Final Project Report

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Abstract

Project 16.06.01b has developed and applied Guidance for addressing resilience as part of the SESAR Safety Reference Material (SRM), based on state-of-the-art Resilience Engineering research. The Resilience Engineering Guidance was iteratively developed and applied through five case studies. Training and dissemination materials for the ATM community have been produced and tested. The Resilience Engineering Guidance is an integral part of safety assessment in SESAR2020 through the SRM.

Authoring & Approval

Prepared By - *Authors of the document.*		
Name & Company	Position & Title	Date
[redacted] NORACON/LFV	[redacted]	30/06/2016
[redacted] EUROCONTROL		30/06/2016
[redacted] FOI on behalf of NORACON		30/06/2016
[redacted] IFATCA		19/05/2016
[redacted] IFATCA		16/05/2016
[redacted] C-LVNL on behalf of ENAV		19/05/2016
[redacted] C-LVNL on behalf of ENAV		16/05/2016
[redacted] NATS		16/05/2016
[redacted] NATMIG/SINTEF		16/05/2016
[redacted] NATMIG/SINTEF		16/05/2016
[redacted] INDRA		16/05/2016
[redacted] NORACON/AUSTROCONTROL		16/05/2016
[redacted] / NORACON/AVINOR		16/05/2016
[redacted] ENAV/SICTA		16/05/2016
[redacted] NORACON/LFV		16/05/2016
[redacted] IFALPA		16/05/2016
[redacted] NATMIG/SAAB		16/05/2016

Reviewed By - *Reviewers internal to the project.*		
Name & Company	Position & Title	Date
[redacted] ENAV/SICTA	[redacted]	16/05/2016
[redacted] NORACON/AVINOR		16/05/2016

Reviewed By - *Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.*		
Name & Company	Position & Title	Date
[redacted] EUROCONTROL	[redacted]	16/05/2016
[redacted] IAOPA		16/05/2016
[redacted] NORACON		16/05/2016
[redacted] DFS		16/05/2016
[redacted] ENAIRE		16/05/2016
[redacted] ENAV/SICTA		16/05/2016
[redacted] NORACON		16/05/2016
[redacted] EUROCONTROL		16/05/2016

Approved for submission to the SJU By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
[redacted] NORACON/LFV	[redacted]	30/06/2016
[redacted] EUROCONTROL		30/06/2016
[redacted] FOI on behalf of NORACON		30/06/2016
[redacted] IFATCA		19/05/2016

[redacted] IFATCA	[redacted]	16/05/2016
[redacted] C-LVNL on behalf of ENAV		19/05/2016
[redacted] C-LVNL on behalf of ENAV		16/05/2016
[redacted] NATS		16/05/2016
[redacted] NATMIG/SINTEF		16/05/2016
[redacted] NATMIG/SINTEF		16/05/2016
[redacted] INDRA		16/05/2016
[redacted] NORACON/AUSTROCONTROL		16/05/2016
[redacted] / NORACON/AVINOR		16/05/2016
[redacted] ENAV/SICTA		16/05/2016
[redacted] NORACON/LFV		16/05/2016
[redacted] IFALPA		16/05/2016
[redacted] NATMIG/SAAB		16/05/2016

Rejected By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
<Name / Company>	<Position / Title>	<DD/MM/YYYY>

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Acronyms

Acronym	Definition
AFIS	Aerodrome Flight Information Service
AMC	Acceptable Means of Compliance
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
ASAS S&M	Airborne Separation Assistance System Sequencing & Merging
ATC	Air Traffic Control
ATM	Air Traffic Management
CTA	Controlled Time of Arrival
i4D	Initial Four Dimensional Trajectory
IANS	Institute of Air Navigation Services
EC	European Commission
EU	European Union
KPA	Key Performance Area
KPI	Key Performance Indicator
RE	Resilience Engineering
SES	Single European Sky
SESAR	Single European Sky ATM Research
SESAR2020	Single European Sky ATM Research 2020
SJU	SESAR Joint Undertaking
SMS	Safety Management System
SRM	Safety Reference Material
T n	Task n
TMA	Terminal Manoeuvring Area
TWR	Tower

1 Project Overview

The main objective of the project was to apply Resilience Engineering Guidance (previously developed in SESAR) to relevant operational environments as well as organizational contexts, and to propose improved Resilience Engineering Guidance integrated into the SESAR methodology for safety assessment as well as into Safety Management Systems.

1.1 Project progress and contribution to the Master Plan

The role of this project in the programme was to provide guidance to address both 1) the resilience of the current ATM functional system that may change as a result of implementing SESAR; and 2) the anticipated resilience of the ATM system with the SESAR solutions implemented, as part of safety assessment and safety management. Resilience here means the intrinsic ability of the ATM system, consisting of people, working methods, and technology, to adjust its functioning and performance goals, in order to sustain operations prior to, during, or following varying conditions.

This project has taken earlier Resilience Engineering Guidance [4] as a starting point and further developed and applied it as the proposed approach to the integration of Resilience Engineering concepts into safety assessment processes in SESAR. The project has enabled progress to a mature, effective, useable, applied, and coordinated Resilience Engineering Guidance for safety assessment as part of the SESAR Safety Reference Material (SRM) [12]. Thereby the project results contribute to achieving the SES high-level safety goals and their translation in the SESAR European ATM Master Plan [2].

Implementing the European ATM Master Plan and, in particular, assuring that the SESAR new concepts and technologies will deliver the Master Plan safety performance gains, can only be successful if innovative and pragmatic solutions to a wide range of safety issues across the SESAR work programme are supplied. Resilience Engineering has early on in the SESAR program been selected as such an innovative approach. The SESAR programme [1] [3] has in its Master Plan [2] extensive references to sustaining and improving resilient performance of the ATM system. During the lifetime of 16.01.02 and now 16.06.01b the application of RE has matured into a pragmatic method that 16.06.01b has shown can be applied to SESAR Solutions. Because in the vast majority of cases, the underlying causes of accidents and incidents can be traced back to design, it is key that explicit consideration of Resilience Engineering can be provided at early definition and design stages. The RE Guidance, as part of the SRM, aims to contribute to the delivery of safety benefits and identifying how problems in adaptive capacity could occur. The 16.06.01b project has delivered and promoted the application of RE Guidance and the addressing of resilience and adaptive capacity into the project lifecycle.

The project progress includes the development of more specified method to be followed as part of the Resilience Engineering Guidance, more in line with ATM operational terminology as well as with safety assessment processes in SESAR. This means that the RE Guidance can be understood and applied more easily by air traffic controllers and safety assessors. The RE Guidance was fully integrated with the SRM.

The project developed advanced techniques for analysis of resilience and for identification of design recommendations to improve the resilience of ATM operations. A number of techniques were developed and applied that as part of the RE Guidance provide additional means for analysis of work-as-done and interactions between actors in complex ATM operations.

The project applied the Resilience Engineering Guidance to five SESAR Solutions (two main applications and three additional applications that used synergetic effects). The project thereby showed that the Resilience Engineering Guidance can be used effectively for ATM, providing new insights to safety assessment and design processes of operational and technical solutions.

The project's main contribution to SESAR is a methodological contribution to the whole programme, rather than a contribution to a specific operational solution. The project has provided a means for the SESAR programme to address resilience in the development of new operational and technical

solutions, to the extent that would not have been possible without the completion of this project. This project has thereby added to the capability for safety assessment in SESAR by extending its safety assessment process with Resilience Engineering concepts and techniques.

The progress towards the project's main contribution, the final Resilience Engineering Guidance, used an iterative approach consisting of the following main steps: (1) Developing an approach and techniques for Resilience Engineering in safety assessment through Resilience Engineering Guidance. (2) Training of safety assessment experts on the Resilience Engineering Guidance to be able to critique and apply RE, and create awareness and understanding of the Guidance. (3) Applying the updated approach for Resilience Engineering to ATM test cases. Using the ATM test cases, lessons learned for the further development of the Resilience Engineering Guidance were fed back into the project.

Through the application and further development of the Resilience Engineering Guidance for the SRM, contributions were made to the following specific SESAR Solutions, in terms of issues for further development of the design of the Solutions in order to sustain or improve resilient performance: "Remote tower for two low-density aerodromes" and "ASAS spacing applications 'Remain behind' and 'Merge behind'" (the two main application cases for 16.06.01b). SESAR Solutions that could be contributed to through synergy opportunities with three additional application cases for 16.06.01b's results, were: "Multi-sector planning", "Point merge in complex terminal airspace", "Initial Four Dimensional Trajectory" (i4D) and "Controlled time of arrival (CTA) in medium density/medium complexity environment".

1.2 Project achievements

The project results enable the SESAR programme to address the resilient performance of the operational and technological solutions it is developing, by adding Resilience Engineering principles and methods to the safety assessment processes.

The project achievements thereby allow SESAR to apply Resilience Engineering principles in safety assessment in order to prepare the ATM functional system to manage the consequences of unexpected disturbances and demands. Particularly the project produced the following achievements as part of the Resilience Engineering Guidance:

- A method for safety assessment addressing resilience within the safety assessment process;
- A set of principles derived from state-of-the-art Resilience Engineering research;
- A description of how resilience links to Key Performance Indicators, applying the principles to safety management, including examples for design and Safety Management Systems; and
- A training package to train the safety assessor on Resilience Engineering within SRM.

The following achievements are reported in connection to the application of Resilience Engineering principles to the "Remote Tower for two low density aerodromes" SESAR solution, the first of the two main cases that the project contributed to:

- Investigation and application of the available Resilience Engineering methodologies;
- Development, and validation of the Resilience Engineering Guidance through the assessment of the resilient performance of Multiple Remote Towers, focused on adaptive capacity (the capacity to adapt to varying conditions, i.e. anticipate them, detect them, react on them, and learn from them), work-as-done and varying conditions (the changing conditions of operations, expected and unexpected). Two applications were studied to this end:
    - Sundsvall Multiple Remote Tower ATC services, and
    - Bodø Multiple Remote Tower AFIS;
- Improvements to the preparation, data collection and analysis, and requirements identification phases of the RE Guidance.

- Increase of the understanding of the significance of the change brought by the solution's design, and identification of challenges that could impact safety and other Key Performance Areas as well as of potential opportunities for increased resilience in the Multiple Remote Tower design and solution.

The following achievements are reported in connection to the application of Resilience Engineering principles to the "ASAS Spacing applications 'Remain behind' and 'Merge behind'", the second of the two main cases that the project contributed to:

- Development of a pragmatic approach to RE, focusing on exploring strategies that experienced operational experts have when dealing with varying conditions. Application and validation of this approach through the assessment of the resilience of ASAS S&M operations.
- Identification of recommendations to the further development of the ASAS S&M design, aimed to improve resilience at the design level, the management level, the operational level and the Key Performance Area (KPA) level, including effects on safety, capacity, environment, cost-benefit.
- Development of an innovative technique for adaptive capacity analysis, and its validation through application to the test case.

Besides the two main application cases of "ASAS Spacing applications 'Remain behind' and 'Merge behind'" and "Remote Tower for two low density aerodromes" reported above, synergies and coordination with other projects have been achieved during the duration of 16.06.01b so that its project results could be applied to three additional application cases. The Resilience Engineering Guidance and specific techniques contained in it were applied and improved by applying these to an exercise validating solutions of "Initial Four Dimensional Trajectory" (i4D) and "Controlled time of arrival (CTA) in medium density/medium complexity environment", and the development of two operational solutions of "Multi-sector planning" and "Point merge in complex terminal airspace". The results allowed the solution developers to overcome a number of design hurdles, provided added value to the solution development process, while addressing several Resilience Engineering principles. In the case of i4D/CTA the RE assessment was integrated into the final validation report of the exercise.

In connection to the project's training and communication activities, communication materials (a training package, and presentations to industry and academic meetings) have been produced and tested to train and educate in the Resilience Engineering Guidance and increase awareness of RE in ATM. NORACON has trained safety assessors in the Guidance who then applied it.

The results of this project are expected to be implemented in the following way:

- It is expected that the RE Guidance will continue to be used for the duration of SESAR2020 as part of the SRM.
- Education is being made available (e.g., through the IANS) as part of SRM training.
- Several ANSPs are expected to integrate the project results into their safety assessment and safety management activities.

The vision of the future is that ANSPs can use Resilience Engineering as a proactive and efficient way of doing safety assessment towards a more effective safety understanding. If applied in a systematic way it is seen as a useful tool for reviewing and improving safety and resilience of ATM operations and new solutions.

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by the project.

Reference	Title	Description
D02-003	Remote TWR - Final Report	A final report [6] that provides the background to the development of the Resilience Engineering Guidance (changing the emphasis of the Guidance to adaptive capacity) and to the experience of applying this guidance to the Multiple Remote Tower development simulation. The changes to the Guidance include 1) the analytical approach to investigating work-as-done and work-as-imagined as workshop preparation, that forms the basis for the RE workshop; 2) an iterative structure to the workshop moving from a duty cycle to an event that elicits the strategies used to adapt; 3) the inclusion of a session to explore how resilience can be improved and related to KPA assessment; 4) the use of various scientific methods to analyse data.
D03-003	ASAS - Final Report	A final report [8] that further develops RE guidance and applies it to a solution of ASAS S&M, with the following results: 1) pragmatic sequence of steps for RE, which uses a workshop with operational experts as a central element, 2) development of agent-based modelling and simulation as an innovative technique for adaptive capacity analysis in RE, 3) application of this sequence of RE steps and the innovative technique for adaptive capacity analysis to the ASAS S&M operation, 4) recommendations for improving the resilience of the ASAS S&M operation.
D04	T4 Final Report	A final report [9] that presents the Guidance developed for resilience assessment into the SESAR safety approach. The deliverable describes the four-step process of application of methodology, it provides the review of techniques and tools available for each step. It describes the integration within other activities of safety assessment. The document proposes a set of resilience-derived KPIs that could be implemented in the design phase or into Safety Management Systems.
D05-005	Information - Final Report	A final report [11] that summarises the achievements and key communication activities during the project and lists the various groups and contexts. Feedback during these activities has been instrumental to guide the efforts and the design of a training package. Further, abstracts from published articles and posters with references are described. Finally, abstracts for future papers are presented.

1.4 Contribution to Standardisation

The project's contribution to standardisation is indirect via the SESAR Safety Reference Material (SRM) as the guidance developed by this project is part of the guidance to the SRM [12]. The SESAR SRM and companion guidance is positioned within the scope of the Acceptable Means of Compliance (AMC) or Guidance Material to the European Commission implementing the Regulation laying down common requirements for service providers and the oversight in air traffic management/air navigation services and other air traffic management network functions, repealing Regulation (EC) No 482/2008, Implementing Regulations (EU) No 1034/2011 and (EU) No 1035/2011 and amending Regulation (EU) No 677/2011.

1.5 Project Conclusion and Recommendations

The overall conclusions from the results of this project are:

- The Resilience Engineering Guidance that was developed can be applied to SESAR operational improvements and enablers as part of the safety assessment. Thereby Resilience Engineering can be applied to ATM solution development and yield meaningful and useful results. It enables safety assessors to address the perspectives of the various stakeholders involved in or affected by changes in the ATM system as a result of SESAR, considering trade-offs between safety and other Key Performance Areas under varying conditions, and consequences for adaptive capacity.
- Any safety practitioner can conduct an RE analysis, with adequate RE training provided, and with input from experienced operational experts (air traffic controllers, airline pilots, supervisors, technical equipment experts, etc.).
- Application of RE provides relevant additional feedback to inform the development of resilient operational solutions, and has the potential to make safety assessment more holistic to address the expected functioning of the system of operators and technology as part of a network of multiple aviation actors.

The project recommends:

- SESAR2020 partners to apply the Resilience Engineering Guidance to the development of ATM solutions through application of the SRM Guidance I, in order to adequately and efficiently address the impact of SESAR2020 on the adaptive capacity of the future ATM operational environment. This contributes to eventually achieving the SES high-level safety goals and their translation in the Master Plan. To make RE Guidance application consistent the application of the Guidance should be supported through training.
- The application of the RE guidance outside SESAR to promote a seamless approach to safety management practices throughout the entire lifecycle. (Project 16.06.01 which developed the SRM has also warranted the re-usability for further development/adaptations of SESAR Safety Documentation by those who will co-ordinate the deployment of SESAR and operationally deploy the SESAR solutions.)
- ANSPs to complement their Safety Management System with the Resilience Engineering guidance that has been developed in connection to SRM and SESAR KPIs.

2 References

[1] SESAR Programme Management Plan, Edition 03.00.01

[2] European ATM Master Plan

[3] Multilateral Framework Agreement ("MFA") signed between the SJU, EUROCONTROL and its 15 selected members on August 11, 2009, amended on 14 June 2010, 19 October 2010 and 2 July 2012

[4] SESAR Project 16.01.02, Final Resilience Guidance Material for Safety Assessment (SRM) and Design, D14, Edition 00.01.00, 6 December 2013

[5] SESAR Project 16.06.01b, Remote TWR - Interim Report 2014, D02-001, Edition 00.01.00, 15 February 2015

[6] SESAR Project 16.06.01b, Remote TWR - Final Report, D02-003, Edition 00.03.00, 27 May 2016

[7] SESAR Project 16.06.01b, ASAS - Interim Report 2015, D03-002, Edition 00.01.00, 27 April 2016

[8] SESAR Project 16.06.01b, ASAS - Final Report, D03-003, Edition 00.01.00, 11 May 2016

[9] SESAR Project 16.06.01b, T4 Final Report, D04, Edition 00.01.00, 27 May 2016

[10] SESAR Project 16.06.01b, Information Report 001 and 002, D05-001 and D05-002, Edition 00.01.00, 16 January 2015

[11] SESAR Project 16.06.01b, Information - Final Report, D05-005, Edition 00.01.00, 27 May 2016

[12] SESAR Project 16.06.01, Guidance to Apply the SESAR Safety Reference Material, D27, Edition 03, 9 May 2016

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