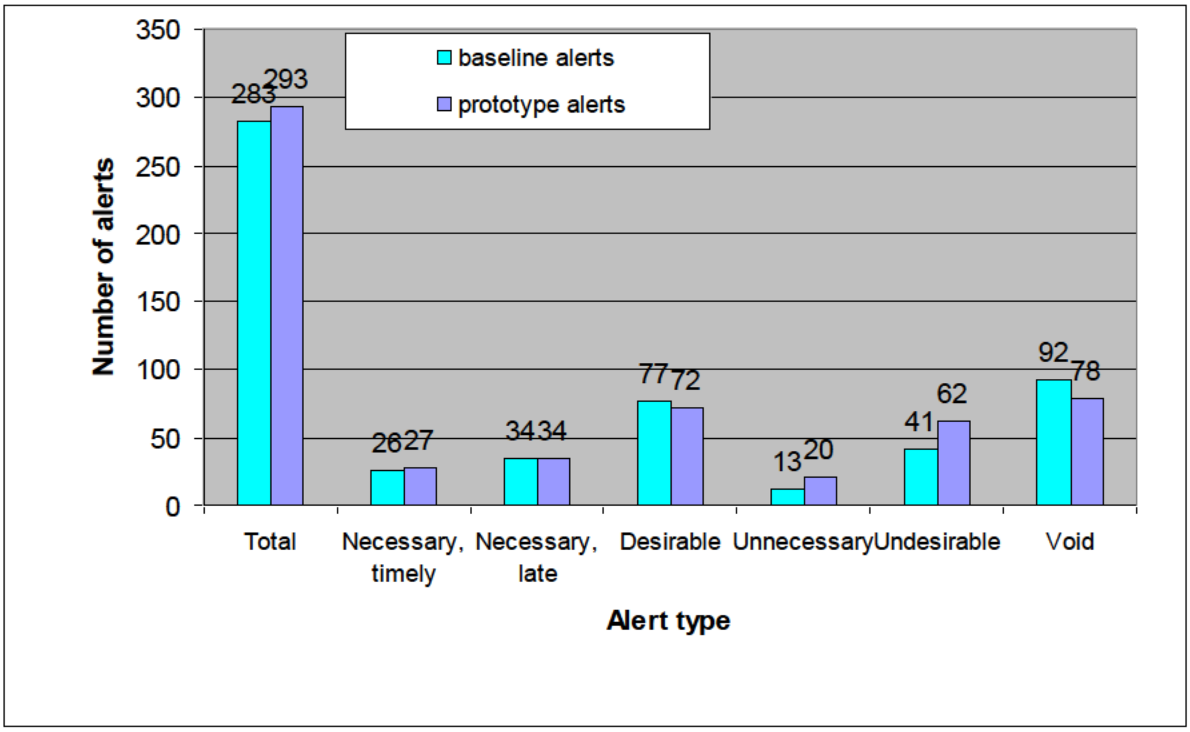

Figure 11 Number of alerts: total and per alert type

Figure 12 shows that of the 64 necessary alerts raised by the two systems combined, the prototype detected 61 (95.3%) and the baseline 60 (93.8%). From Table 5 the corresponding value for minimum percentage of necessary alerts is 95%. Similarly, of the 88 desirable alerts raised by the two systems combined, the prototype detected 72 (81.8%) and the baseline 77 (87.5%). The corresponding guideline for the minimum percentage of desirable alerts is 80%. It should be noted however that the combined number of necessary or desirable alerts raised by the two systems is just an approximation (underestimate) of the total possible.

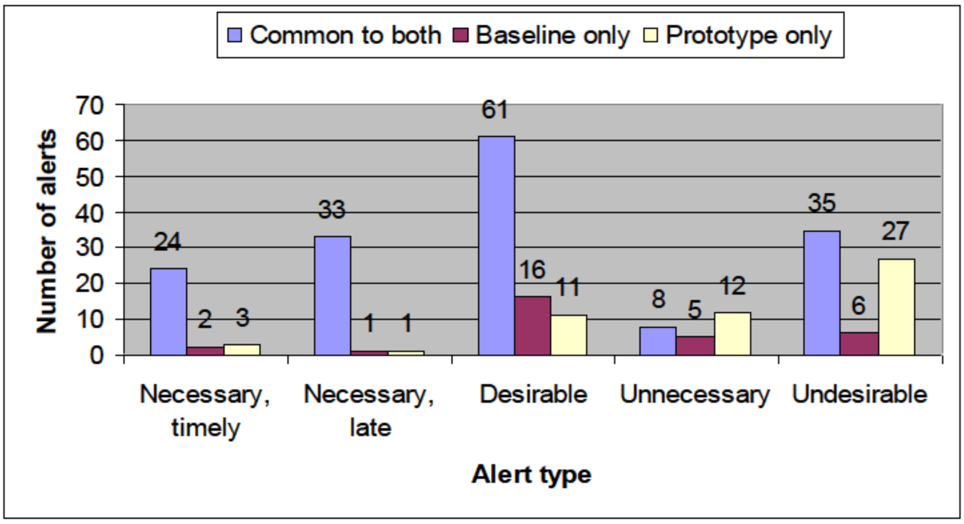

Figure 12 Number of alerts versus alert type (excluding void) and STCA type

Figure 13 shows the average difference between the start time of the prototype STCA alerts and the start time of the corresponding alerts of the baseline STCA, for each alert type. A student's t-test indicates that the differences in means are not statistically significant with a 95% confidence level (all p values less than 0.62). This implies that the alert warning times were comparable for the two systems.

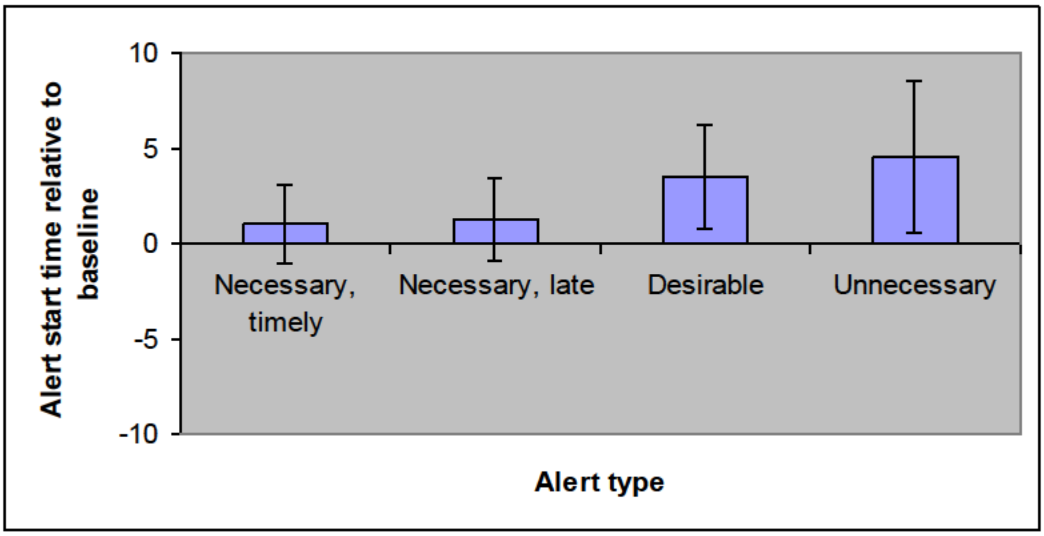

Figure 13 Alert start time relative to baseline versus alert type (excluding void)

6.1.3.1.2.2 Detailed comparison with baseline

Figure 14 shows the prototype raised significantly more alerts (135) involving VFR (Visual Flight Rule) traffic with IFR (Instrument Flight Rule) traffic or VFR with VFR traffic than the baseline (106).

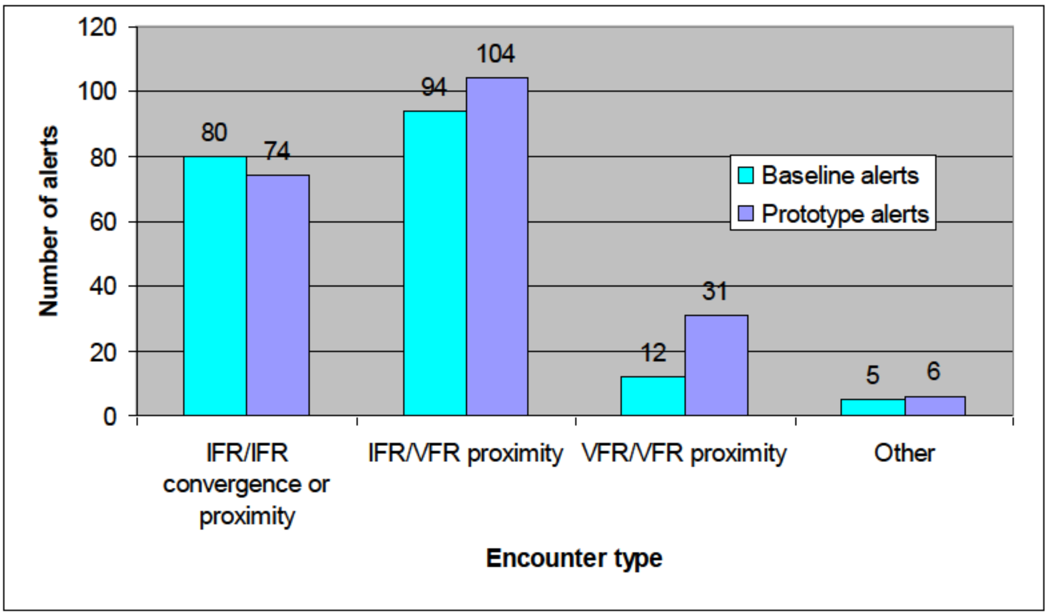

Figure 14 All alerts (excluding void): number of alerts versus encounter geometry

Figure 15 shows for different encounter types, necessary, desirable, unnecessary and undesirable alerts raised by the baseline but missed by the prototype.

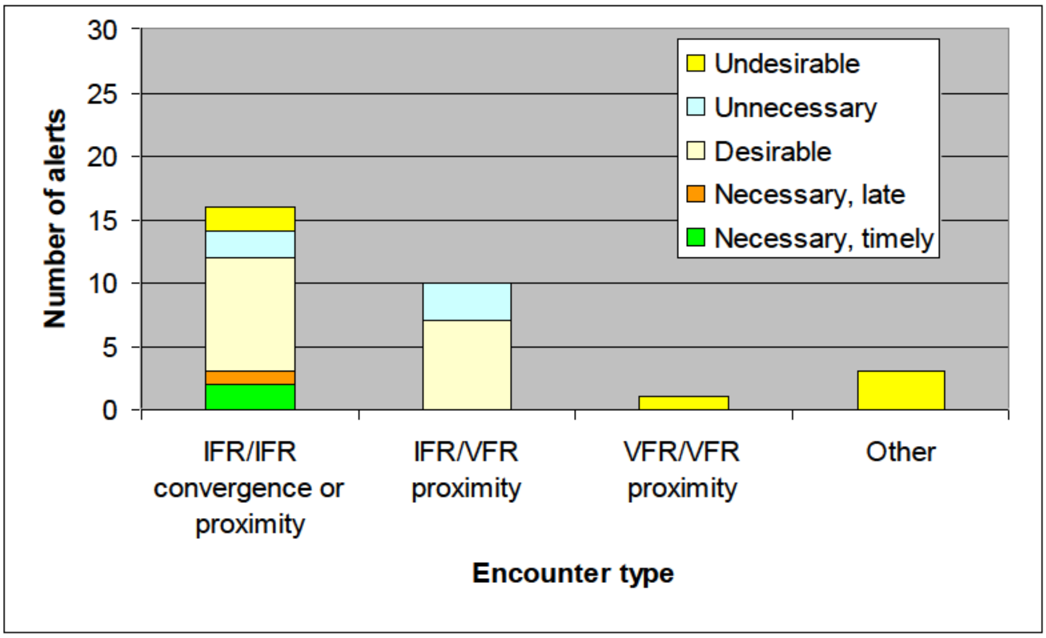

Figure 15 Baseline alerts not raised by prototype: number of alerts versus encounter type (excluding void)

Figure 16 shows for different encounter types the necessary, desirable, unnecessary and undesirable alerts raised by the prototype but missed by the baseline. Figure 16 shows that most of the undesirable alerts raised by the prototype which were not raised by the baseline, are close encounters between VFR and VFR traffic.

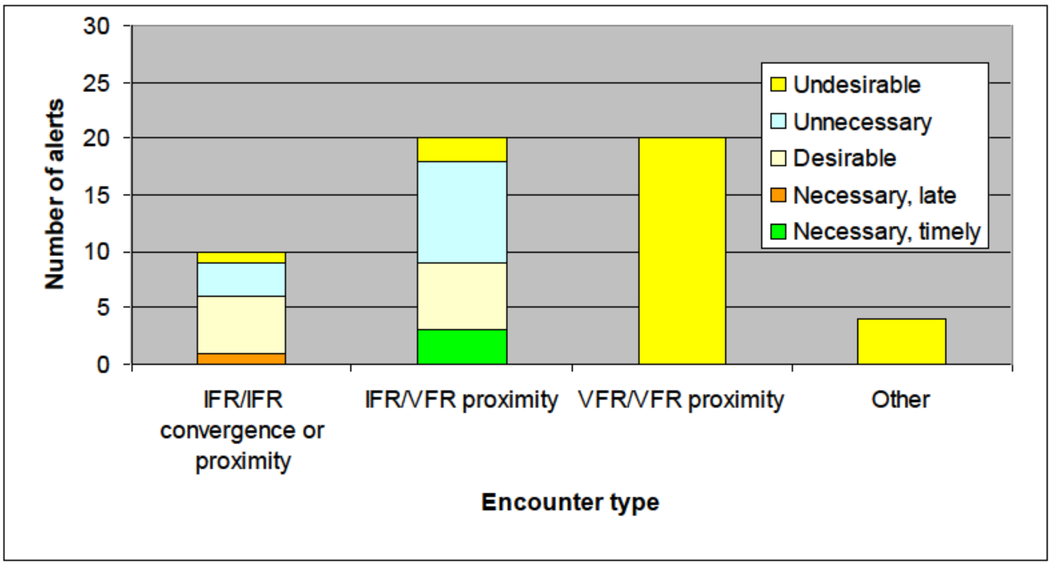

Figure 16 Prototype alerts not raised by baseline: number of alerts versus encounter type (excluding void)

Figure 15 and Figure 16 show that the baseline necessary and desirable alerts missed by each system are all associated with IFR/IFR convergence or proximity encounters, or IFR/VFR proximity encounters.

Figure 17 and Figure 18 show how alerts are distributed by alert type and encounter type for the baseline and prototype STCAs respectively.

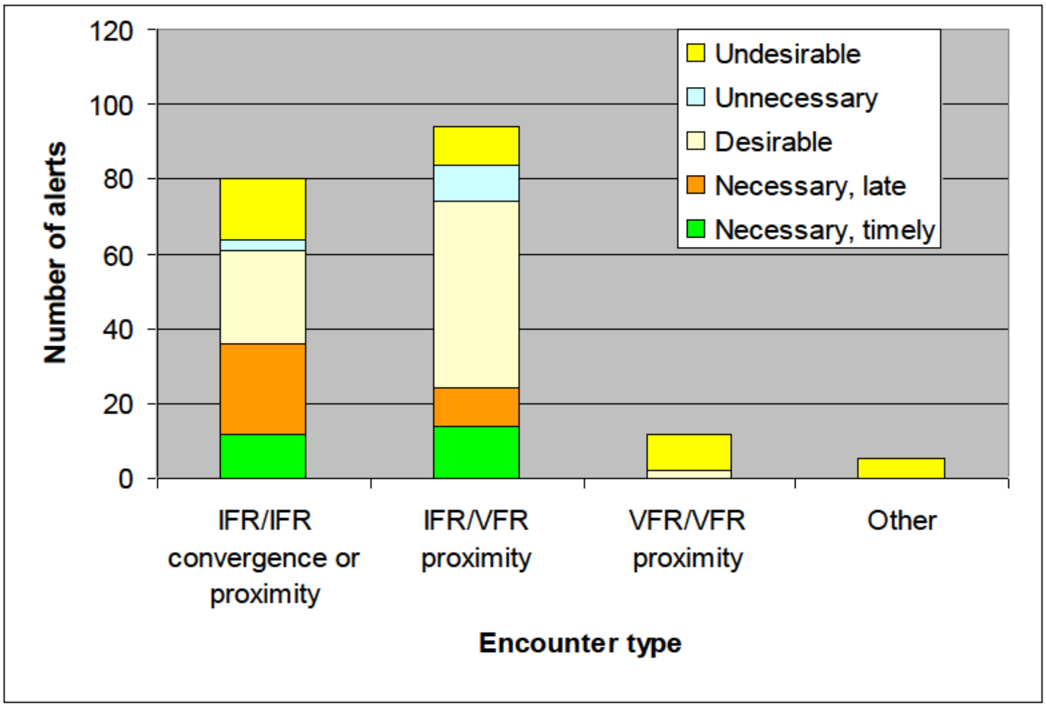

Figure 17 Baseline: number of alerts versus encounter type (excluding void)

The increase in undesirable alerts for VFR/VFR encounters by the prototype can be clearly seen. This has a potentially negative impact on human performance

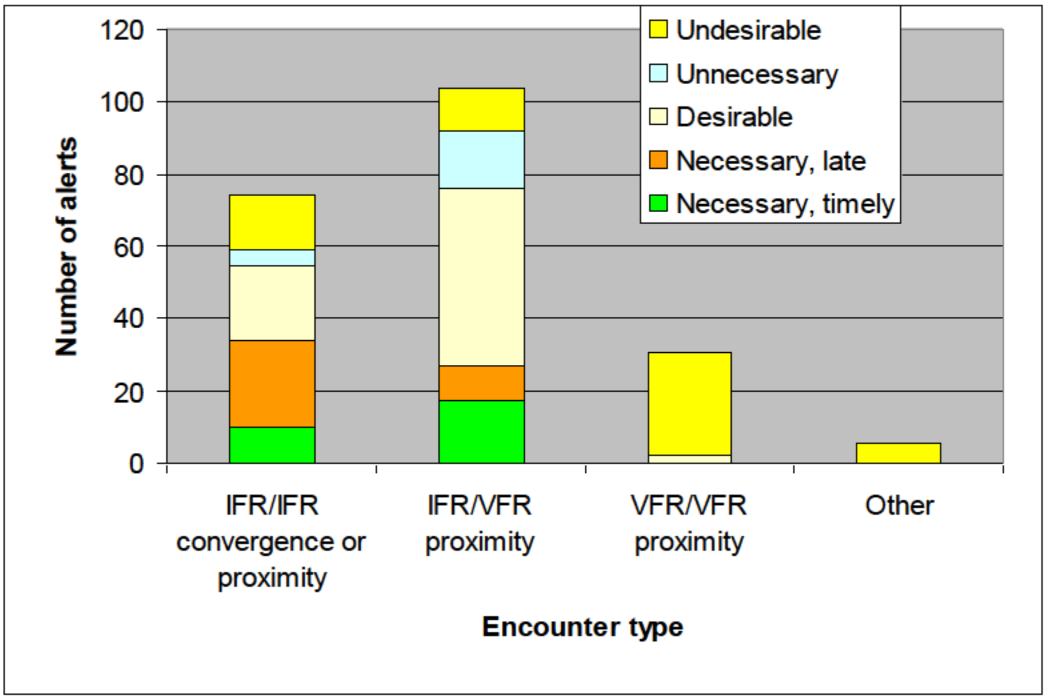

Figure 18 Prototype: number of alerts versus encounter type (excluding void)

Figure 19 is a more detailed analysis of IFR/IFR encounters by encounter geometry. Note that the prototype raises the same or fewer alerts for all geometries except for convergence on approach to different airports where the baseline has none. Levelling off and catching up encounters account for significantly more alerts than crossing and convergence.

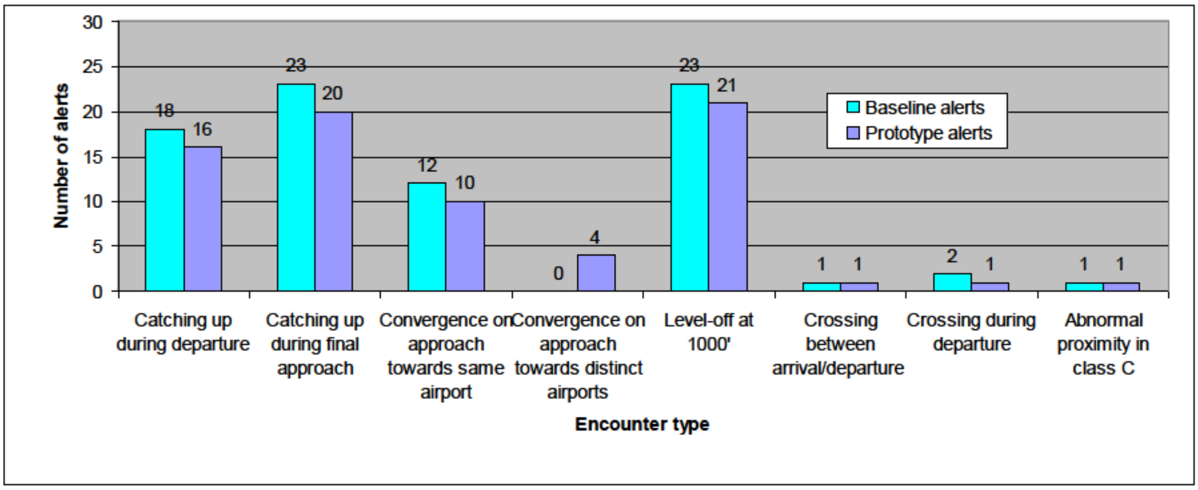

Figure 19 IFR/IFR encounters: number of alerts versus encounter type (excluding void)

Figure 20 shows that for IFR/VFR encounters, the prototype raises more alerts than the baseline in all airspace types.

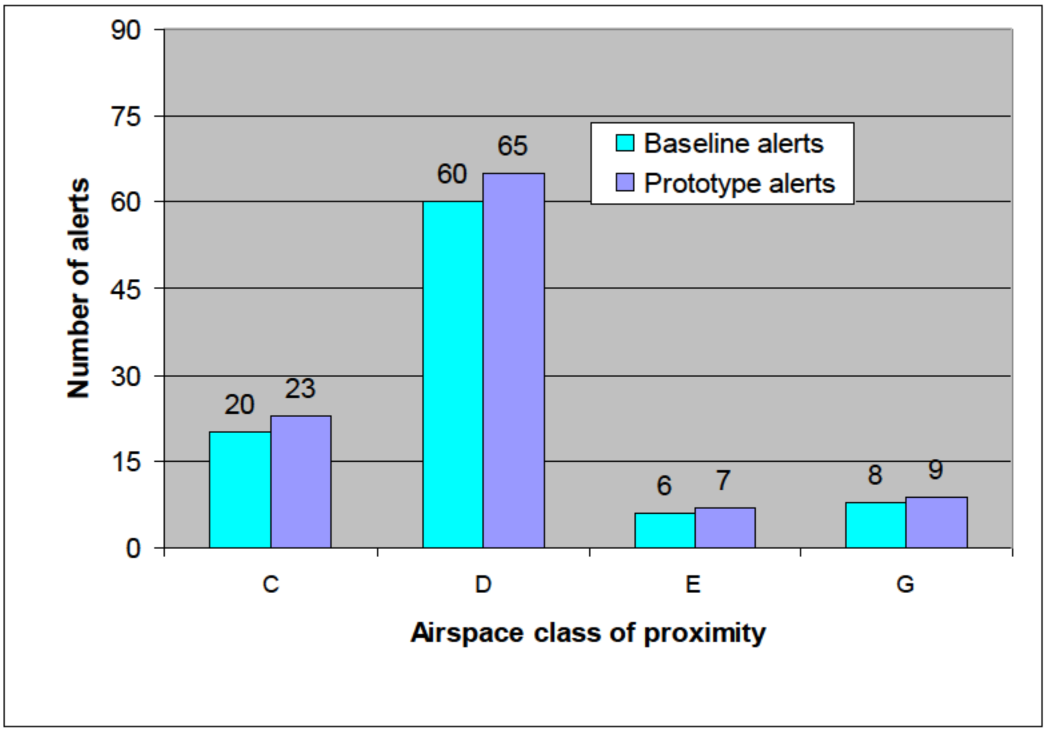

Figure 20 IFR/VFR encounters: number of alerts versus airspace class of proximity

Figure 21 shows that for VFR/VFR and all other non-IFR encounters, the prototype raises at least as many encounters as the baseline. Note that the prototype produces significantly more alerts with VFR/VFR encounters in class G airspace. This is a potential area identified in which the prototype can be improved.

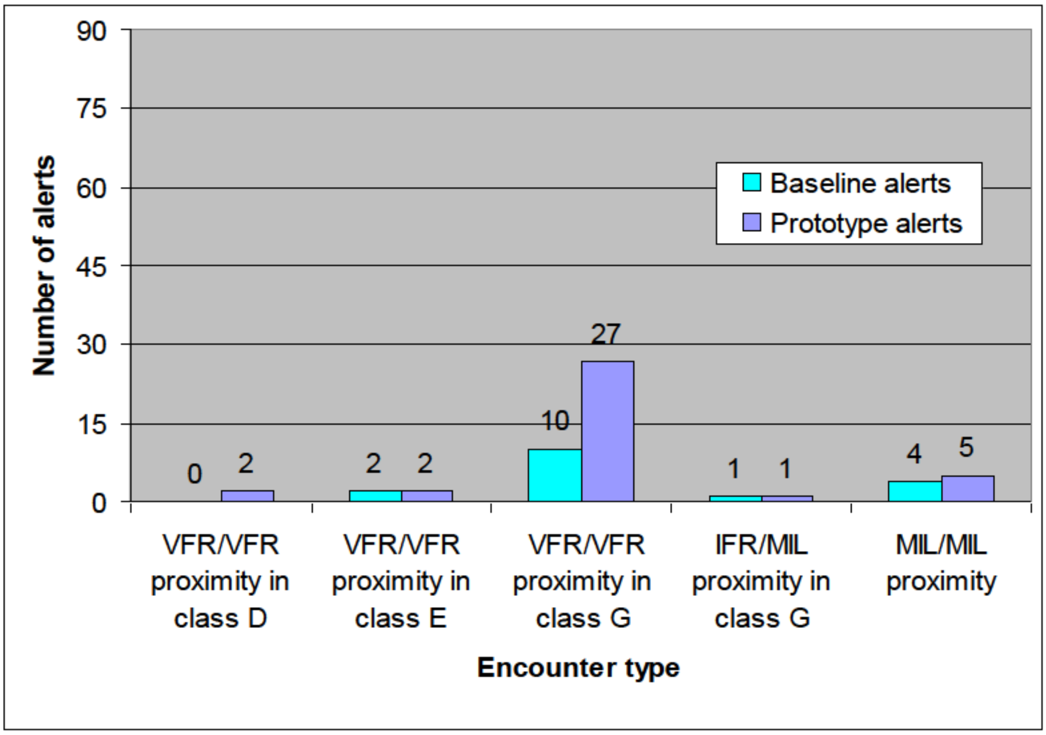

Figure 21 VFR/VFR and other: number of alerts versus encounter type

6.1.3.1.2.3 Subsequent investigation

1) THALES suggests that five unnecessary alerts are raised and 1 desirable alert is missed by the prototype due to a difference in ceiling levels of inhibition areas. The problem has been traced to discrepancy in QNH corrections.
2) THALES has determined that 23 alerts from the 31 new alerts raised by the prototype and classified as undesirable have a similar cause. They are raised between VFR flights on the first occurrences of the tracks. Mode A is invalid during a few updates and therefore not processed by the inhibited mode A function. The conflicts are raised temporarily and then inhibited as soon as the mode A (inhibited mode A) is known. THALES reckons that these undesirable alerts may be suppressed by a single refinement of algorithm during step.

6.1.3.1.3 Results impacting regulation and standardization initiatives

See section 4.1.3

6.1.3.2 Analysis of exercise results

See section 4.2.

6.1.3.3 Confidence in results of validation exercise

See section 4.3.

6.1.4 Conclusions and recommendations

See section 5.

7 References.

7.1 Applicable Documents

[1] V&V Plan Latest version

[2] SESAR V&V Strategy Latest version

[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]

7.2 Reference Documents

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

[7] SESAR P4.8.1 Consolidated baseline framework for safety and performance evaluation of STCA, 4.8.1-D03-SPR-STCA-V2, Edition 00.01.00, 1st March 2011

[8] SESAR P4.8.1 Final validation plan (V3) for enhanced STCA for TMA specific operations, 4.8.1-D04-VP-TMA-STCA-V3, Edition 00.01.00, 29th June 2011.

[9] SESAR P10.4.3 Project Initiation Report, Edition 1.04, 25th May 2010

[10] SESAR P10.4.3 Preliminary Definition Report for Phase 1 (enhance STCA), 10.04.03-D01, Edition 00.01.00, 10th March 2011

[11] SESAR P10.4.3 Preliminary Operational System requirements Synthesis Report for Phase 1 (Enhance STCA), 10.04.03-D02, Edition 00.01.00, 11th March 2011

[12] European Single Sky Implementation Plan (ESSIP), Edition 2011, SESAR Joint Undertaking, 9th December 2011.

[13] SESAR WP 4.2 Enroute operations Detailed Operational Description, Step 1 “Time-based operations”, D06 Draft Edition 00.00.11, 3rd March 2011

[14] SESAR WP 5.2 TMA Step 1 Detailed Operational Description, D101, Edition 0.01, 13th October 2011

[15] SESAR Project 4.8.1 Stakeholder consultation November 2010, Edition 1.0, 15th April 2011

[16] SESAR WP16.6.1, Enhanced STCA (OFA) safety plan, Draft edition 0.06, 16th May 2011

[17] SESAR 16.6.5, Human performance assessment of 4.8.1 Evolution of ground based safety nets (Release 1scope), 19th April 2011.

[18] EUROCONTROL Safety net Performance Improvement Network (SPIN) sub-group, Specification for Short Term Conflict Alert, 19th May 2009.

[19] EUROCONTROL Safety net Performance Improvement Network (SPIN) sub-group, Guidance material for Short Term Conflict Alert, 19th May 2009.

[20] EUROCONTROL Performance and safety Aspects of Short term conflict alert: full Study (PASS), Final report – synthesis and guidelines, 17th November 2010.

[21] SESAR P4.8.1 D04 SJU Assessment report – with project responses, 8th September 2011

[22] ICAO Annex 11 to the convention on international civil aviation air traffic services, thirteenth edition, July 2001

8 Acknowledgements

The authors would like to thank: [redacted] SELEX, members of WP16.6.1 [redacted] and WP16.6.5 [redacted] for their contributions to the validation plan; and SESAR project 10.4.3 members [redacted] from Thales, for their collaboration and support in configuring the platform and running the exercise.

Appendix A ICAO airspace classification

Table 16 is an extract from Appendix 4 Air traffic services airspace classes of ICAO Annex 11 to the convention on international civil aviation air traffic services, thirteenth edition, July 2001.[22]

Class	Type of flight	Separation provide	Service provided
A	IFR only	All aircraft	ATC service
B	IFR	All aircraft	ATC service
B	VFR	All aircraft	ATC service
C	IFR	IFR from IFR IFR from VFR	ATC service
C	VFR	VFR from IFR	1) ATC service for separation from IFR; 2) VFR/VFR traffic information (and traffic avoidance advice on request)
D	IFR	IFR from IFR	ATC service, traffic information about VFR flights (and traffic avoidance advice on request)
D	VFR	Nil	IFR/VFR and VFR/VFR traffic information (and traffic avoidance advice on request)
E	IFR	IFR from IFR	ATC service and, as far as practical, traffic information about VFR flights
E		Nil	Traffic information as far as practical
F	IFR	IFR from IFR as far as practical	Air traffic advisory service; flight information service
F	VFR	Nil	Flight information service
G	IFR	Nil	Flight information service
G	VFR	Nil	Flight information service

Table 16 ICAO airspace classification

Appendix B Coverage Matrix

This appendix is not intended to be filled in by the project. Coverage Matrix is constituted by the list of all relevant Operational Requirements (and V&V Concept/System Under Test requirements if any) with associated Validation Method, associated Validation Objectives and Validation Exercise in which these Validation Objectives are embedded.

This Coverage Matrix corresponds to the Preliminary Coverage Matrix proposed in the corresponding Validation Plan [1] completed with validation exercises results.

Requirements that are considered as relevant to appear in this Validation Report coverage matrix are those expressed in the OSED/SPR/INTEROP.

In addition, this coverage matrix provides the Validation Objectives analysis status and Requirement V&V status as the outputs of the Validation exercises execution and analysis.

Here follows an example of coverage matrix:

Requirement ID	Requirement Text	Req V&V Status	V&V Objective ID	V&V Objective Text	V&V Objective Analysis Status	V&V Objective Analysis Status per Exercise	Exercise ID	Exercise Title
Req #1	Req #1 Text	NOK	Obj #12	Obj #12 Text	NOK	NOK	Exercise #56	Exercise #56 Title
Req #1[1]	Req #1 Text	NOK	Obj #25	Obj #25 Text	OK	OK	Exercise #35	Exercise #35 Title
Req #1	Req #1 Text	NOK	Obj #25[2]	Obj #25 Text	OK	OK	Exercise #39	Exercise #39 Title
Req #1	Req #1 Text	NOK	Obj #23	Obj #23 Text	NOK	NOK	Exercise #2	Exercise #2 Title
Req #2	Req #2 Text	OK	Obj #39	Obj #39 Text	OK	OK	Exercise #21	Exercise #21 Title
Req #3	Req #3 Text	OK	Obj #3	Obj #3 Text	OK	OK	Exercise #35	Exercise #35 Title
...	...		...	...	...	...	...	...

Table 17: Coverage Matrix

Note:

1 *For each requirement, please add as many lines as there are covering Validation Objectives.*

2 *For each Validation Objective, please add as many lines as there are embedding Validation Exercises.*

Details of the fields of the coverage matrix:

- *Requirement ID: requirement identifier, following guidelines provided in [4].*
- *Requirement text: Title of the requirement*
- *Req V&V Status: synthesis of analysis status of associated V&V objectives*

- *V&V Objective ID: V&V Objective identifier, following guidelines provided in [4].*
- *V&V Objective Text: V&V Objective description*
- *V&V Objective Analysis Status: Final analysis status of the V&V Objective: synthesis of its Analysis Status in all Exercises it is embedded in.*
- *V&V Objective Analysis Status per Exercise: analysis status of the V&V Objective in the considered exercise*
- *Exercise ID: V&V Exercise Reference identifier, following guidelines provided in [4].*
- *Exercise title: Title of the V&V Exercise*

- **END OF DOCUMENT -**