D2.2 - PRELIMINARY MARKET AND SOCIETY IMPACT ASSESSMENT AND STATE-OF-THE-ART IN SAFETY RESEARCH PART 2

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Abstract

In 2015 OPTICS performed a preliminary market and society impact assessment to give answers to the question: are we doing European aviation safety research right? OPTICS also extended its state-of-the-art assessment of European research and organized its 2nd Expert Workshop. These two activities provide answers to the question: are we doing the right research? The insights from the preliminary market and society impact assessment are already seen as interesting, and will be further explored in the remaining two years of OPTICS. The continuation of the state-of-the-art assessment and the 2nd workshop provided additional understanding of the remaining research needs and bottlenecks to meet Europe's aviation safety goals.

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Table of Contents

OPTICS is a Coordinated Action funded by the European Union Seventh Framework Programme (FP7-AAT-2013_RTD-1) under Grant Agreement n° ACS3-GA-2013-605426.

OPTICS is a Coordinated Action funded by the European Union Seventh
Framework Programme (FP7-AAT-2013_RTD-1) under Grant Agreement n° ACS3-GA-2013-605426.

List of Figures

OPTICS is a Coordinated Action funded by the European Union Seventh Framework Programme (FP7-AAT-2013_RTD-1) under Grant Agreement n° ACS3-GA-2013-605426.

List of Tables

Acronyms and Terminology

Term	Definition
ACARE IRG	Advisory Council for Aviation Research and Innovation in Europe Implementation Review Group
ACARE SIB	Advisory Council for Aviation Research and Innovation in Europe Strategy & Integration Board
ACARE WG4	Advisory Council for Aviation Research and Innovation in Europe Working Group 4 Safety & Security
ANSP	Air Navigation Service Provider
ARP	Aerospace Recommended Practice
ASD	AeroSpace and Defence Industries Association of Europe
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Service
CAA	Civil Aviation Authority
CAT	Commercial Air Transport
CIRA	Italian Aerospace Research Centre
CORDIS	Community Research and Development Information Service
CSA	Coordination and Support Action
DLR	Deutsche Zentrum für Luft- und Raumfahrt
EASA	European Aviation Safety Agency
EASA MS	European Aviation Safety Agency Member States
EASN	European Aeronautics Science Network
EASp	European Aviation Safety Plan
EC	European Commission
ENAC	École Nationale de l'Aviation Civile
EREA	Association of European Research Establishments in Aeronautics
ETOPS	Extended-range Twin-engine Operational Performance Standards
EU	European Union
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration
FOD	Foreign Object Damage
FP7	7th European Framework Programme for Research and Technological Development

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HEFA	Hydroprocessed Esters and Fatty Acids
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
MS	Member State
MTOM	Maximum certificated take-off mass
NLR	Netherlands Aerospace Centre
ONERA	French Aerospace Centre
R&D	Research and Development
RPAS	Remotely Piloted Aircraft System
SAR	Search and Rescue
SARP	Standards and Recommended Practices
SES	Single European Sky
SESAR	Single European Sky ATM Research Programme
SJU	Single European Sky ATM Research Programme Joint Undertaking
SRIA	Strategic Research and Innovation Agenda
TRL	Technology Readiness Level
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle

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Executive Summary

This report documents the work performed by OPTICS in 2015. It addresses two fundamental questions for European aviation safety research: (1) are we doing the right research? (2) are we doing the research right? The first question is answered by mapping European aviation safety research to the Strategic Research and Innovation Agenda (SRIA) and by soliciting the opinion of aviation safety experts in a workshop setting. The second question is addressed by an assessment of the impact European aviation safety research can have on society and market in Europe.

Part 1 of this OPTICS Report D2.2 presents the results of a trial assessment conducted to better understand the impacts aviation safety research can have on society and the economy. OPTICS has developed a methodology to address these impacts, based on a range of indicators and sources. The first set of indicators that was described in the OPTICS report D1.4 were revised and served as a basis for an information collection phase that provided the consortium with the information presented in this document. A critical review of the process described in this deliverable will feed into the construction of a further improved assessment framework as the whole process of developing a framework for a market and societal impact assessment within OPTICS is set up in an iterative manner.

For each indicator one or more of the following information sources were identified: Internet search, survey of public opinion, communication with experts, project coordinators of EU safety projects, coordinators of OPTICS sister projects dealing with topics related to environmental considerations and results from OPTICS WP2.1 (the assessment of safety research). Overall, there are four overarching categories, which are split in 24 indicators.

Indicators in the "**Socio-Economic Needs and Expectations**" category illustrate the overall social and economic well-being of the European society. The creation of jobs, the continuous improvement of safety levels or investments made in aviation safety research, for example, are aspects dealt with in this category. The second category **"Environmental Considerations"** traces the relation between environmental concerns and developments in aviation safety. This category focuses on the effects enhancements in one of these areas can have on the other and whether such cross-impacts are considered in research projects in either field. Indicators relating to **"Industry Competitivity"** cover aspects affecting the position of the European aviation industry in the worldwide market. The category aims at tracing whether research in aviation safety in Europe provides the industry with competitive advantages and thus supports the industry's leadership position. Aspects relating to the available research infrastructure as well as the level of education provided within the area of aviation safety are clustered in the fourth category **"Capacity of EU Safety Research"**. There are also aspects such as the excellence of safety research within Europe and the strategic focus of aviation safety research covered here.

A central result from the assessment is that the public as well as aviation experts trust the air transport system to provide safe services. The feedback from project coordinators leads to the conclusion that results from previous projects are taken into account and that research is structured according to end user needs. Even though there are very few master programmes dedicated to aviation safety, coordinators were satisfied with the skills of the projects' personnel. Download statistics for safety related journals suggest that there is a worldwide interest for aviation safety research with no world region dominating.

Overall, the work on societal impact has demonstrated 'proof of concept' for the methodology, which will now be expanded to more projects in the remaining two years of the OPTICS work programme.

In part 2 of OPTICS Report D2.2 the work conducted in 2015 in relation to the question "are we doing the right research?" is addressed. In 2014 OPTICS started defining the state-of-the-art in safety research by mapping safety-related FP7 projects to the SRIA. In 2015 OPTICS extended the state-of-

the-art assessment by analysing an additional 63 research projects. Projects from the following programmes are considered: SESAR, SESAR WPE, Clean Sky, Future Sky Safety and FP7.

The safety relevance of projects is determined by the OPTICS team by studying available project documentation or in coordination with the programme. Each assessment is done in three stages: a first assessment by an OPTICS team partner, moderation by another OPTICS team partner, and finally a review by the relevant project coordinator. Each project is mapped to one or more SRIA capabilities, and scored for coverage of the capability, as well as maturity and ease of adoption of the researched concepts. From the project assessment a synthesis per SRIA capability and enabler is made.

Parallel to the project assessments, OPTICS organized in 2015 its 2nd Expert Workshop, attended by 50 experts in aviation safety. Their task was to determine the major Research & Innovation priorities for aviation safety, to consider the research pathway laid out by ACARE's SRIA, and then to determine if any significant research avenues were missing. The focus of the Workshop was on four focal areas grouped together in a cluster called 'Air Vehicle Operations and Traffic Management': autonomous systems, use of data, self-healing and weather.

The addition of new projects in the state-of-the-art assessment resulted in bridging gaps that were identified in 2014. The coverage for enabler 1 increased from low-medium to medium-high. The coverage of enablers 3, 5, 6, 7, and 8 increased from low-medium to medium. The coverage score of enablers 2 and 9 did not change. Enabler 10 is not yet addressed by any project assessed by OPTICS.

There are still capabilities not addressed by any of the projects assessed in 2014 and 2015. There are also clear gaps that overarch separate enablers identified by the state-of-the-art assessment and by the expert workshop. These gaps are lack of research into: aspects of multi-modal transport, equity of access to airspace of future aviation concepts (other than remotely piloted aircraft systems (RPAS)), and new and more agile V&V approaches for RPAS. As a whole, research in the maintenance domain is under-addressed. Lastly there is a research void between near-term research close to implementation, and research projects that can be seen as thought experiments that are unlikely to be implemented in the near or medium-near term.

This year's OPTICS work gave rise to possible improvements to the SRIA. OPTICS recommends to ACARE to include in an update of the SRIA the need for research into: determining success factors in automation and its development cycle that lead to human trust in automation; moving from process-based maintenance to evidence-based maintenance; and determining the required skills of software engineers.

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PART 1:
PRELIMINARY MARKET AND SOCIETY IMPACT ASSESSMENT

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1. INTRODUCTION

OPTICS poses two fundamental questions for European Aviation safety research:

Are we doing the right research?

Are we doing the research right?

In the first OPTICS State-of-the-Art report (OPTICS 2015a), the focus was on the first question, evaluating the degree to which safety research (Projects in the FP7 Research Programme) is helping European aviation realise the safety goals of FlightPath2050. In Part 2 of this report this assessment continues, now adding in the important institutionally-funded programmes including SESAR, Clean Sky and FutureSky.

The first part of this report, however, addresses the second question, which is a societal question, and concerns how aviation safety research is impacting European citizens. It can be broken down into four sub-questions:

Does the travelling public feel it is safe to fly?

Is safety research likely to impact the environment?

Is safety research giving us a competitive edge in the global market?

Are we doing world-leading safety research?

These are important but broad questions, and not so easy to answer. For this reason OPTICS has developed a methodology to address them, based on a range of indicators and sources, and the first part of this report effectively trials this methodology, and shows the types of answers the methodology can deliver. Even though the samples of people, sources, and Projects used to test the methodology are small in this preliminary phase, the insights are already seen as interesting, and will be further explored in the remaining two years of OPTICS with larger samples, so that more definitive answers can be given.

Part 1 of this OPTICS Report D2.2 therefore presents the results of a trial assessment conducted to better understand the impacts aviation safety research can have on society and the economy. This part of the deliverable builds on work described in OPTICS D1.4. In preparation of this deliverable the set of indicators presented in OPTICS D1.4 was refined, and metrics as well as possible sources of information related to each indicator were specified. An information collection phase followed these steps of which the results will be presented in this deliverable.

One very important, if not the most important, goal of the efforts towards the creation of an ever safer air transport system is that people feel good when flying, and that they do not feel they are taking a risk when boarding an aircraft. As one example from the study, this indicator was investigated by simply asking aviation experts whether they feel safe when flying. 38 out of 40 people that responded to this question answered that, indeed, they do feel safe. To complement this assessment by the opinion of the general public we developed a short questionnaire to ask the public what keywords come to their mind when they think about air transport. The three keywords mentioned most often by the nearly one hundred people that were asked in this trial assessment was “safety”, “security” and “time savings”. This indicates that people are aware of safety as well as security issues when flying, but they also reported that aircraft are their preferred mode of transport for longer distances. It should be noted that these results are not representative but rather on the level of a pre-study, aiming to test the methodology in order to improve it.

The feel good factor (safe to fly) is an indicator placed in the category **“Socio-Economic Needs and Expectations”** (for the indicator structure see Appendix 1). Overall, there are four overarching

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categories, which are split in 14 components and 24 indicators. Indicators in the "Socio-Economic Needs and Expectations" category illustrate the overall social and economic well-being of the European society. The creation of jobs, the continuous improvement of safety levels or investments made in aviation safety research, for example, are components under which the indicators are subsumed.

The second category **"Environmental Considerations"** traces the relation between environmental concerns and developments in aviation safety. This category focusses on the effects enhancements in one of these areas can have on the other and if such cross-impacts are considered in research projects in either field.

Indicators relating to **"Industry Competitivity"** cover aspects affecting the position of the European aviation industry in the worldwide market. The category aims at tracing whether research in aviation safety in Europe provides the industry with competitive advantages and thus supports the industry's leadership position. For example, components address standardisation and regulation issues as well as the availability of an appropriately skilled workforce.

Aspects relating to the available research infrastructure as well as the level of education provided within the area of aviation safety are clustered in the fourth category **"Capacity of EU Safety Research"**. There are also components addressing the excellence of safety research within Europe and the strategic focus of aviation safety research.

The results obtained from the trial application of the assessment framework are presented per indicator in this deliverable in Section 2. At the beginning of a subsection the category which the following indicators relate to is introduced and a brief synthesis of the central findings is presented which yields an overview of the most central results. Then the information collection process and the gathered data are described for each indicator. A first possible visualisation of results is presented in Section 3, where the overall process of data gathering will also be reviewed critically. The process of developing a framework for a market and societal impact assessment within OPTICS is set up in an iterative manner. This means that the lessons learned from the preliminary assessment presented in this part of the deliverable will feed into a refinement of data gathering strategies, as well as the preparation of results and their visual representation. So the critical review of the process described in this deliverable will feed into the construction of a further improved assessment framework.

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2. Results from the Preliminary Market and Society Impact Assessment

The framework for the preliminary assessment of the societal and economic impact of aviation safety research is based on a set of 24 indicators. The indicators were developed based on a literature study, expert discussions and a workshop within the OPTICS consortium. They were derived in an iterative manner. A first status was published in OPTICS D1.4 and later improved in preparation of this deliverable. The indicators are structured into 14 different components which again are split in four categories. A chart of all indicators can be found in Appendix A. For each indicator one or more information sources were identified. These sources cover a broad range of different data gathering strategies:

- Internet search,
- Survey of public opinion,
- Communication with experts (ACARE IRG, ACARE SIB, ACARE WG4, ASD, EASA, EASN, EC, EREA, EUROCAE, FAA, ICAO, SJU),
- EU safety project coordinators,
- Coordinators of OPTICS sister projects dealing with topics related to environmental considerations and
- Results from OPTICS WP2.1.

In Appendix B a table is provided listing which information sources were addressed for which indicator. Internet search as a source of information is self-explanatory. In order to gain insights into the public opinion on a specific indicator a short questionnaire was developed that was used to collect information from the public. This questionnaire can be found in Appendix C. Experts were contacted mainly via e-mail, but for certain indicators the information was collected via meetings as well as within a workshop. For those indicators where the coordinators of EU safety projects were identified as reference person a structured questionnaire was set up that was distributed via e-mail to the coordinators of those projects selected for the trial assessment phase. This questionnaire can be found in Appendix D.

As the main focus of this deliverable is to test the methodology and to learn how to improve the approach iteratively, only four projects were chosen for this assessment: HAIC, Prospero, AircraftFire and A-Pimod. These projects were drawn from a database assembled by the OPTICS consortium for the assessment of FP7 projects with explicit safety content. Since these projects were analysed by OPTICS (see OPTICS deliverable D2.1) certain project details were already collected in a repository. For efficiency reasons only a small number of safety projects from this range was selected. HAIC, Prospero, AircraftFire and A-Pimod were chosen because representatives of these projects had presented their work during the 1st OPTICS conference and were thus already familiar with the goals of the OPTICS project. It was assumed that this would increase the probability that the questionnaires would be returned. Three of the four coordinators provided feedback and filled out the questionnaires. Although this is not a representative sample, it gives a first indication as to how the assessment framework can be improved.

In this section, the indicators that serve as foundation for the assessment framework are presented individually, sorted according to the four overarching categories “Socio-Economic Needs and

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Expectations", "Environmental Considerations", "Industry Competitivity" and "Capacity of EU Safety Research".

2.1. Socio-Economic Needs and Expectations

In this category, indicators are assembled that relate to Europe's social well-being and economic development with respect to aviation safety. The air transport system is an important enabler of economic growth and globalisation enabling the fast transportation of goods and people over medium and long distances. To maintain this status, it is important that the European citizens trust the aviation industry to offer reliable and affordable transportation as well as to guarantee high safety standards. Aspects such as the statistical reduction of incidents but also the subjective perception of whether flying is safe or not are addressed in this category. Furthermore, employment figures relating to air transport system safety are gathered and the monetary investment in safety is traced. The analysis of the socio-economic needs and expectations comprises data from different sources. For example, the feel good factor was investigated from different perspectives: the public perception relies on interviews with the general public, internet research served as source for getting an impression of the political perception, and members from ACARE WG4, ACARE SIB, ACARE IRG and EASN were consulted to complement the expert perception on aviation safety.

A first brief overview of the results discloses that the public preferably chooses the aircraft as means of transport for longer travel distances. When asked about their associations with air transport people spontaneously mention safety, time saving and security, not indicating any direction of valuation. European politicians have recently resumed the review and the analysis of aviation safety procedures due to the Germanwings accident and the increasing market penetration of RPAS technologies in the EU. Furthermore, the consulted experts mentioned safety statistics and personal knowledge about safety as the predominant reasons why they felt safe when flying. Their experience in the field of aviation safety encourages their positive perception. Weather conditions, however, are rated as a potential negative external influence on aviation safety. Employment figures for the aerospace and defence sector in Europe have steadily increased in the recent years. Distinct data for the aviation safety sector is not available.

For the three EU safety projects that returned the questionnaire, the coordinators indicated that two to five researchers per partner work in a project and around 10 experts additionally support their work. The investment share for aeronautics and air transport within the EU FP7 budget amounts around 1,000,000,000 € between 2007 and 2013. Aviation safety related activities received 23.5% of that budget (35.8% including private and national investments). French and Irish regions combined obtain more than 25% of this funding. Between 2004 and 2013, the number of accidents in states covered by the European Aviation Safety Agency (EASA) has decreased while, during the same time period, the number of flights has increased. Europe reveals the lowest rates of fatal accidents per 10 million flights compared to other global regions with an average of 1.8 between 2004 and 2013.

The following sections further describe the information collection process and the related assessment results on an indicator level.

2.1.1. "Feel good factor" (safe to fly)

Public perception

Public perception of aviation safety relates to the difference between an objective "truth" based on statistics and facts and a subjective "truth" shaped e.g. by personal experience, public opinion and/ or

media coverage. The people's attitude towards certain topics is composed of the subjective perceptions from individuals representing a certain population group.

This study on public perception has been conducted using a one-page questionnaire (see Appendix C) which was circulated to the members of the OPTICS consortium asking them to interview a number of random people on the street. On average, answering partners have sent 20 filled-in questionnaires containing raw data which has been collected and processed in a spreadsheet. Nearly a hundred entries have been processed using the four tabs: "Input Data", "Segmentation", "Transports" and "Keywords". The analysis presents the most important results of the survey.

"Input Data" gathers the information provided where each row represents a questionnaire and each column its detailed fields. As there are different types of data, different approaches have been taken into account. Some data can only be expressed in fixed values such as the organization that submitted the document, the frequency of flights taken by the interviewee, age range and gender. This data are structured in segments. In contrast, hand-written responses present much more variability and, therefore, a tagging system has been adopted as an effective method to handle the data. Comments from the respondents help to refine the tagging procedure and are, thus, included in a pertinent cell if applicable. The "Segmentation" tab contains categorised lists of predefined answers created to improve the collection process of those parameters. A table counts the number of data entries and calculates its frequency. The results are unbiased with respect to gender but not with respect to age as the group of people aged between 35 to 49 years is prevailing. The results of surveyed travellers are similarly distributed covering all possible flight ranges. The tabs "Transports" and "Keywords" include the record of distinct replies, the tags assigned to them and the unique values to be evaluated. The data input was summarized in tables, where the top 20% of answers are highlighted in every column.

Figure 1 shows the results for the public selection of the preferred transport mode on predefined route distances. When subdividing travel into different distance categories, short routes of about 200 to 400 kilometres, medium routes of about 400 to 600 kilometres and long routes for over 600 kilometres, car and train are the preferred transport modes up to medium distances and aircraft for long routes.

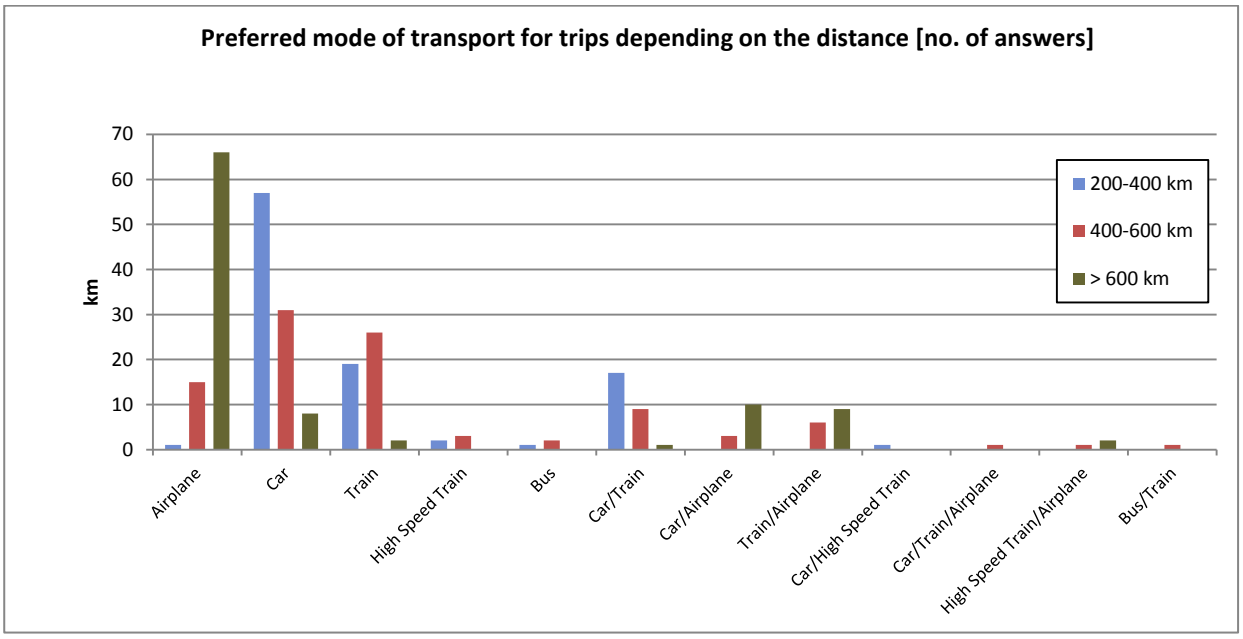

Figure 1: Preferred mode of transport depending on the distance. (Source: results from public consultation)

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More than 30 keywords have been considered and represented in the study with safety, time saving and security as the top three aspects firstly coming to the respondents' minds when thinking of air transports. Taking into regard only terms which were mentioned 20 times or more the public associates "safety", "time-saving", "security", and "holidays" with air transport. Most of the respondents did not indicate whether they perceive, for example, "safety" or "security" positively or negatively when mentioning it in connection with air transport. Terms which indicate a judgemental statement such as "annoyance" or "wait" and "delay" came to the public's mind less often, being mentioned 13 to 16 times.

The data presented in this section indicates that the people that were asked for their opinion generally were aware of aspects related to "safety" and "security" in air transport and that their general perception of aviation was linked rather to positive aspects such as "holidays" and "time-saving". That people generally prefer an aircraft for journeys over 600 kilometres indicates that the benefits this mode of transport offers outweigh negative associations such as "delay." A more differentiated picture could be created if a market study with a representative sample of European citizens and more specific questions was conducted.

Political perception

This indicator investigates the perception of aviation safety from the perspective of authorities and politics. It represents an intermediary level between public perception and expert perception: Political instances develop an informed opinion based on personal experience and/ or media coverage like the public but also have access to background information, consultants and dedicated expert groups complementing the opinion-forming process.

At EU level, the political body in charge is the EU Parliament who has recently been reviewing aviation safety proceedings (European Parliament (2010)) mainly due to the Germanwings accident (European Parliament (2015a)). Furthermore, the EU Parliament expressed its concerns about the safe operation of remotely piloted aircraft systems (RPAS), commonly known as unmanned aerial vehicles (UAVs), in the field of civil aviation (European Parliament (2015b)).

Parliament's proactive support for the establishment of an effective European system for civil aviation safety has always placed particular emphasis on air passenger rights regarding information and the effectiveness of the European Aviation Safety Agency. Therefore, key European Parliament documents in this domain are:

- Recommendation of March 21, 2002 on the Council common position for adopting a European Parliament and Council regulation on common rules in the field of civil aviation and establishing a European Aviation Safety Agency (A5-0093/2002),
- Report of March 9, 2004 on the joint document approved by the Conciliation Committee for a European Parliament and Council directive on safety of third countries aircraft using community airports (A5-0125/2004),
- Report of October 19, 2005 on a regulation proposal from the European Parliament and the Council for air transport passenger-related information, for information of the operating carriers' identity and for communication of safety information by Member States (A6-0310/2005) and
- Legislative resolution of December 12, 2007 on the Council common position for adopting a regulation of the European Parliament and of the Council on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (P6_TA(2007)0607).

The internet search conducted to collect this information suggests that aviation safety is mainly discussed on a political level in relation to specific incidents or technological/ processual innovations that require legislative actions. It is thus possible that the awareness of aviation safety issues is higher for people involved in the political sphere than for the general public.

Expert perception

This indicator addresses the personal opinion of experts with respect to the question whether they feel safe when flying. Experts have acquired knowledge and skills through study and practice over many years in different areas of the air transport system (not necessarily aviation safety). It is assumed that expert perception is strongly influenced by in-depth knowledge of the system's functioning and statistical data, e.g. on incidents and accidents. Expert perception can differ from public perception because of the experts' ability to acquire and understand relevant information based on a large body of background knowledge.

To address this dimension three simple questions were formulated. Members of ACARE WG4, ACARE SIB, ACARE IRG and EASN were individually asked to answer the following questions, either personally in a workshop or via e-mail:

1. "Do you feel safe when flying? If yes, why?"
2. "Are there any external influences that effect your perception of the level of your personal safety?"
3. "Do you think that your perception is influenced by your expert knowledge on this topic?"

There were no pre-defined answer categories (except YES/NO), which means that each candidate was completely free in his or her answers. Consequently, some experts gave more reasons why they feel safe or unsafe than others. However, each reason given accounted for one response so that an aggregation and categorization was possible. The answers were collected and analysed with respect to similarities and major differences using descriptive statistics. In total, 40 expert opinions were gathered: 20 from ACARE WG4, 7 from ACARE SIB, 5 from ACARE IRG and 8 from EASN. Each observation had the same weight. Concerning the first question, 92% of all participants indicated that they felt safe when flying and only 8% said that they did not feel safe (WG4: 90/10, SIB: 100/0, IRG: 80/20, EASN: 100/0; numbers in %). The main reason for feeling safe was related to safety statistics (27% of all answers) followed by personal knowledge about safety (19%).

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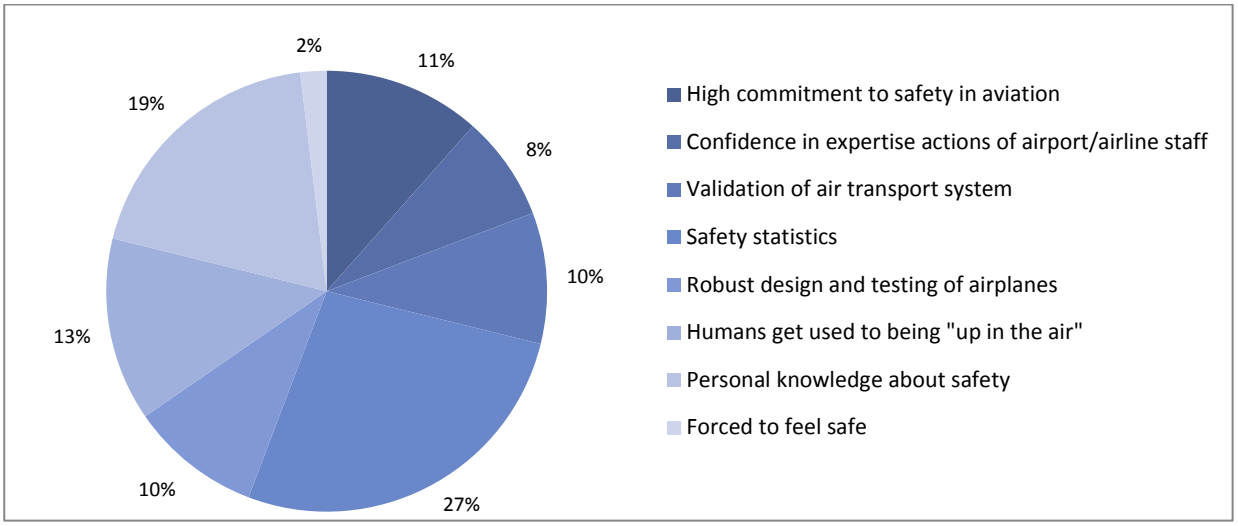

Figure 2: Results of expert opinion for the question "Why do you feel safe when flying?" (Source: results from expert consultation)

As the second question was an open question, too, a multitude of reasons was given specifying aspects that influence the perception of the level of personal safety. Including aspects that were only mentioned by one respondent, 21 different reason categories were identified. Omitting single mentions resulted in 13 categories, which are depicted in the Figure 3. According to these numbers, weather conditions (24%) are the crucial factor influencing the feeling of personal safety, followed by turbulences (11%) and airline reputation (10%).

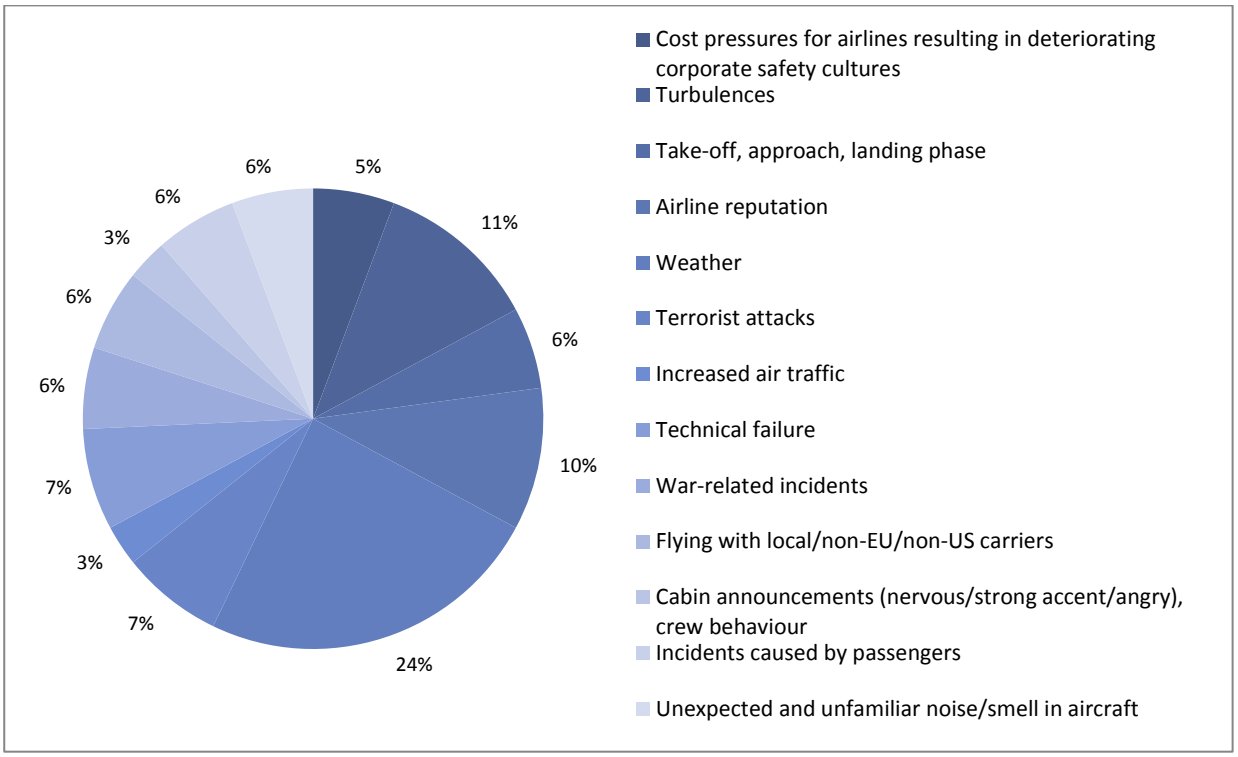

Figure 3: Results of expert opinion for the question "Are there any external influences that effect your perception of the level of your personal safety?". Categories were defined within the assessment. (Source: results from expert consultation)

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For the third question, answers were documented only from ACARE SIB, ACARE IRG and EASN, which means that the number of observations was reduced to 20. 85% of these experts believe that their perception is influenced by their expert knowledge on the topic, 5% claim the opposite and 10% are neither supportive of the first nor the second notion.

The results from the ACARE WG 4 workshop and the answers returned via e-mail show that aviation experts really trust the air transport system to provide a safe travelling experience. They rely on their background knowledge on air transport technologies and processes which gives them confidence rather than making them unsecure

Summarising this category it can be observed that experts as well as the general public are aware of aviation safety related topics but to not judge them as being an important factor to consider before taking the decision to step on board of an aircraft. This can be rated as a success for the industry and all institutions involved in providing a safe air journey. The next section will focus on employment figures related to aviation safety.

2.1.2. Employment

People directly / indirectly involved in safety research / in safety (project)

One central basis for the well-being of society and economy is the employment level. The impact an industry sector or R&D efforts in that sector have on the creation of new jobs, thus, is a direct benefit for society and economy. This indicator aims at specifying this benefit for the sector of aviation safety. To this end, data, that indicates the amount of people who are full-time or part-time employed in aviation safety research, is required. Three different sources of information were addressed: ASD, EREA and the project coordinators of the four EU FP7 research projects that were picked for the trial assessment.

ASD and EREA both indicated that they cannot provide employment figures broken down to the level of detail that would be needed to extract figures for safety (research) since employment figures are not collected at this level of detail. ASD, however, gathers direct employment figures for the overall aerospace and defence industry in Europe. For 2013, ASD (2014) recorded 777,900 people being employed in this industry sector. This figure has been continuously increasing over the period of five years by almost 100,000 people. 66% of the people employed in the Aerospace and Defence Industry work in the aeronautics sector, 29% in land and naval defence and 5% in the space sector.

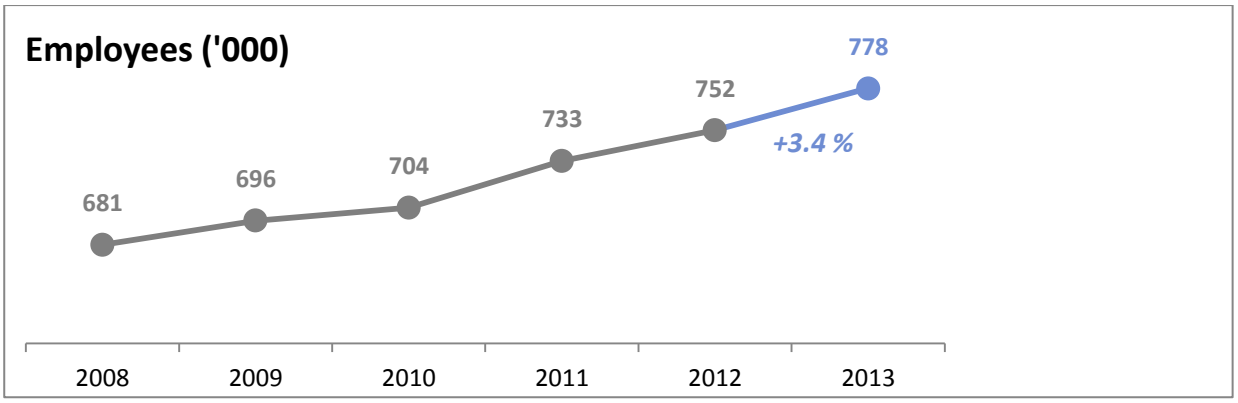

Figure 4: Aerospace and Defence Industry employment in Europe between 2008 and 2013 (Source: ASD, 2014).

EREA focuses on the aviation and aerospace research community and collects statistics from its members, 11 European research centres active in aeronautics and air transport including NLR, DLR,

CIRA and ONERA. In 2013, 4,517 people were employed in aviation research by the member institutes. There is no further breakdown provided regarding the different areas of aviation research.

An additional internet search revealed that a report was prepared for the European Commission in 2012 by Steer Davies Gleave (2012) analysing available sources concerning direct and indirect employment in the air transport sector. The authors of this report highlighted that the data for air transport employment in Europe is fragmented and inconsistent leading to severe uncertainties regarding the results. The report differentiates between main employer groups such as airports or ANSP but does not extract safety related figures. Based on a range of sources, they estimate a total of 698,200 people being directly employed in the EU air transport sector (excluding regulatory functions).

The project coordinators of the four EU FP7 research projects that were selected for this trial assessment were asked to give both the total number of researchers involved in their project and the number of experts beyond the core project team. Despite minor inconsistencies within some of the questionnaires, the number of researchers per project ranges between 30 and 39 for the three projects where data was available. The number of additional experts related to the project varies between 10 and 12. If such an analysis was conducted throughout all projects of e.g. a Framework Programme one could derive an average number of researchers per consortium. However, this would not allow to make a statement on the total number of people employed in safety research in Europe as there are many different ways in which one can be involved in aviation safety research (e.g. industrial R&D projects or national research projects). Furthermore, many researchers simultaneously work on different projects.

The information collection process for this indicator showed that the data that would be necessary to gain an overview of the number of people involved in aviation safety is not available. Neither on an industry nor on a research level is such data collected. It is, consequently, not possible to make any statements about the impact certain EU research projects had on the overall employment level as even the baseline data does not exist. Only a large-scale, representative study across the EU would be able to provide some insights into this aspect.

2.1.3. Investment in safety research

Capital investment

The indicator is defined as the funding invested in aviation safety related research. When looking at projects funded by e.g. an EU Framework Programme the cost of research is generally shared between the EU and the institutions involved in the project. Of course, aviation safety research is also taking place at the industry level which is not necessarily supported by third party funding. It is, however not possible to collect any data on these efforts. The measurement of this indicator, thus, focusses on capital investment as part of EU safety research projects.

Information about the total budget that the EU spent on research in FP7 as well as about programme details are published online (European Commission 2015a). These figures can be used to calculate the share of EU-investment in aviation safety research in relation of the total EU-investment in FP7.

The total FP7 budget was set at 50,521m€. While the sub-programme Cooperation with a volume of 32,413m€ can be regarded as the core of FP7, the remaining building blocks Ideas, People, Capacities and Nuclear Research (EC) focus on topics such as “frontier research”, researcher mobility and career development, research capacities or nuclear research. In the sub-programme Cooperation research is carried out in ten key thematic areas, one of which is transport (including aeronautics). Between 2007 and 2013 the EU spent around 1,000m€ on research in the field of aeronautics and air transport. Aeronautics and air transport entailed the following sub-categories: Greening of air transport,

increasing time efficiency, customer satisfaction and safety, improving cost efficiency, protection of aircraft and passengers, air transport of the future.

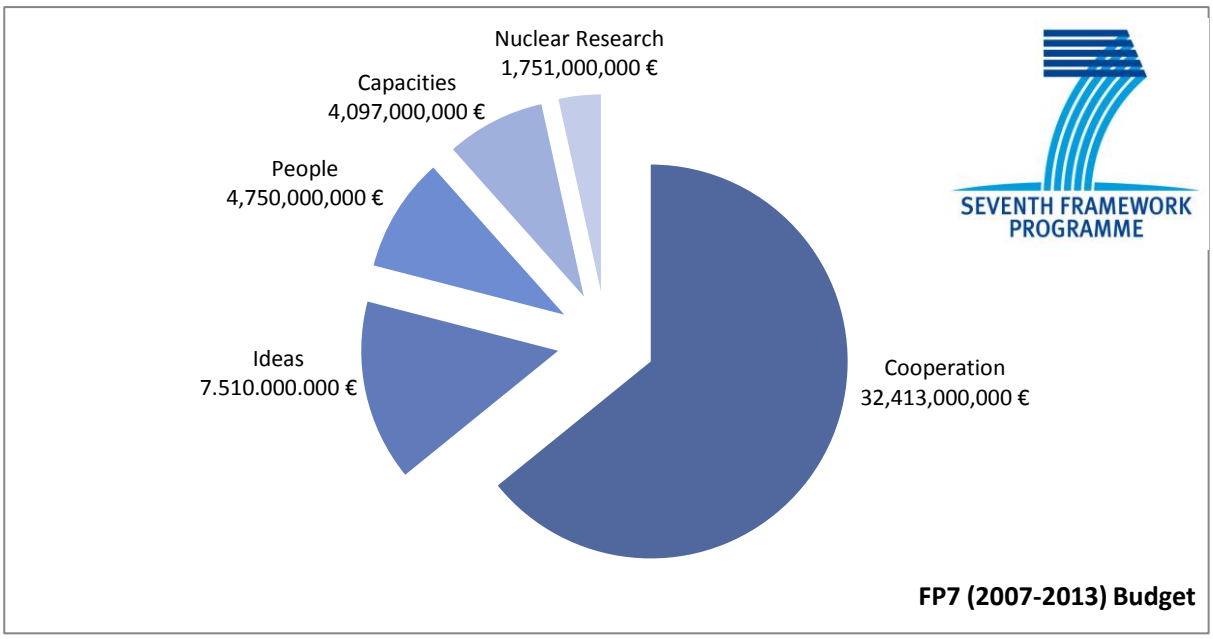

Figure 5: Total budget of the 7th Framework Programme (FP7) of the European Union. (European Commission 2012)

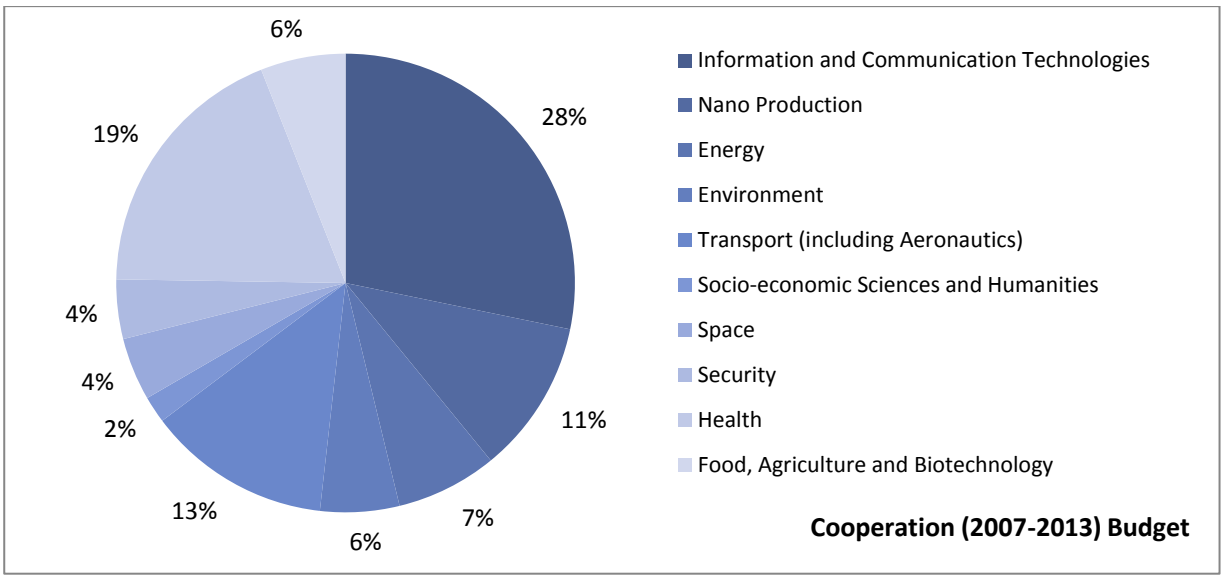

Figure 6: Budget distribution of the FP7 sub-programme *Cooperation.* (European Commission 2015b)

EU FP7-funded projects with explicit safety content have already been identified by the OPTICS consortium as the basis for OPTICS D2.1. In this deliverable the contributions of EU FP7 projects towards long term goals specified in the ACARE SRIA are presented. The EU's Community Research and Development Information Service (CORDIS) provides both the total cost of these projects and the contribution of the EU. Aggregating the numbers of these projects produces the amount spent for projects with explicit aviation safety focus by the EU between 2007 and 2013. Within FP7 projects relating to aviation safety research had a total volume of about 358,5m€. The EU contribution in the course of FP7 was about 235m€, thus accounting for around 60% of research investment in this area. This represents around 0.47% of the total FP7 budget.

The overall capital investment for safety research projects funded with the EU FP7 as well as the share of the EU contribution can be specified based on published data. However, this does not allow a statement about the total investment made in aviation safety in Europe as there are a number of different research programmes, funded by industry as well as third parties that add to this number. It is possible to broaden the scope of the capital investment data analysis over the course of the next years as the OPTICS consortium will collect data not only related to Horizon2020 but also research programmes such as SESAR and Clean Sky as well as national research initiatives.

Dispersion of capital investment

This indicator aims at collecting information on the regional distribution of capital investment in aviation safety research throughout Europe. The results are based on the four chosen safety projects AircraftFire, HAIC, A-PIMOD and Prospero. The results can, thus, only be interpreted from a methodological point of view as the numbers collected are not representative for the overall FP7 investment in aviation safety research and, hence, do not allow for any generalisation. If, however, such an approach was pursued for all projects contributing to aviation safety research, areas of excellence could be identified.

In a first step, information about the total budget and the EU budget per project partner for the chosen safety projects was collected. As the chosen projects are co-funded by EU FP7, project information can be obtained online via CORDIS and the project homepages. All project participants are listed in CORDIS together with the amounts of EU funding they receive. Furthermore, CORDIS publishes the total project budget of each project but does not present a breakdown by partners. The project homepages as well as the available material from the selected safety projects were scanned in order to collect information about the project budget. Both sources did not contain any information about the total project budget breakdown. The analysis presented in this section thus only refers to the EU contribution per partner for a given project which necessarily produces a distorted picture.

In a second step, additional information about all project partners was collected concerning their countries and regions. This step would allow the identification of regional aviation safety research centres if more than four projects were analysed. The resulting capital dispersion map is shown in Figure 7. However, the depiction is not fully comprehensive because the distribution of privately funded aviation safety research across the project partners is not available.

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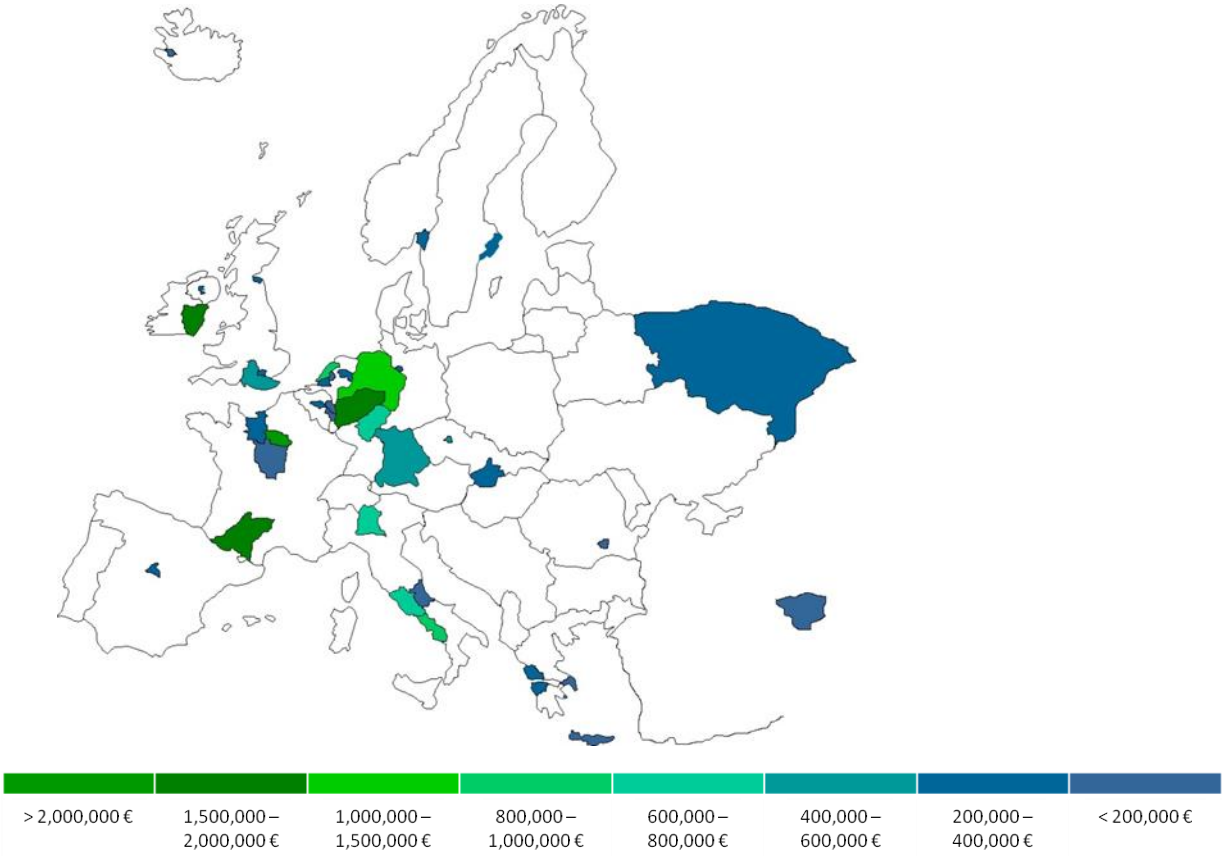

Figure 7: Regional dispersion of EU aviation safety research funding for selected projects. (Source: own depiction based on CORDIS data)

EU funding for all four projects amounts to 25.3m€. Total funding, including the project partner's investments, adds to 38,352,295€. More than one fourth of the EU funding is invested in projects located in the French region Île-de-France (7.7m€) followed by the Irish region Leinster (1.9m€) and Midi-Pyrénées, France (1.7m€).

As the data in Figure 7 only represents the capital dispersion of four EU projects no further conclusion can be drawn on this basis. If such an analysis was, however, conducted for all projects within a certain Framework Programme or any other funding scheme it would allow to identify regional areas of concentration. These could then be analysed further based on additional data, e.g. share of research institutes, academia and industry or share of specific safety topics.

2.1.4. Safety improvement

Reduction of incidents

This indicator addresses the development of aviation accidents/ incidents in Europe over time. This is an important area were the benefit that aviation safety research can create for society and economy is very clear.

The European aviation safety review that is published annually by EASA serves as the main source of information for this task. These reviews include statistics about accidents and incidents in the aviation sector in Europe. In addition, the following safety reports were scanned for reports on the reduction of incidents: Boeing Safety Report 2014, CAA Global Fatal Accident Review 2002-2011, ICAO Annual

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Safety Report 2014 and IATA Safety Report 2014. The gathered information enabled an overview over both the European and worldwide aviation accident statistics.

The main statistics show that despite some bigger accidents flying has become safer in the last ten years (2004-2013), not only in Europe but also on a global scale. This conclusion becomes even clearer when a longer period back to the 1960s is examined. Generally, major improvements in aviation safety were achieved. The following Figures 8 and 9 display the development of fatal accident figures between 2004 and 2013.

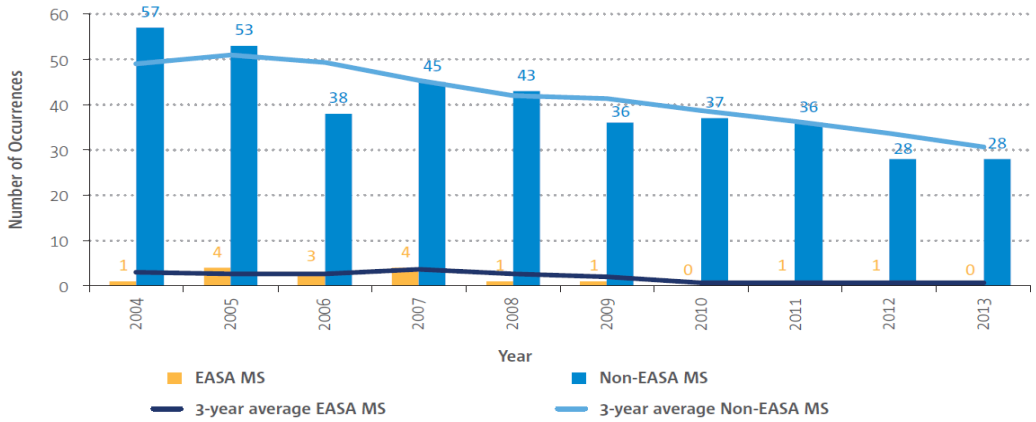

Figure 8: Number of fatal accidents in EASA Member States (MS) and third country operated CAT aircrafts, above 2,250 kg MTOM, 2004-2013. (EASA 2013)

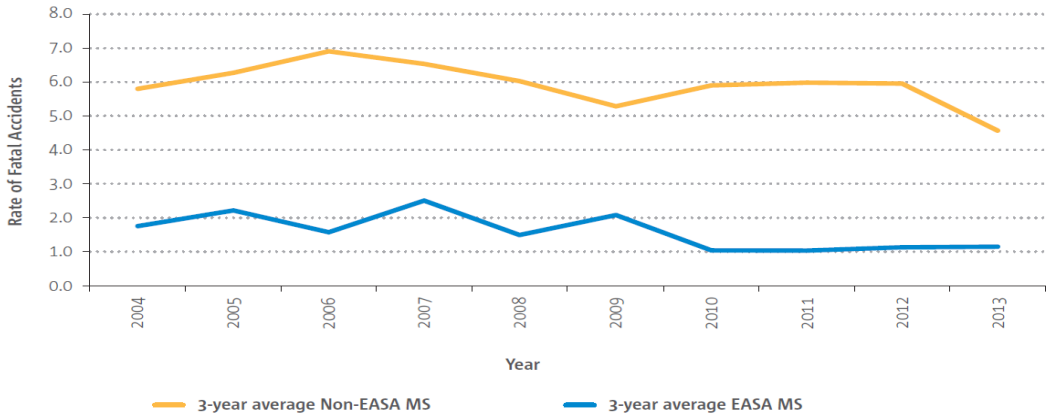

Figure 9: Rate of fatal accidents per 10 million flights in EASA MS and third country operated scheduled passenger operations, aircrafts above 2,250 kg MTOM, 2004-2013. (EASA 2013)

EASA also collects and processes figures for different occurrence categories for fatal and non-fatal accidents involving EASA member states operated aircrafts between 2004 and 2013. Figure 10 gives an overview of the occurrence rates of the defined categories as cumulative figures for the period between 2004 and 2013.

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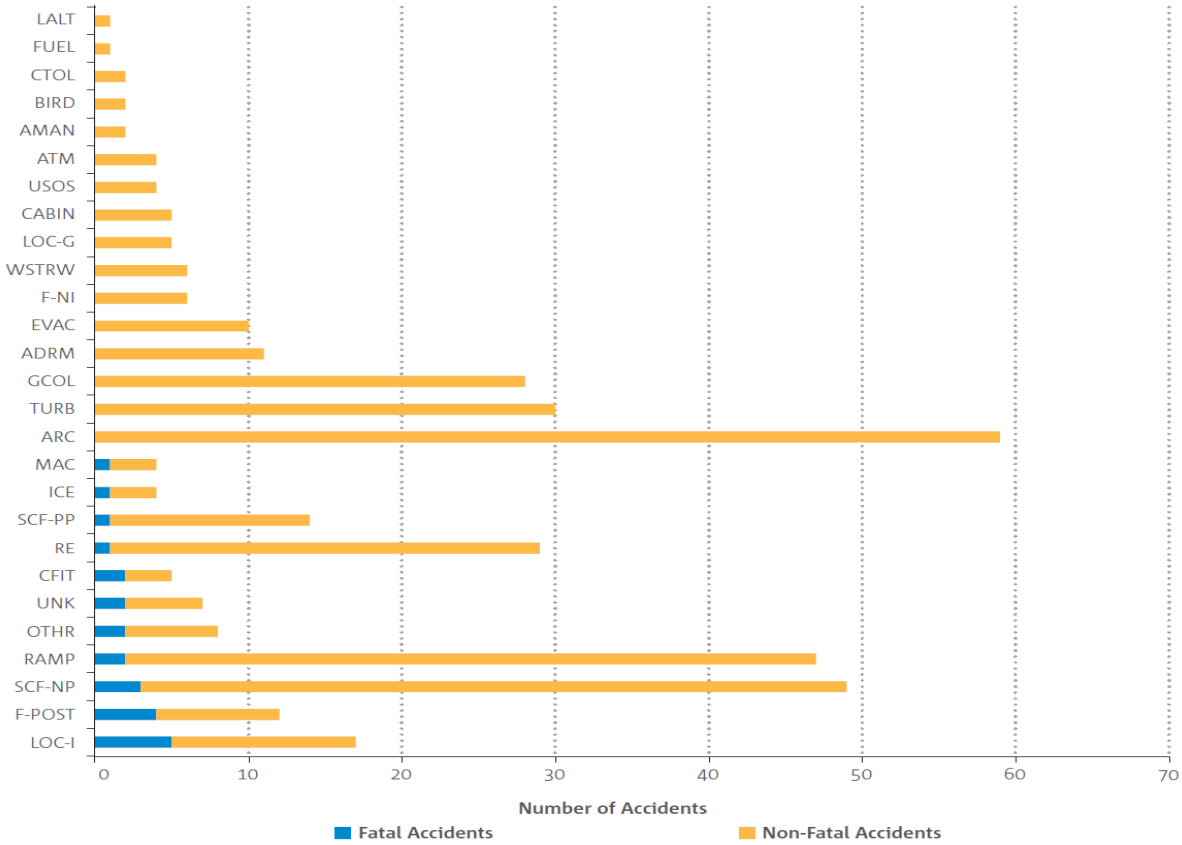

Figure 10: Occurrence categories[1] for fatal and non-fatal accidents involving EASA MS operated aircrafts, 2004-2013 (EASA 2013)

The main reasons for non-fatal accidents were Abnormal Runway Contact (ARC), System/Component Failure or Malfunction power plant (SCF-PP) and Ground Handling (RAMP). For fatal accidents, three main categories were identified: Loss of Control - In-flight (LOC-I), Fire/Smoke post-impact (F-POST) and System/Component Failure or Malfunction power plant (SCF-PP).

According to EASA, the number of flights in EASA member states has increased by about 5% between 2004 and 2013 with a pointed decrease caused by the financial crisis between 2008 and 2009. In the same period, based on a 3-year average, the number of fatal accidents per year dropped from around 3 per year to almost 0. On a 3-year average the rate of fatal accidents in commercial aviation per 10 million flights dropped from around 1.9 to around 1.1. On average, the rate of fatal accidents in commercial aviation per 10 million flights between 2004 and 2013 was around 1.8 for Europe, which is the lowest number of all world regions.

[1] Abbreviations: LALT – low altitude operation, FUEL – fuel related, CTOL – collision with obstacle(s) during take-off and landing, BIRD – (near) collision with bird(s), AMAN – abrupt manoeuvre, ATM – air traffic management/communication navigation surveillance, USOS – undershoot/overshoot, CABIN – cabin safety event, LOG-G – loss of control (ground), WSTRW – windshear or thunderstorm,F-NI – fire/smoke (non-impact), EVAC – evacuation, ADRM – aerodrome, GCOL – ground collision, TURB – turbulence encounter, ARC – abnormal runway contact, MAC – airprox/TCAS alert/loss of separation/near midair collisions/midair collision, ICE – icing, SCFPP – system/component failure or malfunction (powerplant), RE – runway excursion, CFIT – controlled flight into or toward terrain, UNK – unknown or undetermined, OTHR – other, RAMP – ground handling, SCF-NP – system/component failure or malfunction (non-powerplant), F-POST – fire/smoke (post-impact), LOC-I – loss of control (in-flight)

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Summarising the development of safety incidents over the past decade one can observe a steady decline. Compared to other regions of the world Europe has the lowest rate of fatal accidents. This means that the efforts in creating an ever safer aviation system for the European citizens have been a success. In the next category “Environmental Considerations” the focus will shift from specific socio-economic aspects to the interdependency of safety-related research and environmental concerns.

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2.2. Environmental Considerations

This category addresses the relation between research in the area of aviation safety and environmental concerns. Technological and process innovations improving the safety level affect the environmental impact of the air transport system and, vice versa, advancements aiming at reducing the ecological footprint of aviation could impact aspects related to safety. It is relevant to investigate whether research projects focussing on aviation safety also take effects on the environment into account and, if they do so, if this impact is considered implicitly or explicitly. This relation is also interesting from the reverse perspective: do research projects, mainly focussing on environmental aspects, also take into account the possible impact of their developed solutions on safety? This trade-off between safety solutions and environmental impact is traced in this category. The coordinators from aviation safety related projects reported that environmental impacts are neither explicitly nor implicitly considered in their project work. The coordinator from CORE-JetFuel, a CSA project dealing with sustainable alternative fuels for aviation, identified one project that deals both with safety-related aspects and alternative fuels.

2.2.1. Impact

Trade-off between safety solutions and environmental impact

Because there is only one indicator in this category, it directly deals with the trade-off between environmental consideration and effects on aviation safety described in the previous paragraph. Two different information sources were identified: Coordinators of EU safety projects and CSA projects addressing various aspects related to environmental considerations.

In the questionnaire distributed to the project coordinators of the safety projects selected for this trial assessment, the coordinators were asked if the projects considered explicit or implicit environmental impacts. Feedback from all three projects indicated that neither impact was taken into account. One project coordinator indicated, though, that the approach, developed in the course of the project, could integrate risks related to environmental aspects in the developed assessment framework.

In order to approach this indicator also from the environmental side, the CSA sister projects of OPTICS – X-Noise, CORE-JetFuel and FORUM-AE – were contacted. They were asked whether any EU research project they assessed considers possible relations between advancements related to environmental benefits and effects on the aviation safety level. Only CORE-JetFuel provided feedback on this, indicating that impacts on safety should be considered if non-drop-in fuels are concerned. The coordinator highlighted two projects that took safety-related aspects into account: SAFUEL and burnFAIR. SAFUEL was part of the OPTICS analysis of FP7 projects as it explicitly deals with safety. In this project a safer fuel system of the future is developed, tested and validated and alternative fuels are taken into account in this analysis. In burnFAIR the aim was to generate data on the regular use of alternative fuels over a long period of time. To this end, a Lufthansa A321 was operated with one engine fuelled with a 50% blend of conventional jet fuel and HEFA synthetic fuel over a period of six months. After this operational period thorough technical analysis was conducted to identify possible consequences on engine health and potential operational issues that were not found in laboratory tests or single missions.

Based on the available information sources it can be concluded that neither safety projects address environmental impacts regularly nor the other way around. Consequently, this might be an area where a broader cooperation between different research focus areas should be considered.

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2.3. Industry Competitivity

Innovation is becoming a major competitive differentiator not only in Europe but worldwide. Revolutionary and evolutionary technological and process advancements are major drivers for the air transport system. It is a central goal of the European Commission to maintain the global leadership of the aviation industry in the future (European Commission, 2011). One important aspect of this high level goal is to ensure the competitiveness of the European aviation industry. This is a major challenge as the market requests shorter cycles for the integration of new technologies and international competitors enter the market with an aggressive approach on prices.

This category collects information related to the preservation of leadership of the European industry. To cover different aspects associated with this goal, industrial as well as regulatory concerns from the initial development of new ideas to the actual introduction to the market are addressed. An important prerequisite is the access to a workforce with appropriate skills and experience before ground-breaking solutions can be developed. These solutions have to adhere to certain standards and regulatory restrictions before they can finally be introduced to the market.

Project coordinators from four aviation safety related projects were asked for their feedback on the indicators in this category. In addition, different experts provided their opinion in relation to questions concerning e.g. the global standardisation/regulation process, the impact of research on workforce skills and the facilitation of time to market.

Results from the coordinator survey point out that spin-off activities and business cases do emerge from safety research projects. However, the occurrence of patents as a result of safety research attempts was not reported. Standardisation requirements are considered within the safety research projects. Two project coordinators report that regulation changes required in order to implement the project results are noticed during the project work. One project coordinator reported that the consortium contributed to the development of international safety regulations for testing procedures of the materials they investigated within the project. One of the project coordinators highlighted that end users are integrated in the development of a new technology in order to get feedback in an iterative manner and to ensure market acceptance of the project's outcome. In the following, indicators relating to the "Industry Competitivity" category are presented in detail.

2.3.1. Leadership of safety innovation & technology

Development of cutting edge safety solutions/technologies

This indicator addresses the introduction of truly innovative processes, technologies and services based on advancements related to EU research projects in the aviation safety area. The project coordinators of the safety projects chosen for the trial assessment were identified as information source for this.

They were asked if they could make any statements about the possible market penetration of their developed solution. As the assessed projects do not aim at high TRL levels (e.g. beyond TRL 6) this was not possible.

A comprehensive answer to this question is only possible if a research project moves from the development of a solution to its actual implementation. At early TRL stages the focus lies more on basic research than on detailed market studies and the assessment of a possible penetration potential.

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Creation of new business opportunities

This indicator takes one step back, asking not for results of a fully-fledged market study but investigating whether the coordinators of the research project have already thought about possible business cases for their results in the course of the research project.

The project coordinators were asked whether they foresee the delivery of a business case in relation to the work conducted during the research project as an indicator for cutting edge solutions. Two of the three coordinators denied this statement. Of course, the development of a business case is strongly linked to the TRL levels reached within a project and projects aiming at low TRL levels cannot be expected to already deliver a business case. One project coordinator, however, reported that a business case actually is envisaged and that the consortium is exploring the regulatory framework and working closely with operational partners to better understand specific user needs.

Furthermore, the project coordinators were asked if they planned any direct spin-off, e.g. a regular business case or the setting up of an internal research unit, based on the results. Two of the three coordinators stated that this was not planned at the moment but the third indicated that a commercial spin-off is indeed planned linked to the envisaged business cases described above.

New findings in research projects can open up opportunities for business. If a research project is working on low TRL levels the potential benefits envisaged for the introduction of a solution are, however, not yet realisable. In such cases the projects try to collect more knowledge to decide whether the research path they are following is worthwhile to continue or not. If research produces promising results it is important to start thinking about possible obstacles to market introduction at an early stage to be able to prepare for future challenges. This is reflected by the information that was collected from the project coordinators on this indicator.

2.3.2. Global standardisation/regulation driven by Europe

Standards developed from safety research outcomes

The development process of standards requires in-depth knowledge in a certain field and relevant experience on technical as well as methodological aspects. This indicator aims at a better understanding of the relation of the results obtained in EU safety research projects and the generation of standards.

Safety research projects, especially when rethinking existing constraints and developing technological and procedural advancements, bring together experts in a specific safety topic. Having a number of experts grouped in a consortium is a great chance to discuss the need for new standards based on the development of the technologies or processes extending current limitations and best practices. The project coordinators of the safety projects chosen for the trial assessment as well as experts from EUROCAE and ICAO were approached for information concerning this indicator.

ICAO indicated that they could not provide any information on the relation of research projects and the introduction of new standards as they do not track the development of “Standards And Recommended Practices” (SARPs). Also EUROCAE had no information on this relation but highlighted that not many standards are generally developed as part of a research project. This perception is mirrored by the answers of the project coordinators: none of the research projects they represented contributed to the development of new standards. The information collected in relation to the creation of standards shows that this process is not something that is generally focussed on by research consortia. Rather, standards are discussed and developed by dedicated expert groups brought together specifically for this purpose.

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Regulation based on safety research project outcome

Technological or processual improvements as an outcome of safety research projects can challenge existing regulation and certification processes. Cooperation between representatives of the safety research projects and the responsible regulator at all levels can thus be crucial for a successful implementation of the research project outcome. Again, project coordinators as well as experts from EASA and FAA were consulted to gain insights into the regulatory process.

The project coordinators were asked whether they considered the impact their developed solution could have on the current regulatory framework. Two of the three project coordinators that provided us with feedback stated that their project results could have an impact on the current state of the regulatory framework. Safety topics that could be affected comprise, amongst others, the implementation of a safety management system, testing standards and procedures with respect to the threat of fire on-board the aircraft and the outcome of performance reviews of the implementation of the Single European Sky programme.

One project coordinator highlighted that his project contributed to the discussions on testing standards and procedures for composite materials and passenger evacuation. The second project coordinator indicated that the results from his project could potentially affect the development of a next generation safety management system and risk regulation, but that it was too early to make any definite statements. In line with the indicator “Creation of new business opportunities” regulatory aspects become more and more relevant if higher TRL levels are reached. An expert from EASA confirmed that there is still room for improvement when it comes to the cooperation with research in the area of regulation and certification. To this end, it is important to better comprehend the whole landscape of safety activities but also to improve the regulation development process. Aviation safety research projects do not always consider the mandatory changes in regulation their achieved results may evoke because they focus on the development part and not so much on the implementation of their outcomes. Amendments to existing aviation regulations sometimes can be linked to new operational or technical concepts that are based on specific research projects, but not all new concepts imply regulatory changes. The FAA could not provide any input to this indicator.

Based on the answers provided in relation to this indicator, one can conclude that there is a need for even more cooperation between the research community and the regulator. It is important to integrate the findings from research projects in the regulatory process at the right moment. If a project is working on the early stages of a development process (low TRL levels) regulatory aspects can be rightly left out but the contact should be established as soon as the results prove to be beneficial as well as feasible.

Global penetration of EU standards and regulation

Achieving and maintaining safety in aviation is a global objective. If standards and regulatory procedures based on European research and innovation are established on an international basis, Europe’s leading role at an international level is strengthened. This indicator collects information from EASA on the implementation of EU regulation on a national level as well as the uptake of rules and regulations defined by EASA on a non-EU level.

EU member states are mandated to implement standards and regulations from EASA. Transitioning options occasionally enable the European member states to delay the national implementation. Several EU-neighbouring countries, for example Norway or Switzerland, are part of the EASA system and, thus, adopt EU regulations as well. Main regulations for other states are derived from ICAO conventions. Additionally, bilateral working arrangement between EASA and ICAO assure a continuous exchange and collaboration.

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Based on the information collected in relation to this indicator it can be concluded that for a research project to have an impact on national, EU-wide or non-EU regulation it is important to involve EASA at an early stage. EASA acts a central focal point for this topic within Europe and can also facilitate exchange of best practices beyond its Member States.

2.3.3. Impact of research on workforce skills

Appropriateness of skills to the aviation sector needs

To remain competitive, the industry sector depends on the availability of a qualified and highly skilled workforce. A significant contribution of safety research in supporting this need is the ability to locate people with the necessary workforce skills and to further educate young professionals. This indicator focusses on whether the aviation safety sector can choose their employees from a sufficiently large workforce that has the right type and level of qualification.

The project coordinators were asked whether they had to recruit any personnel to be able to conduct the project and if they were satisfied with the quality of education the universities deliver in relation to the safety specific tasks within the project. All three coordinators indicated that they did not have to recruit any new personnel for the project to be conducted. Furthermore, they agreed that the universities were providing them with sufficiently qualified personnel. An expert representing both ASD and EREA was asked whether he had any information on the availability of the appropriate workforce for the aviation safety sector, which he did not.

The small number of projects investigated does not allow for any generalisation but it is a good sign that all coordinators were very satisfied with the education and skills of their workforce. This becomes even more important when looking at the indicator “Number of people taught in safety related classes” that is described in Section 2.4.5 where this topic will be picked up again.

2.3.4. Facilitation of time to market

Preparation of adoption of safety project results

The indicator “preparation of adoption of safety project results” aims at obtaining information about the evolution of time to market of research results and related costs including aspects such as end user involvement, the preparation of a business case and the consideration of certification and regulatory conditions within the project timeframe. Project coordinators and ASD were identified as information sources for this indicator.

The project coordinators were asked different questions with regard to this indicator, some of which also link to other indicators taken into account in this study: business case development based on the project (Section 2.3.1), consideration of certification requirements related to the project’s results (Section 2.3.2) and impact on regulatory framework (also Section 2.3.2). One question specific to this indicator aimed at gathering information about end user involvement in the projects. All coordinators indicated that they involved end users. They were involved either directly in the consortium, through an Advisory Board, through workshops or through validation activities where they could test and interact with the project results.

Strong emphasis on the orientation of research towards the needs of the end users makes their involvement more or less mandatory for every project. It is a crucial step to raise awareness for the potential outcome and ensure that research efforts address needs of the operational field. There are many different ways of doing so as the three investigated projects demonstrate. The three projects all involved at least ten experts from outside in of the consortia in the project. A further advantage of the

involvement of end users beyond the direct input from these experts is the multiplication effect since they can act as multiplicator in their own networks, making the existence and also the results more widely known.

As already presented in Section 2.3.1 and 2.3.2 the delivery of a business case after addressing certain weaknesses of the developed approach was only foreseen by one of the investigated projects. The project coordinator related to this project and another one indicated that they were considering impacts of their project's results on the regulatory framework. Again, as research projects are often oriented towards lower TRL levels this is not a surprising outcome. An expert from ASD noted that he personally thought that the time to market and related costs for aviation safety research results did change over the past years but did not specify the direction.

One crucial aspect of how project consortia can facilitate the time to market of a solution developed in the course of a research project is by making sure that the results are tailored to address specific market needs. To be sure to take them into account at the earliest possible stage of research, end user involvement has been followed widely. Taking regulatory aspects into account is very important too, but often comes at a later stage in the development process. The next section will focus on the current and future capacity of safety research in Europe, looking for example at educational aspects, available resources and the coordination of safety research across different projects.

2.4. Capacity of EU Safety Research

Research and development activities shape the future of aviation. Decisions on which research projects to fund, the differentiation between promising and less promising research paths and aspects such as the availability of testing facilities and highly educated workforce, have consequences for the future of the aviation sector even decades after they have been made. In order to maintain market leadership and a competitive advantage in the dynamic world market, Europe's aviation sector must be underpinned by world class capabilities and facilities in research, development, test and validation, and should provide the current and future employees of the sector with a top level education that is adapted to the sector's needs (ACARE 2012).

The major source of data and information regarding the capacity of EU safety research were interviews with the coordinators of several aviation safety projects. Besides, aviation safety experts were interviewed to obtain input to the strategic focus, the supply chain and supply chain dynamic and the excellence of safety research. An internet research on the excellence of safety research complemented the information and data gathering process. The following paragraph gives an overview of the key results before the findings are explained in more detail in the subsequent sections.

The SESAR Joint Undertaking (SJU) is a good example of successful strategic management of safety research. It was established to manage the development and implementation of a modernized Air Traffic Management System for Europe throughout the research and innovation cycle. The EU FP7 project coordinators of the projects selected for this trial assessment indicated that different shares of their budget are dedicated to short term and long term goals, ranging from 20:80 to 50:50. Multidisciplinary research is assured by bringing partners with different backgrounds together in a consortium where their competencies can complement each other on a project level. The input from all three project coordinators that answered the questionnaire indicated that a research project requires partners from various disciplines to be carried out successfully. Other results, for example on the male-female ratio, the researchers' nationality or education were furthermore collected but cannot be generalized for Europe.

Development and transfer of knowledge and skills in aviation safety is taking place according to the feedback that was provided from the project coordinators. Especially, the transfer of knowledge to

other transport or industry sectors, e.g. maritime, automotive, building, and health, as well as contribution to previous aviation safety projects where knowledge can be transmitted to new project proposals is perceived as very positive by the project coordinators.

Summing up the main results of the internet search regarding the international recognition of the research activities and the attraction of young researchers, one can note that the only university programmes of relevance in Europe are the Master programmes "Aviation Safety" at the Technical University of Graz, "Safety and Accident Investigation – Air Transport" as well as "Safety and Human Factors in Aviation" at Cranfield University and "Aviation Safety Aircraft Airworthiness" at ENAC. However, these programmes seem to be designed for professionals rather than for students who have just finished their Bachelor studies. Consequently, few chairs at European universities explicitly practice safety research in aviation and can offer safety related classes. Outside Europe, however, this picture looks different. Especially in North America, several universities offer study programmes related to aviation safety for undergraduates and graduates.

In the following sections the range of indicators addressing different aspects of the capacity of safety research with Europe will be outlined and the information gathering processes as well as related results will be described.

2.4.1. Strategic management of safety research

Managed life cycle of research and innovation

This indicator addresses how research and innovation processes can be managed throughout the development process. On the micro level, i.e. the level of single research projects, this is linked with progress on TRLs and is closely related to the indicator "Knowledge transfer of safety research projects" described in Section 2.4.4. On the macro level i.e. the level of European aviation safety research, it is linked to a structured and deliberate approach to e.g. funding procedures. Project coordinators and the EC are approached in the course of information collection in relation to this indicator. Furthermore, SESAR Joint Undertaking (SJU) has established as noteworthy process to actively manage research efforts which will be described briefly.

Two of the three project coordinators confirm that the specific solution they address in their research moved up on the TRL scale throughout the project duration. The third coordinator did not provide any information on this aspect. How the research projects integrated results from past research (projects) is elaborated in Section 2.4.4. The EC indicated that they have an overview of the transition of safety topics across different projects and Framework Programmes but that this overview is not necessarily exhaustive. An aspect that complicates the tracing of the development of aviation safety topics across different TRL levels (especially early incubation and/or late maturation) is that research is not always funded by the same institution, e.g. third party funding can be granted under national or intergovernmental frameworks.

To trace the developments research funded by the SJU undergoes a process has been implemented that helps to manage research efforts and results effectively. This is presented in the following. The (SJU) was established in 2007 under Article 171 of the Treaty establishing the European Union, to develop a modernized Air Traffic Management (ATM) system for Europe in pursuit of EU Air Transport Policy, notably, the Single European Sky (SES).

The SJU is an effective management tool that coordinates relevant research and development in the domain of ATM, ensuring that all EU resources and investment undertaken by its members are focussed upon realising challenging goals relating to the provision of ATM services, underpinning efficient, safe and environmentally sustainable air transportation for the next decades.

The SJU provides a robust management framework over a multi-annual research programme directed towards the implementation of the European ATM Master Plan (SESAR 2014), the agreed European "roadmap" connecting research and innovation with deployment, that outlines the essential operational and technological innovations required to deliver the SES performance objectives in a timely, coordinated and efficient manner, while also ensuring alignment with ICAO for global interoperability.

The SJU exercises control over the full spectrum of the research and innovation lifecycle, ensuring the transition from exploratory research through a development and validation process underpinned by an acknowledged methodological framework that prepares solutions for industrialisation and operational deployment, providing essential material to ATM stakeholders to support uptake and the development of the necessary regulatory material.

The SJU has successfully demonstrated its capacity to efficiently manage the progression through the research and innovation lifecycle, with a significant number of solutions being trialled operationally. Investment in ATM research is now directed towards achieving a comprehensive strategic roadmap of operational and technological improvements that have been negotiated at a global level with ICAO, eliminating unnecessary competition and duplication.

The longer term has not been neglected, where there is evidence of loose coupling with the ACARE's SRIA and Flightpath 2050. Exploratory activities in this segment have provided opportunities to establish the embryos of academic "centres of excellence", within which a number of PhD students are actively pursuing their research. Scientific excellence is assured with the support of a Scientific Committee, composed of globally recognised academics, which selects and reviews activities. International recognition is high, both from events organised under the SJU umbrella and through the presence of researchers at international events.

The SJU has implemented an approach to effectively manage and calibrate the match between strategic goals and research projects set in place. The broader the goals are that need to be managed, and the more projects are initiated to reach these goals, the more difficult it gets to monitor and align the research. The example of SJU, however, might serve as a best practice model which could inspire similar processes on the level of national of EU Framework Programmes.

Quality of scientific output

The quality of scientific output is very hard to specify in quantitative terms as it is influenced by many different factors that can be very specific to the different fields of research. However, the number of conference and journal publications, of citations and/or of filed patents is often identified as acceptable approximation in the absence of a better alternative. The project coordinators were, thus, asked to provide these numbers for their projects.

All project coordinators published a number of conference papers related to their research projects: two projects published eight conference papers each and one six conference papers. One of the projects that published eight conference papers also published eight journal papers; the other projects did not publish any research results in journals. All coordinators could either made no statement on the number of citations stemming from the publications or indicated that no citations were made so far. Up to today, there were no patents filed in relation to the projects' results.

This information is complemented by feedback provided with relation to the indicator "Knowledge transfer of safety research project" that is presented in Section 2.4.4. To assure a high quality of research it can be very helpful to discuss intermediate steps and achieved results with experts across different fields. Presentations at conferences and journal papers offer a good opportunity to interact with other people across the research landscape and to learn from their feedback and experience. The project coordinators addressed in this trial assessment made use of this possibility by publishing their

research widely. It is, however, generally agreed upon in the research community that journal papers are to be rated higher in terms of scientific excellence as they are peer-reviewed.

2.4.2. Strategic focus of safety research

Balance between reactivity and proactivity of safety research

This indicator addresses the question whether European aviation safety research focusses on short-term goals as a reaction to urgent problems or on long term visions. It is also investigated if strategic plans like EASp and SRIA are being followed and managed.

The project coordinators of the four selected aviation safety research projects were asked to comment on the balance between reactivity and proactivity in addressing future challenges in their research project. What specific time horizon short-term and long-term goals relate to can differ by the research topic that is pursued in a project. One project coordinator indicated that his budget was split equally 50:50 to short-term and long-term goals. However, short-term goals for his project related to a time horizon of 2016 and long-term goals to 2020. The two other project coordinators that returned the questionnaire both stated that 80% of their projects' budget is being invested in long-term research goals. One specified that short-term goals in the project's context for him relate to 2015 and long-term goals to 2025, the other indicated that in his project's context 2020 was considered short-term and 2040 long-term.

All three projects addressed goals from EU strategic visions and initiatives. One project coordinator indicated that their research project specifically addressed goals of the EU FP2050 vision.

From the information obtained from the project coordinators it is clear that they do take strategic vision such as the SRIA or the Flightpath 2050 document into account when setting up and implementing their research project. The definition of the concepts "short-term goals" and "long-term goals", however, seem to vary greatly according to the research topic a project focusses on. It is thus very important to clearly define these terms when making statements about e.g. implementation pathways.

2.4.3. Supply chain and supply chain dynamics

EU safety research network

To achieve ground-breaking, innovative results it is often necessary to bring different competencies and people together in a research project to work jointly towards a certain goal. A balance between true in-depth knowledge and skills in a certain area and a good understanding of the requirements stemming from the overarching needs of e.g. the air transport systems has to be assured. This indicator aims at tracing, on the one hand, the connections between different research entities and, on the other hand, the workforce composition of safety research projects.

In the project coordinator questionnaire, the coordinators were asked to indicate how many project partners are/ were involved in the research project and if there were cases where more than one team/ department/ chair was involved per partner. If this was the case, the coordinators were asked to indicate the number of researchers per team/ department/ chair in order to gain insights into the composition of the project consortium as such as well as into the composition of contributing partners' teams.

In two of the three projects, where information was available, certain partners involved more than one team/ department/ chair from their organisation on the subject. One of those two projects has eleven project partners and for two of them, two teams are involved. The number of researchers per team

was not given for this project. In the second project, three of a total of eight project partners involved two teams. Each team consists of one to four researchers. According to the third completed questionnaire, there was only one entity involved for each of the 15 individual project partners. Multidisciplinarity within a consortium, thus, often is rather achieved by bringing together partners from different organisations with complementary competencies than by involving many different teams or departments within the partners' organisations.

In the same questionnaire, the project coordinators were asked to provide feedback concerning the composition of their workforce. Three categories were distinguished: Nationality, gender and educational background of the workforce. All questionnaires, that were returned, contained inconsistencies with regards to the overall number of researchers involved in the project and the share for each of the categories above. Thus the decision was taken to relate to the more detailed specifications resulting from the workforce composition question.

While the male-female ratio for the first project was around 7:1, the second project had a ratio of 2:1 and the third project a ratio of 3:1. Feedback on the different nationalities of the researchers was only provided by two project coordinators. Their project workforce comes, to a large part in accordance with the place of business of the project partners, from six different European countries: Ireland, Sweden, Italy, France, Greece and Norway for the first project; Italy, Germany, the Netherlands, Belgium, Czech Republic and Slovakia for the second project. Additionally, information was requested concerning the educational background and degrees of the workforce. Expressed in percentages, the result for the one project that answered this question is as follows: 10% Bachelor, 20% Master, 20% Diploma and 50% PhD. Thus the share of experienced, highly qualified personnel contributing to the three research projects is exceptionally high and the workforce is built from researchers from a variety of countries. The male-female ratio, however, leaves room for improvement.

The number of involved researchers per project partner and per research project as well as the geographical location of these research entities can give a first indication as to where centres of aviation safety competence can be found. Of course, this information would have to be collected from a representative sample. Together with the indicator "dispersion of capital investment" presented in Section 2.1.3 an even more comprehensive picture could be developed. To complement the information provided by the project coordinators, aviation safety experts from ASD, EREA and EASA were asked whether they had an overview of competencies of different research entities across Europe. One stated that, based on past projects his institution had a relatively good overview of existing capabilities for traditional aviation research topics, however, their overview concerning new research subjects was less profound. The expert indicated that research was a dynamic field and, thus, always having an up to date compendium of all aviation safety research entities was a hard task. A second expert stated that his institution did not have an overview of all European research entities. They rather had in-house experts and a small number of universities and research institutes that they were able to consult. Both experts indicated that they were not aware of any reliable data source providing such an overview of competencies in aviation safety research within Europe.

The information collected in relation to the indicator "EU safety research network" reveals that based on personal experience experts in the field of aviation safety are able to identify relevant areas of competence but that there is no common source available for this information. The workforce composition of the research projects investigated demonstrates certain similarities: in all projects female researchers were under-represented, the level of education generally is very high and the consortia do rely on a broad range of different partners rather than including many departments from a single project partner. This should allow research results to be based on a broad knowledge base and should also facilitate dissemination of project results.

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2.4.4. Resources of safety research

Development of skills and in-depth knowledge in safety research project

This indicator aims at the development of skill sets (personal/interpersonal) and the acquisition of expert knowledge in the course of an EU research project in order to add value for safety-related organizations and own career developments.

The project coordinators of the selected aviation safety research projects made specifications about the scientific output in terms of Master, PhD and other theses produced as a result of ongoing project work. This indication gives an idea about personal and interpersonal knowledge acquisition of researchers involved in the projects at least on a formal basis. In the course of one of the projects two Master theses and one PhD thesis were completed and a second project provided the basis for one PhD thesis. In the third questionnaire that was returned there was no information provided on this aspect.

An interesting observation was that in two out of the three projects the work was connected to other safety critical sectors. Cross-cutting research topics were identified with regard to the maritime, automotive, building and health sectors. It can, thus, be assumed that researchers that gathered skills and expertise in the aviation safety field can transfer and share their knowledge to and with experts from other safety critical sectors and vice versa.

Third party funded research projects provide young researchers with a good opportunity to broaden their skills and pursue their educational paths. That there were not more theses linked to the research projects might be due to the fact that 50% of the projects' workforce of the analysed projects already held a PhD. The fact that the projects' work was connected with other industrial sectors is a positive observation as aviation safety can benefit from the influx from other sectors.

Knowledge transfer of safety research projects

The process of transferring ideas, research results and skills beyond the boundaries of research projects is very important so the resources available for aviation safety research can be used efficiently. Dissemination of results can be achieved through communication in personal networks, the organisation of workshops or conferences, publications, project deliverables and other channels. Effective communication will enable a wider community to take up innovative ideas, new methodologies and other results from the conducted research. This is an important factor towards the creation of societal and economic benefit as it helps to avoid duplication of research efforts and consequently supports an economical handling of tax money.

If knowledge transfer is performed within the safety research community, it is likely that new research projects profit from previous efforts in the same field. For this reason, the project coordinators were asked whether their project built on previous research and, if that was the case, whether they could name research projects that contributed to the knowledge base they started from. If they named a specific project they were, furthermore, asked to rate the importance of the contribution of these projects to the success of their own research. Two of the three project coordinators answered that they were building upon previous knowledge. But as the third coordinator ticked "no" but then gave examples for projects that influenced the consortium's work (specifically ADAMS EU FP4 1994-1999; HILAS EU FP6 2005-2009; MASCA EUFP7 2010-2013) and rated their contribution as being "very important", it is assumed that the answer should have been positive, too. The HUMAN project (EU FP7 2013-2018) was mentioned by another coordinator as delivering input for the project's research endeavours. All three coordinators rated the importance of the contribution of other projects to the success of their research either as very important or important.

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If projects are to build upon results achieved by other researchers the formal deliverables can be a good source of information. But it sometimes is a challenge to make them publicly available as confidentiality restrictions may apply. Often a project's homepage is used as platform to publish at least those deliverables that can be made publicly available. However, these homepages are often not maintained after the end of a project and often taken offline after some time. The project coordinators were asked how deliverables are treated in their research projects. Within all three projects some deliverables were not being made publicly available due to confidentiality restrictions. For one project this was true for 45% percent of the deliverables, for another it was 10% and the third did not specify a percentage. The projects homepage and conference/ journal publications were mentioned as being the chosen communication path for the results of the three projects.

It is a positive result with respect to knowledge transfer in aviation safety that all project coordinators indicated that they built their research upon previous knowledge and that they published their deliverables, at least partially, on the projects' homepages. Another important aspect was already addressed in relation to the indicator "Quality of scientific output" in Section 2.4.1: the presentation of results at conferences and the publication in conference and journal papers as these papers are mostly accessible even after the project has ended.

Access to relevant testing capabilities

If new materials are used or new devices are developed, strengths and weaknesses have to be explored and tested, and sometimes highly specialised testing facilities are necessary to conduct the research. This indicator, therefore, examines to what extent investigated research projects had access to the testing facilities relevant to them and how they secured this access. A shortage in relevant testing facilities or difficulties in accessing them could impede necessary steps towards innovation.

Two of the three coordinators who returned the questionnaire indicated that their projects required certain testing facilities and that these were available through partners of the project consortium. One coordinator answered that the consortium of his project did not need access to any testing capabilities. It is an important task in the course of setting up a project to thoroughly address questions relating to necessary research infrastructure. The best way to address this issue is, as demonstrated by the two project consortia in need of testing infrastructure, to integrate partners with access to these facilities in the consortium.

2.4.5. Excellence of safety research

International (beyond EU) recognition across the aviation sector

Excellent research and related technological as well as processual innovations greatly enhances visibility of the European research efforts on an international level. This indicator traces the worldwide recognition of EU research on the basis of download statistics of journal publications. Relevant international safety research journals were identified and their download statistics analysed. Following this approach, information on readership and authorship of the relevant journals can be obtained.

An internet search showed that it is hard to get access to journal download statistics for journals that are not published by big academic publishing companies. For this reason, the assessment is limited to safety journals published by Elsevier. Elsevier publishes 18 journals that are related to different aspects of safety research (Elsevier 2015a). Out of these 18 journals, eight were identified that are expected to also cover topics related to aviation safety: "International Journal of Impact Engineering", "Journal of Hazardous Materials", "Journal of Safety Research", "Reliability Engineering and System Safety", "Safety Science", "Accident Analysis and Prevention", "Structural Safety" and "Engineering Failure Analysis".

For seven of these journals, journal metrics were available online via Elsevier. These metrics included either the number of downloads at country level over the last five full years or the number of primary corresponding authors at country level over the last five full years or both. For the journals "International Journal of Impact Engineering", "International Journal of Safety Research" and "Safety Science" only information about authors was available whereas for the journals "Engineering Failure Analysis", "Reliability Engineering and System Safety" and "Journal of Hazardous Materials" information included both authors and downloads.

Exemplary authorship and readership figures as provided by Elsevier are shown in the following Figures 11 and 12 for the journal "Reliability Engineering and System Safety".

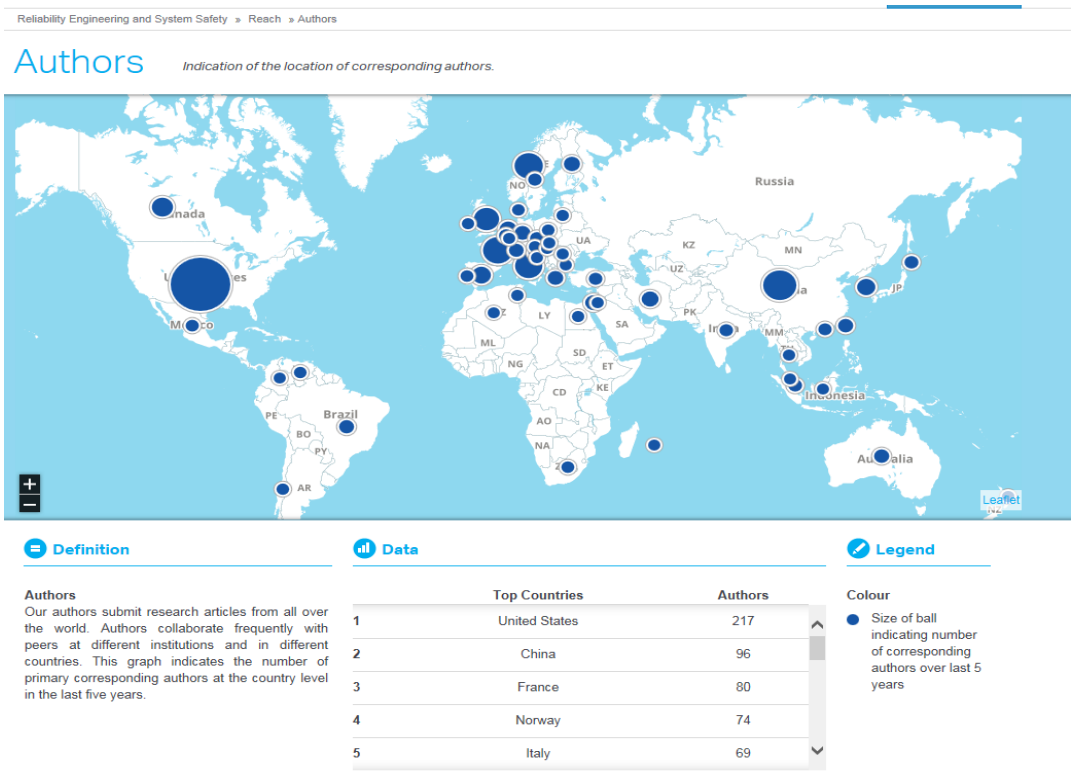

Figure 11: Number of primary corresponding authors at country level 2009-2014. (Source: Elsevier 2015b)

Figure 12: Number of downloads at the country level 2009-2014 (Elsevier 2015b)

Based on the statistics provided by Elsevier for the reach of its safety journals, it does not become obvious if a leading country or continent in safety research exists. On a first glance, Elsevier's graphical presentations of authorship and readership suggest that for most journals China and the United States are centres of safety research. However, the journal metrics provided by Elsevier are given in absolute numbers irrespective of the population size of the respective country. As these numbers are more meaningful when indicated on a per million inhabitants basis, World Bank data (World Bank 2015) about average population sizes was used to calculate the corresponding shares for the given top countries concerning absolute numbers. When switching from absolute to relative numbers (authors and downloads per one million inhabitants), it is not possible to identify a leading nation. There is no clear pattern of high values for specific countries across all journals. For the period under observation, high numbers for some countries and journals cannot be explained without further insight into possible explanatory variables. Europe, North America, Asia, Australia and parts of South America seem to be equally interested in results from safety research.

If download statistics existed for more journals and also for the more specific ones released by smaller publishers they would allow drawing a more differentiated picture of the worldwide distribution of authorship and readership for aviation safety related topics. It is interesting, however, that the analysis conducted based on Elsevier data did not reveal a clear dominance of a world region based on the statistics relative to the population size of the countries.

Attraction of young researchers

This indicator is closely related to recognition and visibility of safety research. It aims at the attraction of young scientific researchers to pursue a career in the area of safety research. One important basis for this is the preparation of future professionals by universities. Consequently, the goal of the internet search, performed for this indicator, was to identify European universities and institutes providing safety education in aerospace and their influx. In a second step the number of people taught in safety

related classes was estimated. This indicator is linked to Section 2.3.3 where the impact of research on workforce skills was addressed and the coordinators were asked if they feel that the universities are providing them with a sufficiently educated workforce, which all three coordinators confirmed.

To collect information concerning the indicator "Attraction of young researchers" the internationally recognized QS Top Universities Ranking[2] (QS 2015 for 2013/2014) was consulted and the 50 best European universities offering study programmes in engineering and technology were selected by making use of a filter for "Europe" and the faculty "Engineering and Technology". Out of these institutes of higher education, a group of 29 universities from ten different European countries (UK, Germany, Sweden, Austria, Netherlands, Spain, Italy, Finland, Belgium and Denmark), which offer programmes in aerospace engineering and related subjects, was chosen. The respective curricula of these programmes were scanned and analysed for classes related to aviation safety.

None of these universities, except for Technical University of Graz ("M.Sc. Aviation Safety") and Cranfield University ("M.Sc. Safety and Accident Investigation – Air Transport"), does offer a degree focussing on aviation safety. The Master programmes of both Technical University of Graz and Cranfield University are extra-occupational programmes and seem to aim at professionals. Another Master programme of Cranfield University deals with aviation safety is the M.Sc. in "Safety and Human Factors in Aviation". This programme is offered as a full-time or as a part-time course. Among the chosen best performing universities, the Belgian University of Leuven offers a Master in "Safety Engineering", though, a special focus on aviation and aerospace is not identifiable.

As the large majority of these European universities do not seem to provide aviation-safety-tailored Bachelor or Master programmes, it is assumed that they do at least offer safety related classes within their aerospace engineering programmes. In order to identify such classes, the aerospace engineering curricula of the best performing university for each of the ten countries – except for the University of Leuven, which does not offer an aerospace engineering but the afore mentioned "Safety Engineering" programme – were scanned (Imperial College London, RWTH Aachen, Delft University of Technology, KTH Royal Institute of Technology Stockholm, Politecnico di Milano, Technical University of Denmark Lyngby, Politecnica de Madrid, Technische Universität Graz, University of Aalto).

Figure 13: European top universities and institutes providing aerospace/safety engineering and related study programmes, 2013/2014. (Source: own depiction, based on input from QS 2015)

[2] The approach, performed and described in the following, is based on the QS Top Universities Ranking. Unfortunately, this selection might exclude universities relevant for aviation safety research.

It is worth mentioning that five out of these nine universities do not offer a Bachelor degree in aerospace engineering, but only a Master. It seems likely that more and more universities decided to incorporate their undergraduate aerospace engineering programmes into the mechanical engineering courses as the lecture contents overlap. Students planning to specialise in aerospace engineering have the possibility to choose a respective Master programme.

Within the aerospace engineering curricula survey only two Bachelor and Master classes related to aviation safety were found. These classes with the titles “Safety of Aviation Systems” and “Passive Safety” are taught in the undergraduate and graduate programme of the Polytechnic University of Milan. In all other curricula, technical aspects of aviation are the central elements. It is not obvious from the curricula in how far safety related issues are discussed in classes with a focus on engineering. However, one can state that virtually none of the universities under consideration does offer classes with a special focus on aviation safety.

Beyond the “top” universities, three European universities were identified that offer complete courses which, on the first glance, deal with (aviation) safety. The German University of Wuppertal offers a Bachelor as well as a Master programme in “Safety Engineering”, the English City University London provides the Master course “Air Safety Management” and the French “École Nationale de l’Aviation Civile (ENAC)” offers the Master Programme “Aviation Safety Aircraft Airworthiness”. A closer look at the respective curricula clarifies that within the Wuppertal course aviation does not play a role and that within the London programme the emphasis is rather on risk and crisis management. Only the ENAC programme explicitly deals with aviation safety.

The lack of a large number of dedicated aviation safety study programmes leads to the interpretation that aviation safety is a topic that (young) professionals are likely to turn to from other careers. As aviation safety research involves a broad range of competencies from highly specialised engineers to human factors experts, employees with experience from different industry sectors or other areas of aviation can contribute their specific knowledge to the very complex task of aviation safety. It might be a challenge, though, to draw the interest of these people to careers in aviation safety if they are not introduced to related topics early in their studies.

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3. Discussion of Results from the Preliminary Market and Society Impact Assessment

The results of the information collection phase have been presented in the previous section. This section focusses on ideas concerning how to present the broad spectrum of information gathered visually and what lessons learned can be taken into account from this trial assessment when setting up the next assessment phase. Due to the iterative manner in which the market and society impact assessment is set up there is a chance to further develop the approach and to hopefully bypass some of the difficulties that were encountered during the information gathering process. In the following a first idea on the visualisation of the results is presented before turning to general insights that have been gained throughout the preparation of this deliverable.

3.1. Visualisation of results

A first dashboard proposal was developed in order to present a way to compare the results from the market and society impact assessment. Figure 14 displays the four different categories assessed, “Socio-Economic Needs and Expectations”, “Environmental Considerations”, “Industry Competitivity” and “Capacity of EU Safety Research”. A scale from the middle of the dashboard to the outside is introduced with the rating “potential for improvement” with the poorest rating and “good” representing a state of the component of a category assessed where no action is currently necessary. The category components are consecutively numbered. Small grey dots with the respective number can be located on the dashboard depending on its individual rating.

It has to be explicitly highlighted that the results displayed in Figure 14 do not represent the assessment results from the previous section but are only meant to illustrate the visualisation concept. The intention behind the depiction is to explain the features of the dashboard and a first idea of how it can be applied. The “feel good factor (safe to fly)”, for example, is rated with a position close to a good status. Categories where the current data and information foundation does not allow sufficiently precise evaluations, can be placed outside of the grid (e.g. ”safety improvement”).

A more detailed overview is displayed in Figure 15. Here the focus is purely on the category “Socio-Economic Needs and Expectation”. This category is further subdivided into four components (see grey box in Figure 15) where “Employment” and “Safety Improvement” are measured one indicator each, “Investment in Safety Research” is assessed with two indicators and the category “Feel good factor (safe to fly)” accounts for three indicators measuring results. This detailed view would allow a further allocation of the results on a component level to an overview of the individual indicator results.

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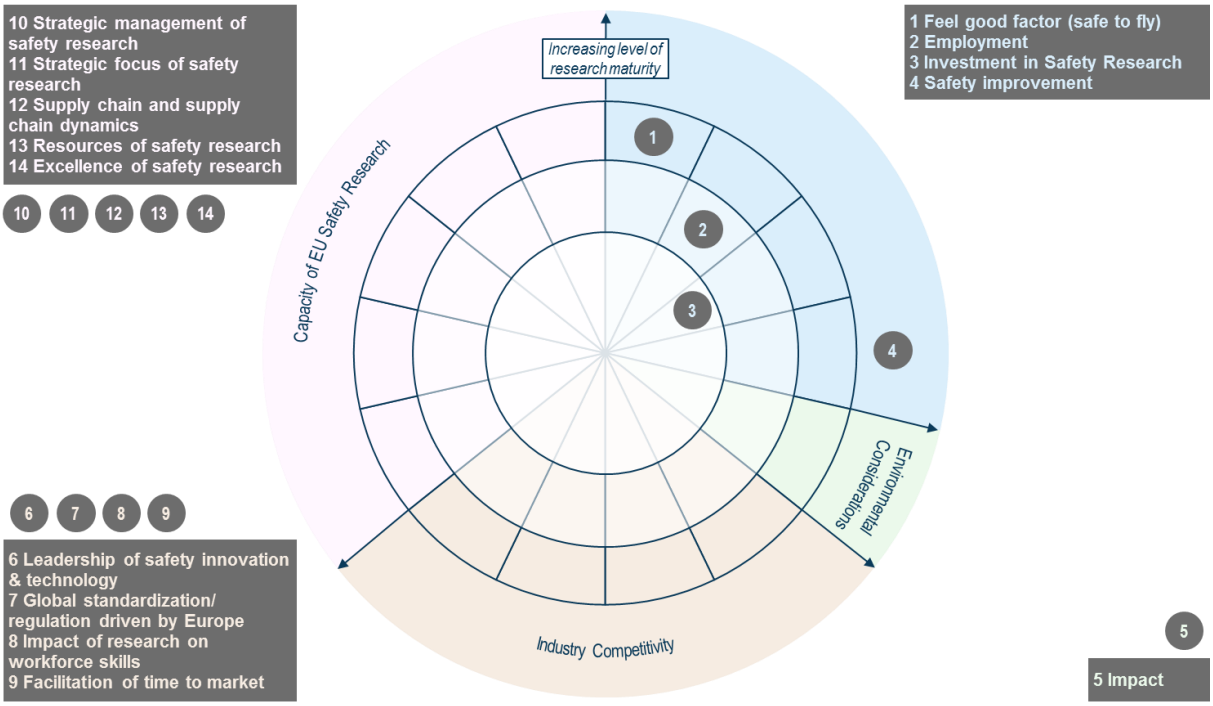

Figure 14: Proposal for a dashboard to monitor and analyse the result of the market and society impact assessment. (Source: own depiction)

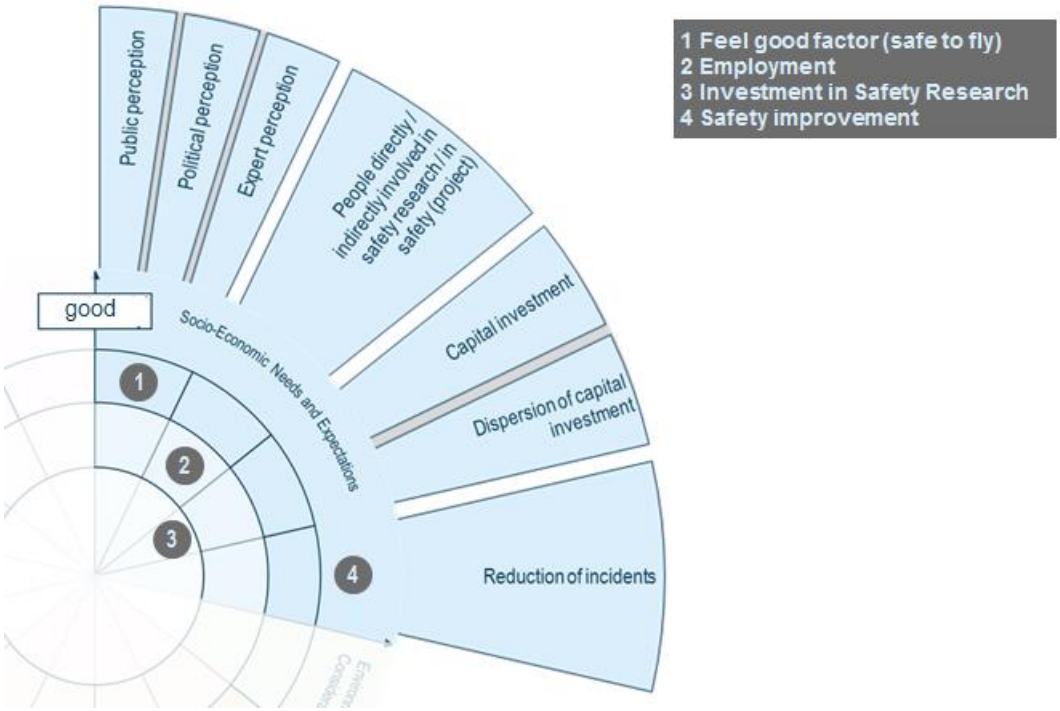

Figure 15: Detailed view on the category "Socio-Economic Needs and Expectations". (Source: own depiction)

Generally, such a dashboard can provide a first brief overview of the major results of the "Market and Society Impact Assessment". However, the diversity of data quality and condition make it not only difficult to normalise the results to one scale but also to compare these. The information and data pool on which the assessment is currently based, consists of quantitative data, for example number of flights (indicator: "Public perception") or employment figures (indicator: "Employment"), as well as qualitative data, for example the associations of the public in relation to air transport (indicator: "Public perception") or statements of the coordinators on environmental considerations (indicator: "Impact"). The fact that components of a category are composed of varying numbers of indicators leads to the question of introducing weights when aggregating indicator figures to the component level.

The structure of the result display in the dashboard was oriented towards the category, component and indicator structure from the development phase of the framework for societal and economic impact assessment. The current state of the dashboard serves as a basis for exchange and discussion on a feasible way to display and analyse the results but a progress of this status is required and envisaged. Further steps of the dashboard development could foresee a different clustering and aggregation of the indicator figures or a selection of a subset of comparable results based on data and information with similar quality and characteristics.

3.2. Discussion of Approach of Trial Assessment

A range of different information sources was identified as a basis for the data gathering process. The different strategies were successful to a variable extent. In preparation of the next phase of this assessment stream within OPTICS, which will include a refinement of the indicators as well as the overall approach, the different data gathering options are discussed in this section.

Internet search

Those indicators where an internet search was identified as the most promising way to gather relevant information were the ones that were the easiest to deal with. If information generally is publicly available and thus accessible via internet there are no general barriers in the information collection process. Together with the results taken from OPTICS WP2.1, this is the most straightforward information source.

Survey of public opinion

The public opinion can only be collected by directly asking the public itself. In the course of the information gathering process for this deliverable, different members of the consortium approached people on the street asking them to fill out a very short, one page questionnaire. Of course, results obtained from this approach can only be seen as first indication but as the effort that had to be invested to obtain these results was rather low, the approach was an efficient way to test the questionnaire. In the questionnaire the people were asked to name the most important keywords that come to their mind when they think about air transport. In the analysis phase it became clear that it would have been useful to also document a short rationale because the answers that were collected are not always straightforward: for example, if interviewees mentioned "Safety" as a keyword, it is not clear if they see safety as a problematic issue when thinking about air transport or if they are aware of the high effort that is invested in aviation and thus regard it as a very safe transport mode. To obtain results that can be generalizable it would be necessary to employ a market research institute to conduct a representative study. This would then also allow expanding the questionnaire and asking more detailed questions.

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Communication with experts

Three different approaches were pursued to collect the feedback and statements from experts: First, a workshop was conducted during a regular meeting with members of the ACARE Working Group 4, second, the networks of ACARE IRG and SIB were used to distribute a short questionnaire to a large group of experts and, finally, specific experts were contacted directly and asked either for their opinion or if they could provide us with specific data.

The workshop with ACARE WG4 and the mailing to ACARE IRG and SIB were based on the same set of questions investigating whether the experts feel safe when flying. In the workshop the questions were answered by everyone present at the meeting, and the possibility to hear what the others answered was clearly of interest for the participants. Members of ACARE IRG and SIB received the questions via e-mail and were asked to respond to those giving short answers. The rate of return was not very high, underlining the advantage of a workshop set-up. To use the different ACARE Working Group meetings for short workshops is a good approach when the input of different aviation experts is needed.

In addition, a number of dedicated experts were contacted directly sometimes in relation to only one indicator and sometimes to more. Due to the nature of our information demand the experts could not always provide the information that was rated as relevant in relation to an indicator. However, it can also be of great help to have someone confirm that there simply is no database available and that it consequently makes sense to abandon the search. Generally, the experts that were approached were very willing to support the OPTICS project in its task.

EU safety project coordinators

The major share of information gathered in preparation of this deliverable is related to quite an extensive questionnaire that was distributed to four coordinators of EU FP7 projects dealing with a variety of aviation safety topics. Three of the four coordinators returned the filled-out questionnaire. We explicitly asked the coordinators also for feedback on the questionnaire and the collection process and one coordinator indicated that answering the questions was sometimes difficult and required time and effort. As the questionnaire sent to the coordinators had the character of a pre-study this feedback will be taken into account when setting up the information collection process for the next assessment phase towards OPTICS D2.4. Especially, the number of questions asked will have to be reduced. Another aspect that could minimise the effort for the coordinators is to connect the questionnaire to their regular reporting periods to the EU where some of the information that we asked for has to be assembled anyhow. This could also help to increase the return rate which becomes particularly important when a larger set of projects is taken into account. Due to the high number of respondents (for some aspects the entire consortium has to be involved) and the length of the questionnaire, using a written questionnaire instead of face to face or telephone interviews still seems to be the right approach. For the next assessment phase the content and structure of the questionnaire and the selection of projects included in the survey will be reconsidered carefully.

Coordinators of OPTICS sister projects dealing with topics related to environmental considerations

The coordinators of CSA projects dealing with topics related to environmental aspects were addressed via email in order to gather information related to the category “Environmental considerations”. From the four projects that were contacted only one was able to provide insights based on their database and studies. To overcome such difficulties it would be possible to interview the coordinators over the phone or even try to meet them face to face either at dissemination events, conferences or ACARE (and other) meetings.

Results from OPTICS WP2.1

In preparation for an assessment conducted by the OPTICS consortium in 2014 all EU FP7 projects with explicit reference to aviation safety were identified and details of those projects collected in a

database. This database served as source for e.g. contact information, involved partners or the funding details for the four projects that were chosen for the trial assessment. The data was collected in OPTICS WP2.1 and results based on this collection were published in OPTICS D2.1.

When turning to the insights that could already be gained from the trial assessment presented in this deliverable there are a number of general observations that can be made. A positive finding is that overall experts as well as the public seem to be feeling safe when flying. The continuous decline regarding incidents and accidents over the past decades provides evidence that this feeling is justified by the actual situation. Recent accidents (such as Malaysia Airlines Flight MH17, Malaysia Airlines Fligth MH340 and Germanwings Flight 4U9525), however, could influence this perception negatively. This possible change will be addressed in the OPTICS D2.4 in 2017 when effects will have The current positive perception should, nonetheless, be rated as a success for the aviation safety community as this is a major goal and one of the most important benefits research in this field can offer to society. An area for improvement in the European context is the lack of university education in the field of aviation safety. Compared to e.g. the USA only a very few Master Programmes are offered in this field and they are mostly oriented towards professionals. The workforce in safety is thus composed of employees with a variety of different backgrounds, accounting for the diverse challenges this field offers. The project coordinators, however, all stated that they feel that universities do provide them with the workforce they need to accomplish the projects' tasks. Still safety research and practice could probably benefit if more emphasis would be put on further development and professional education and training programmes.

For some indicators the information gathering did not lead to satisfying results. For example, no data was available to specify how many people were involved in safety research (projects), because these numbers are simply not collected. Indicators where the information gathering process showed that there is no basis for further investigation can be neglected in the upcoming information collection process. Narrowing down the scope of the data collection will allow to invest more effort in fewer indicators and thus to deepen the analysis in those areas that appear to produce promising results. For the next assessment phase the lessons learned from the various information gathering processes described throughout this deliverable will be processed to develop an improved approach. This will then be tested in a more comprehensive trial assessment.

To summarise the results from this preliminary assessment the following aspects can be highlighted:

1. The public is aware of topics related to aviation safety and security.
2. The vast majority of aviation experts feels safe when flying; safety statistics and personal knowledge are the two top reasons for this.
3. The project coordinators are satisfied with the qualifications of their personnel despite the fact that there are only very few master programmes in the EU dedicated to safety research.
4. The assessed projects benefitted from work that was accomplished in previous research projects and from an influx from other safety critical industry sectors.
5. An orientation towards the application of results of research projects is important for the project coordinators. All projects assessed involve end users and take their needs into account. The projects also make results publicly available and interact with the broader research community in various ways.
6. Download statistics for safety related journal articles at country level suggest that research results create worldwide interest with no world region dominating.

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PART 2:
STATE-OF-THE-ART IN SAFETY RESEARCH YEAR 2

OPTICS is a Coordinated Action funded by the European Union Seventh
Framework Programme (FP7-AAT-2013_RTD-1) under Grant Agreement n° ACS3-GA-2013-605426.

4. INTRODUCTION TO STATE-OF-THE-ART IN SAFETY RESEARCH

4.1. Introduction

Determining the state-of-the-art in safety research is one of the cornerstones of the OPTICS methodology. OPTICS aims to provide a comprehensive overview of safety-related research and innovation activities performed in the European context. The contribution of the identified safety research is assessed to determine progress towards achieving the ACARE Flightpath 2050 challenges and goals. The assessment results are used to develop strategic recommendations on the most promising and important research avenues.

The approach followed in analyzing the state-of-the-art of aviation safety research is based on the approach as initially described in OPTICS D1.3 (OPTICS 2014) and improvements and practical deviations made in the eventual application in 2014, as documented in OPTICS D2.1 (OPTICS 2015a), and 2015. A detailed overview of the approach is given in Appendix E.

The approach combines (cf. Figure 16):

- A bottom-up approach, in which the OPTICS team assesses in a structured way how individual R&I projects contribute to elements of the SRIA; and
- A top-down approach of expert workshops centered on specific aviation safety R&I fields, in which experts with an overview over the field identify gaps in research being performed and new research opportunities.

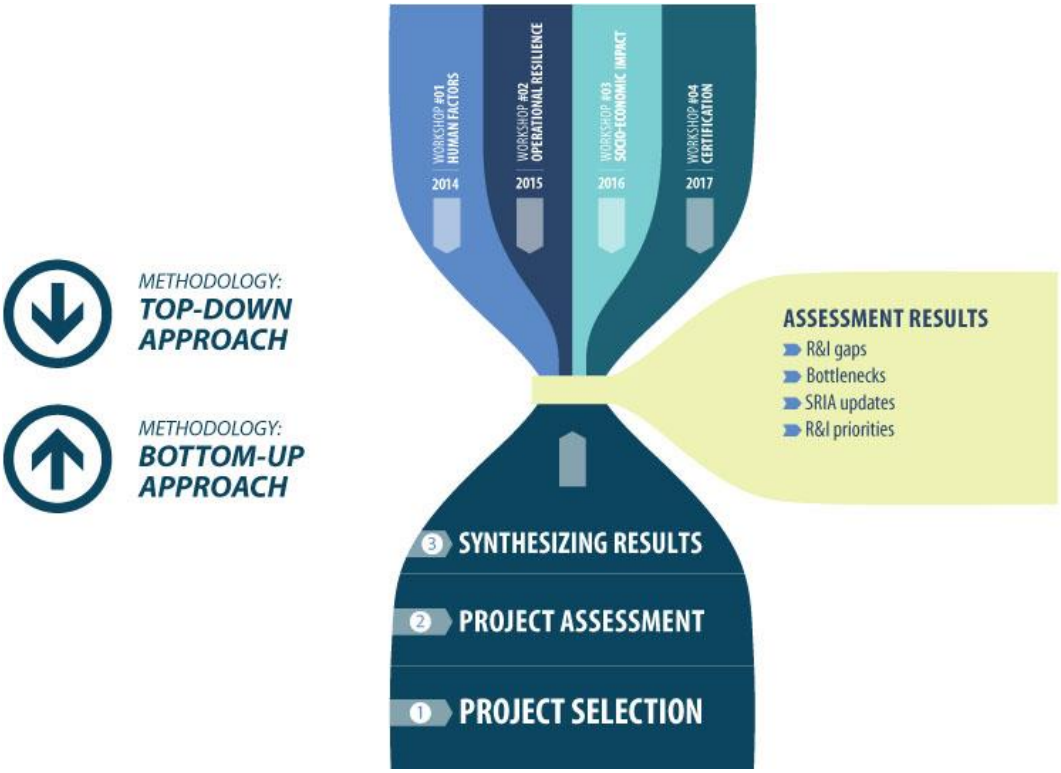

Figure 16: Hour-glass representation of approach

4.2. OPTICS Year 2 project assessments

In year 2 of OPTICS projects from the following programmes are considered: FP7[3], SESAR, SESAR WPE, Clean Sky and Future Sky Safety. The relevance of projects is determined by the OPTICS team by studying available project documentation or in coordination with the programme. Table 1 lists the number of projects assessed this year. Each assessment is done in three stages: a first assessment by an OPTICS team partner, moderation by another OPTICS team partner and finally a review by the relevant project coordinator. The results of the assessments are presented in Section 5.1.

In 2014 projects from Framework Programme 7 were assessed. The projects in this programme are only loosely coupled; the programme encompasses a variety of research directions. In 2015 projects from programmes are assessed that are more tightly coupled because the programmes have a common goal or research area: SESAR (ATM research), Future Sky Safety (aviation safety research) and Clean Sky (Environmental impact of aviation). The assessment of the individual projects within these programmes might not give a complete overview of the total impact of the programme. Currently, the methodology of OPTICS is not catered to the assessment of the contribution to the state-of-the-art in research of a complete programme. This gap might result in a too conservative assessment of the state-of-the-art. In 2016 the OPTICS team will therefore study the possibility of including an assessment of a programme as a whole in the yearly synthesis of research.

Table 1: Number of projects assessed in OPTICS year 2

Programme	Projects assessed
FP7 (projects with an implicit safety part)	18
SESAR	17
SESAR WPE	14
Future Sky Safety	5
Clean Sky	9
Total	63

4.3. 2nd OPTICS Expert Workshop

The 2nd OPTICS Expert Workshop was held on 28 and 29 April 2015 in Toulouse and was attended by 50 experts in aviation safety. Their task was to determine the major Research & Innovation priorities for aviation safety, to consider the research pathway laid out by ACARE's SRIA, and then to determine if any significant research avenues were missing. The focus of the Workshop was on four focal areas grouped together in a cluster called 'Air Vehicle Operations and Traffic Management': autonomous systems, use of data, self-healing and weather. The results of the workshop are presented in Section 5.2.

[3] FP7 projects with an implicit aviation safety part (projects targeting other objectives than safety, in which safety is identified as a crucial issue and managed)

5. RESULTS

5.1. Project assessments

In 2015 OPTICS assessed a total of 63 projects. The assessments were sent to the project coordinators for review after an internal moderation. The fact that coordinators can provide feedback increases the confidence in the project assessment results. The resulting assessments are included in the second OPTICS repository. The following feedback was received:

The assessment of each of the 18 FP7 projects considered this year was sent to the project coordinators for review. Feedback was retrieved from 8 coordinators (44%). 1 coordinator asked for the addition of 2 capabilities, 1 coordinator had comments on the enabler and capability choices (another enabler, related capability and sub-capabilities added), another had minor comments (e.g., textual corrections on the rationale for the enabler/capability choice). 5 coordinators confirmed the assessment. In total 5 new capabilities were added, ratings were not changed.

The assessment of each of the 14 selected projects of SESAR WPE was sent to the project coordinator for review. Feedback was retrieved from 11 coordinators (79%), of which 1 (7%) had substantial comments, while the others had minor comments (e.g., textual corrections and/or the addition of 1 capability) or confirmed the assessment. In total 4 new capabilities were added (2 from the project with substantial comments), and 8 ratings were changed.

The assessments of the 17 SESAR projects were discussed directly with each project coordinator. After these discussions the assessments were reviewed by the SESAR safety officer and 2 other SESAR executives. OPTICS received in-depth feedback on all SESAR project assessments. The final assessments contain some improved ratings as compared to the first assessment performed by OPTICS.

The assessments of the 5 projects of the Future Sky Safety programme were sent to the programme coordinator for review. Therefore OPTICS received feedback on all 5 assessments. For 3 projects minor comments were received. One capability was added for each of these 3 projects, and 3 scores were slightly increased. Some minor changes were made after the review in cooperation with the programme coordinator.

The OPTICS team asked the Clean Sky JU to identify projects relevant to the safety challenge. Clean Sky JU identified 10 projects launched under the umbrella of Clean Sky 1 and provided links to public information. The OPTICS team performed the assessment of the projects and the resulting assessments were sent to Clean Sky JU in order to get their view and modifications. Clean Sky JU accepted the OPTICS assessment without any request for modification.

The following figures list the projects assessed per programme and give summaries of the project assessment results. For reader convenience the results of the 2014 assessments are also given. These results are of course used in the updated syntheses of overall results which are shown later in this section.

It is noted that some of the capability coverages are not assessed as high, although some projects do score a high coverage for that capability. Some capabilities encompass a wide range of research goals for 2020, 2035 and 2050, and it is unlikely one project covers this all. Projects that have a very good coverage - although not complete - are assessed as high however, to make full use of the 3-point scale. For the synthesized score of capability coverage a more stringent assessment is made of the full coverage of that capability, making use of a 5-point scale.

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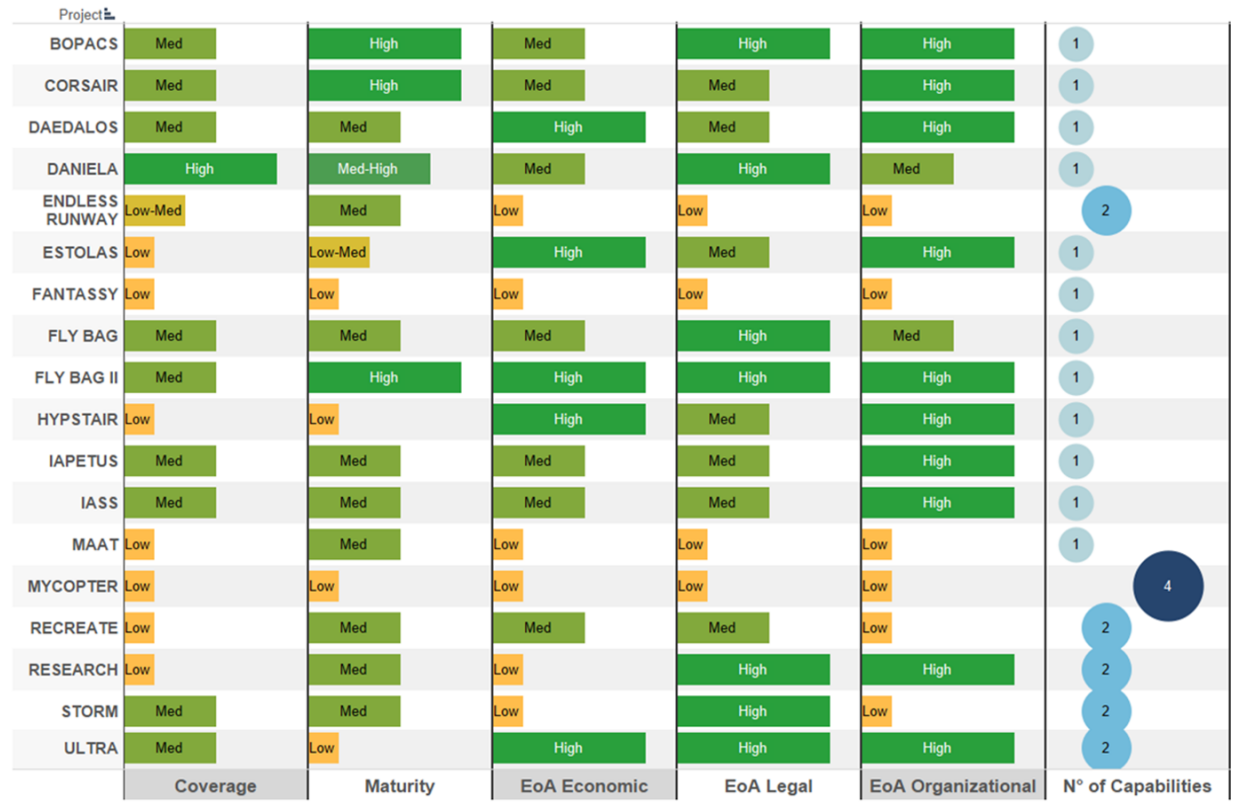

Figure 17: Summaries of assessments of FP7 projects with an implicit link to safety.

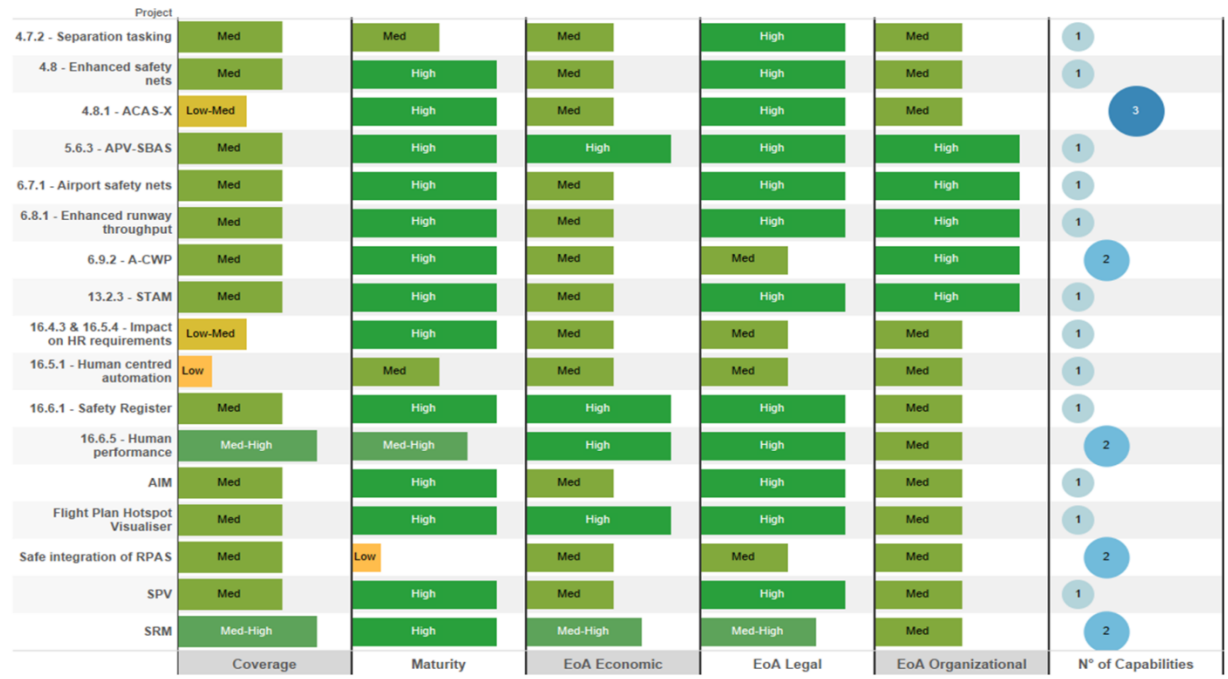

Figure 18: Summaries of assessments of SESAR projects (full project names are given in Table 2).

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Table 2: Short and full names of assessed SESAR projects

Short name	Full name
4.7.2 - Separation tasking	4.7.2 - Separation tasking in en route trajectory based environment
4.8 - Enhanced safety nets	4.8 - Enhanced safety nets for en route and TMA operations
4.8.1 - ACAS-X	4.8.1 - Ground and air safety nets (ACAS-X)
5.6.3 - APV-SBAS	5.6.3 - Approach procedures with vertical guidance - satellite-based augmentation systems
6.7.1 - Airport safety nets	6.7.1 - Airport safety nets project
6.8.1 - Enhanced runway throughput	6.8.1 - Enhanced runway throughput via flexible and dynamic use of wake vortex separations
6.9.2 - A-CWP	6.9.2 - Advanced controller working position
13.2.3 - STAM	13.2.3 - Short-Term Air Traffic Flow Control Management (ATFCM) Measures
16.4.3 & 16.5.4 - Impact on HR requirements	16.4.3 & 16.5.4 - Guidance on impact of future systems in selection, training, competence and staffing requirements
16.5.1 - Human centred automation	16.5.1 - Guidance on human centred automation
16.6.1 - Safety register	16.6.1 - Safety register
16.6.5 - Human performance	16.6.5 - Human performance reference material and human performance case
AIM	Accident Incident Model
Flight plan hotspot visualiser	Flight plan hotspot visualiser
SPV	Separation Performance Visualiser
SRM	Safety Reference Material
Safe integration of RPAS	Steering the safety integration of RPAS

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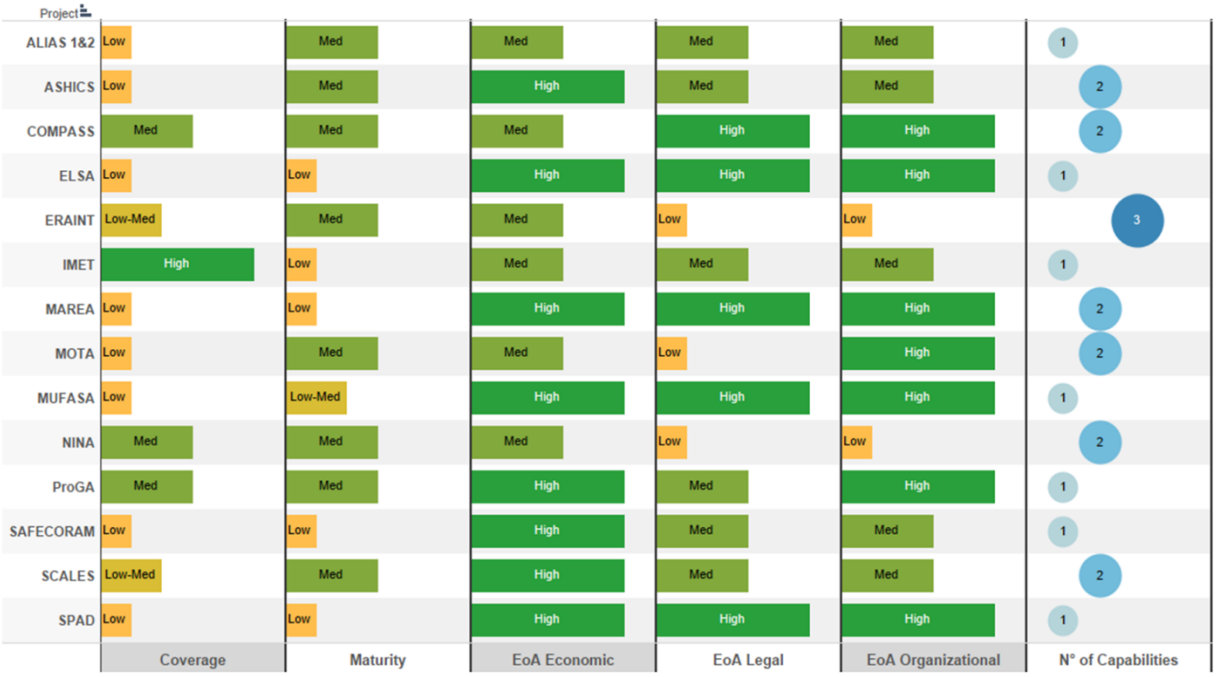

Figure 19: Summaries of assessments of SESAR WPE projects.

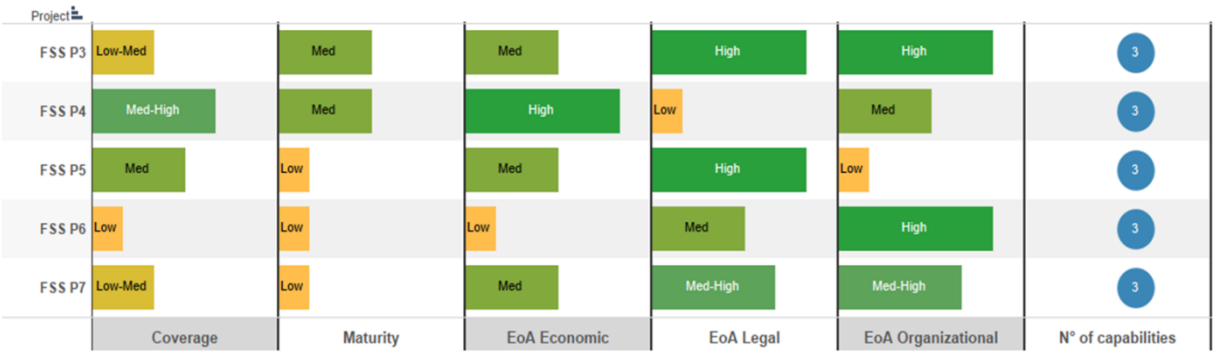

Figure 20: Summaries of assessments of Future Sky Safety projects.

Figure 21: Summaries of assessments of Clean Sky projects.

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Figure 22: Summaries of assessments of FP7 project with an explicit link to safety. From 2014. Part 1 of 2.

Figure 23: Summaries of assessments of FP7 project with an explicit link to safety. From 2014. Part 2 of 2.

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The project assessment results are synthesised at the level of the capabilities and at the level of the enablers, in order to provide a view on how these are addressed by the considered projects. Figure 24 provides an overview of the associated status of the SRIA's safety-related enablers considering the above specified projects. Appendix F and G provide the detailed results of these syntheses.

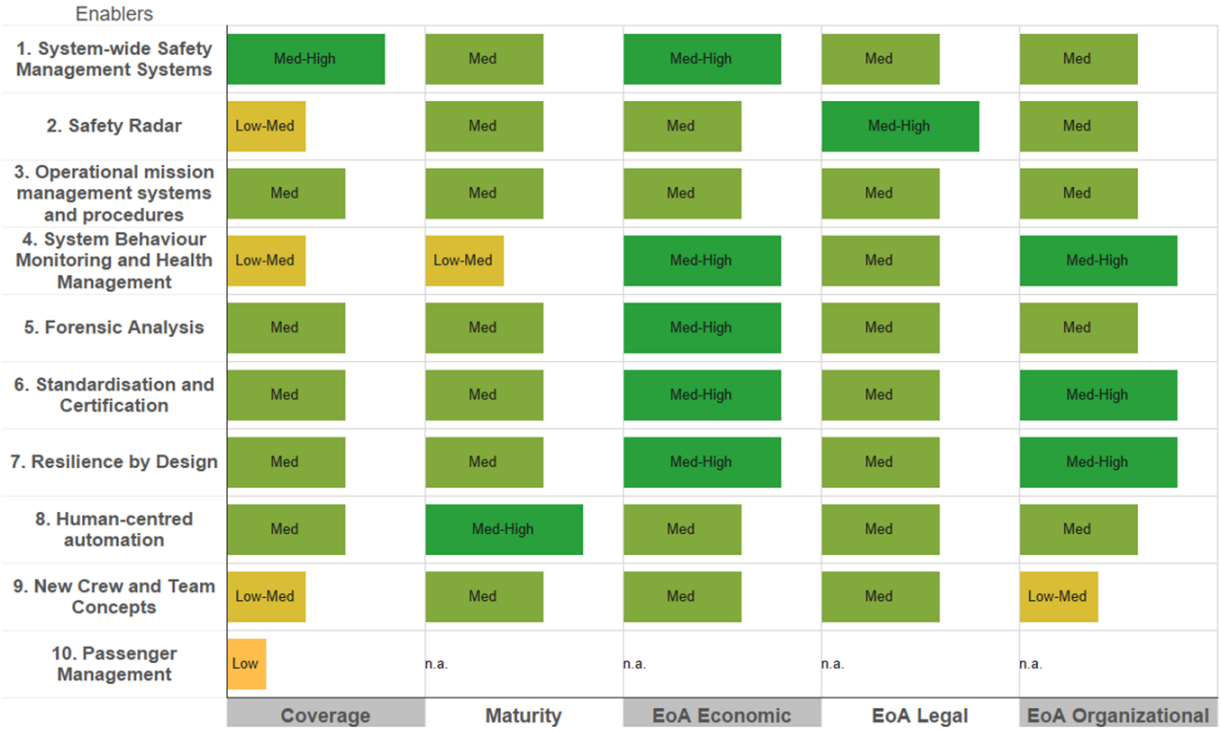

Figure 24: Overview of the status of the SRIA's safety-related enablers.

The coverage of some enablers has shifted significantly due to the inclusion of additional programmes in the year's assessment. The coverage of enabler 1 shifted from a low-medium coverage to a medium-high coverage. This shift is caused by projects in SESAR and Future Sky Safety that cover safety management. The coverage of enablers 3, 5, 6, 7 and 8 shifted from a low-medium to a medium coverage. No change in coverage was achieved for enabler 2, 4 and 9. None of the projects assessed in this year or last year cover enabler 10.

The remainder of this subsection provides for each enabler a graphic representation of the status, and a discussion regarding what is addressed by the considered research projects, and what is not addressed by these projects. Newly and additionally addressed capabilities are described using a bold font. The coverage, maturity and ease of adoption score of each enabler is shown using a gauge. The difference with the 2014 syntheses is also shown using blue bars. An arrow indicates if the change is an improvement or a deterioration compared to last year's assessment. The addressed capabilities are all shown graphically. A colour scheme is used to indicate the capability coverage. The legend of this colour scheme is given in Figure 25.

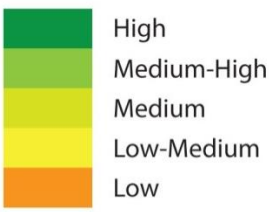

Figure 25: Legend for capability coverage

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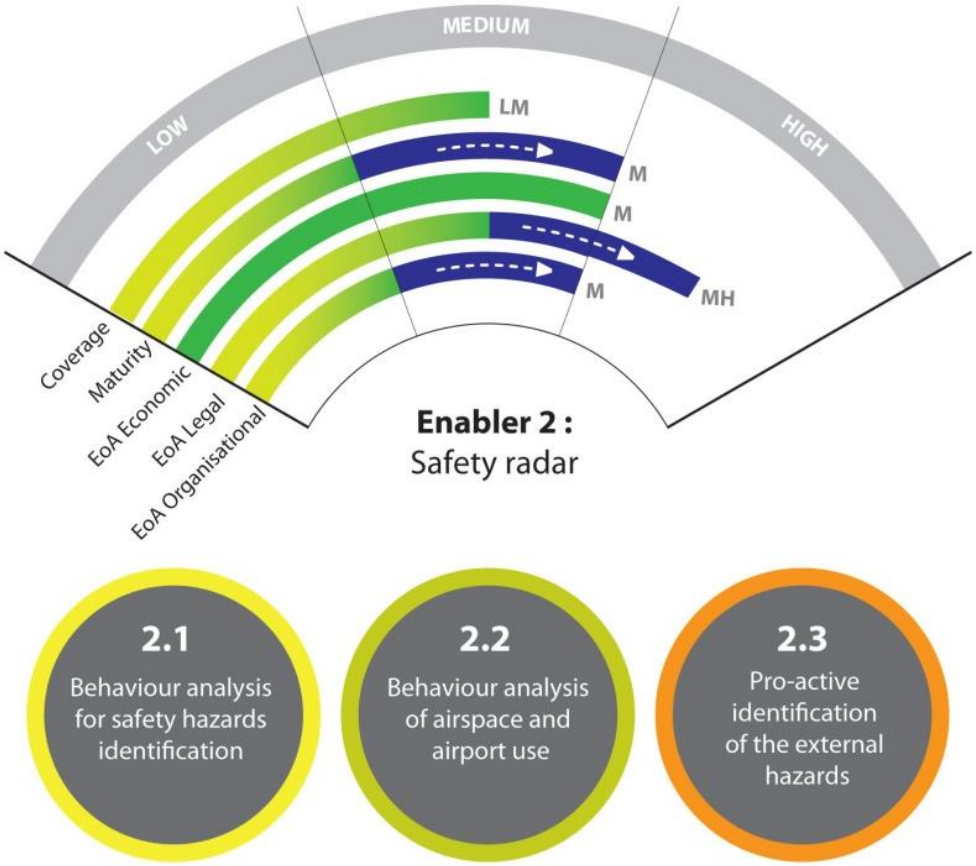
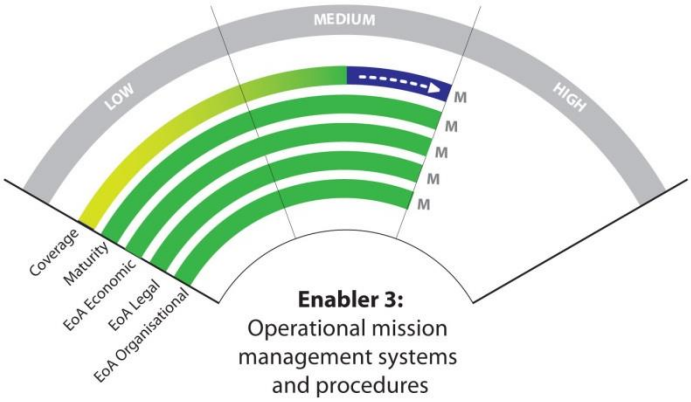
Enabler 1 (System-wide Safety Management Systems) includes 11 safety relevant capabilities.

- *Addressed*: Both capability 1.7 (positive corporate safety culture within organisations) and 1.11 (measurement of system safety performance) are well addressed. **Capability 1.7 was not covered by the research assessed by OPTICS last year, but is well addressed by the Future Sky Safety programme**. Capability 1.2 (system-wide operational risk management system) and 1.9 (tools, metrics and methodologies for risk assessment & managements) are reasonably well addressed. **Capability 1.9 was not addressed by the research covered last year, but is covered by SESAR WPE and SESAR**. Parts of capabilities 1.1 (understanding safety factors on transport system), 1.6 (safety framework that ensures equity in access to airspace by all air vehicles) and 1.10 (pro-active identification of external hazards) are addressed. **Capability 1.6 was not covered last year, but is addressed by projects from SESAR, SESAR WPE and FP7 assessed this year**. **Capability 1.4 (safety management systems integrated with business management systems) is partly addressed by research from the Future Sky Safety programme.**
- *Unaddressed capabilities*: the unaddressed capabilities are related to multi-modal transport (1.3, 1.8), and safety regulations and procedures (1.5).
- *Unaddressed topics within addressed capabilities*: unaddressed topics within the addressed capabilities are interdependencies of transport nodes (1.1, 1.2); the integration of new air vehicles or operations other than RPAS (1.6); the actual ways for pro-active identification of the potential hazards resulting from external hazards (1.10); and indicators of societal perception of safety (1.11).



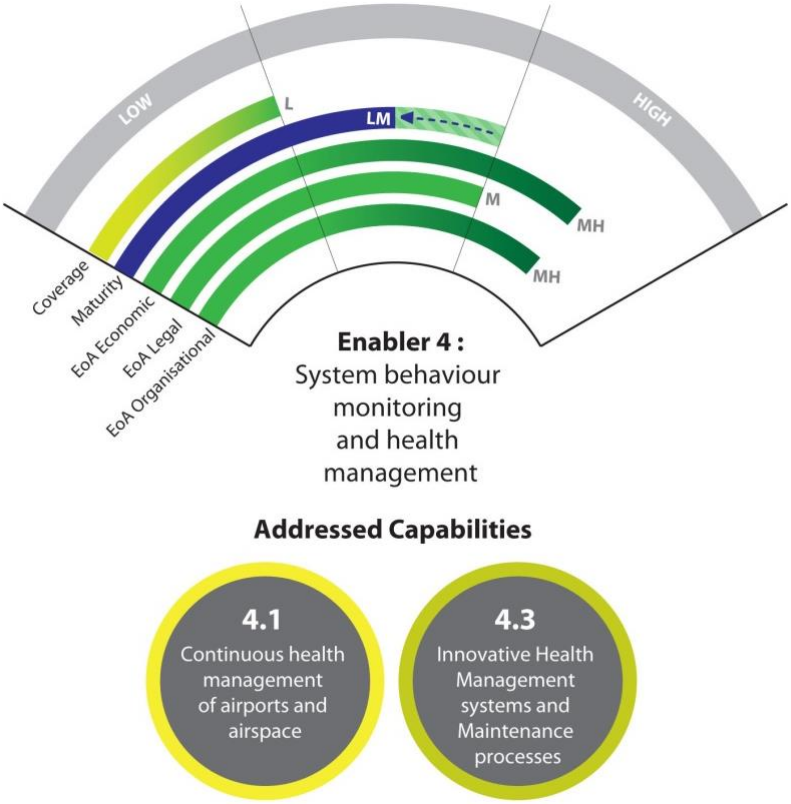
Enabler 2 (Safety radar) includes 3 safety relevant capabilities.

- *Addressed*: parts of each capability are covered. **SESAR provides some additional coverage to capabilities 2.1 (behaviour analysis for safety hazard identification) and 2.2 (behaviour analysis of airspace and airport use)**. This additional coverage of capabilities has not yet an impact on the assessed coverage of the enabler.
- *Unaddressed capabilities*: there are no unaddressed capabilities.
- *Unaddressed topics within addressed capabilities*: the SESAR projects cover ATM, there is a need to expand to the airport and airline domains. The research does not yet provide means for a real-time safety radar function. Capability 2.3's coverage could be increased by research that addresses other external hazards apart from high-altitude icing, e.g. thunderstorms, turbulence, volcanic ash.



Enabler 3 (Operational mission management systems and procedures) includes 11 safety relevant capabilities.

- *Addressed*: capability 3.1 (mission planning models addressing environmental hazards) is reasonably well addressed, **partly because of a high contribution of SESAR WPE**. Parts of capabilities 3.2 (predictive & real time complexity assessment to support mission planning), 3.3 (hazard avoidance in-flight and on the ground), 3.5 (safe integration of e.g., non-commercial flights, personal air vehicles and UAS), 3.6 (adaptive automation allowing human intervention), 3.7 (safety concepts allowing maximum use of resources), and 3.8 (seamless robust CNS coverage) are addressed. **Capability 3.2 is newly addressed this year by research from SESAR and SESAR WPE.**
- *Unaddressed capabilities*: the unaddressed capabilities are 3.4 (commercial Space operations merged safely with traditional flight operations and airspace structures), 3.9 (integrated search and rescue capabilities, rapid and appropriate intervention), 3.10 (all flight objects are uniquely and positively identified, tracked, monitored and neutralised if threatening) and 3.11 (globally networked organisational structures identified and implemented to support safety management).
- *Unaddressed topics within addressed capabilities*: within the addressed capabilities gaps are associated to the avoidance of environmental hazards types other than wake vortex, wind shear, high altitude ice crystals, and clear air turbulence (e.g, volcanic ash) (3.1 and 3.3). There is a lack of validated use of data from aircraft (3.2). There is room for improvement in the coverage of hazard avoidance on the ground and networking of sensor systems (3.3), and for the average maturity of research into the safe access and integration of non-commercial flights, personal air vehicles and UAS to airspace (3.5). Within 3.6 the research assessed there is not a unifying consideration of how far automation should go. For 3.7 there is a gap between near-term research and 'thought experiments' that are unlikely to be implemented in the medium term.



Enabler 4 (System behaviour monitoring and health management) includes 3 safety relevant capabilities.

- *Addressed*: **capability 4.1 (continuous health management of airports and airspace) is partly addressed by SESAR WPE projects.** Parts of capability 4.3 (innovation health management systems and maintenance processes) are addressed, **partly by an FP7 project assessed this year**.
- *Unaddressed capabilities*: capability 4.3 (tracking for search-and-rescue) is unaddressed.
- *Unaddressed topics within addressed capabilities*: a gap to be filled is represented by the need to guarantee reliability and security for these kinds of systems (health management) which are vulnerable to risks (due to technological limits or malevolent attacks). Potential gaps within capability 4.3 are related to investigating health management and self-healing for air vehicle operations in flight and traffic management; and overcoming current limits in fast and efficient implementation of health management facing with critical situations (e.g. weight, real time constraints, reliability, and resilience).

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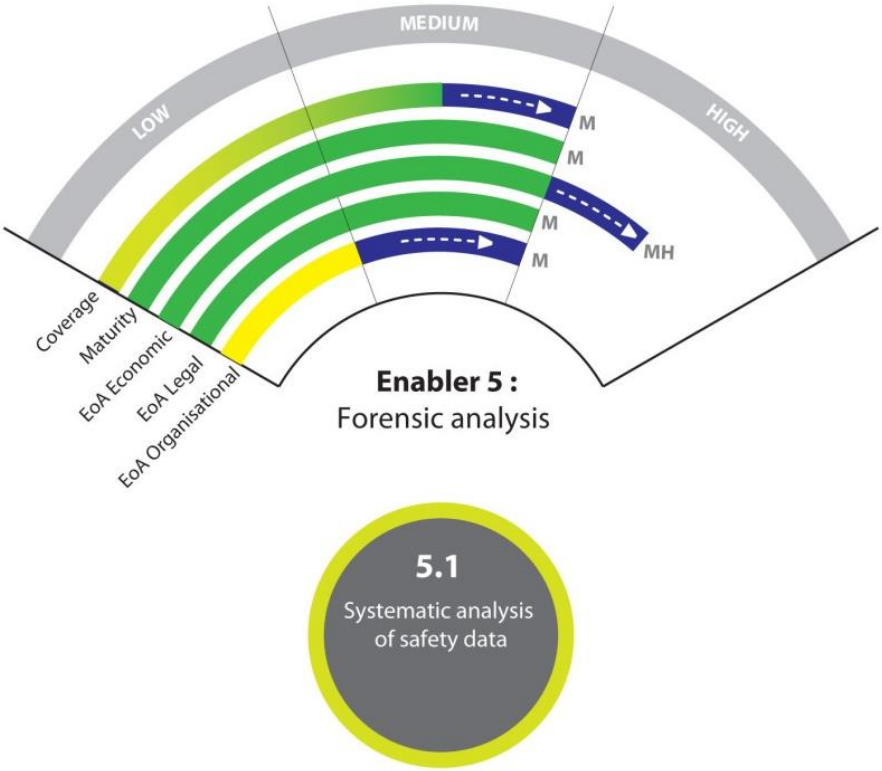

Enabler 5 (Forensic analysis) includes 2 safety relevant capabilities.

- *Addressed*: elements of capability 5.1 (systematic analysis of safety data) are addressed, **partly by research performed in the Future Sky Safety programme**.
- *Unaddressed capabilities*: capability 5.3 (new sensor technology to capture key safety data) is not addressed by the research assessed by OPTICS.
- *Unaddressed topics within addressed capabilities*: significant parts of this enabler are not addressed. This particularly considers: a fully integrated means of capturing safety data of all stakeholders across the ATS (including e.g. general aviation); improvement of the associated safety culture and processes; and the use of these captured safety data by all stakeholders. There is not yet research assessed that is dedicated to the identification of emergent vulnerabilities.

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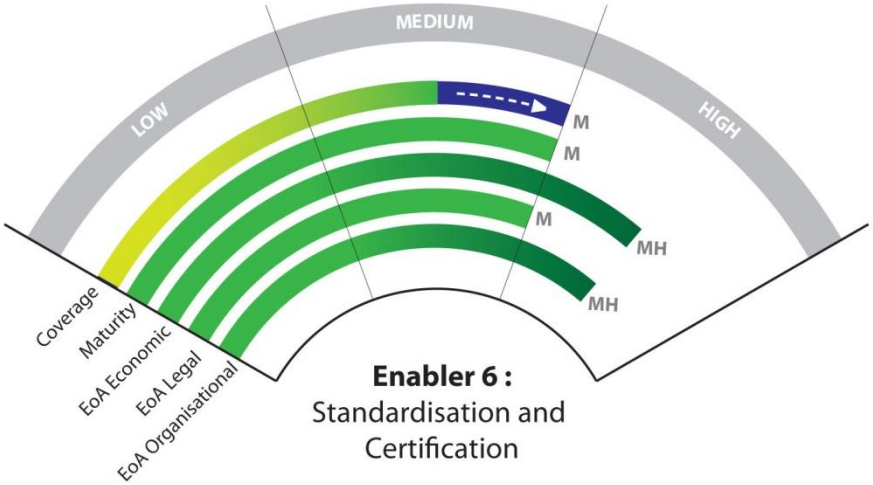

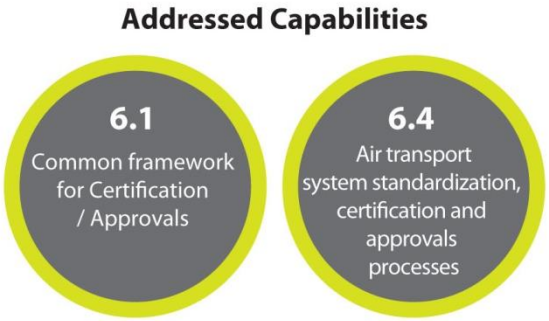

Enabler 6 (Standardisation and Certification) includes 2 safety relevant capabilities.

- *Addressed*: several elements of capabilities 6.1 (improved certification/ approval) and 6.4 (global processes) are addressed by research assessed by OPTICS. **Research projects addressed this year - from FP7, SESAR WPE and Clean Sky - only cover capability 6.1**.
- *Unaddressed capabilities*: all safety relevant capabilities are covered by research assessed by OPTICS in 2014 and 2015.
- *Unaddressed topics within addressed capabilities*: several segments of the total aviation system are not yet addressed (e.g. light aircraft). There is a lack of use of large operational data sets to feed risk models, and the impact of organisational changes is not yet properly addressed.

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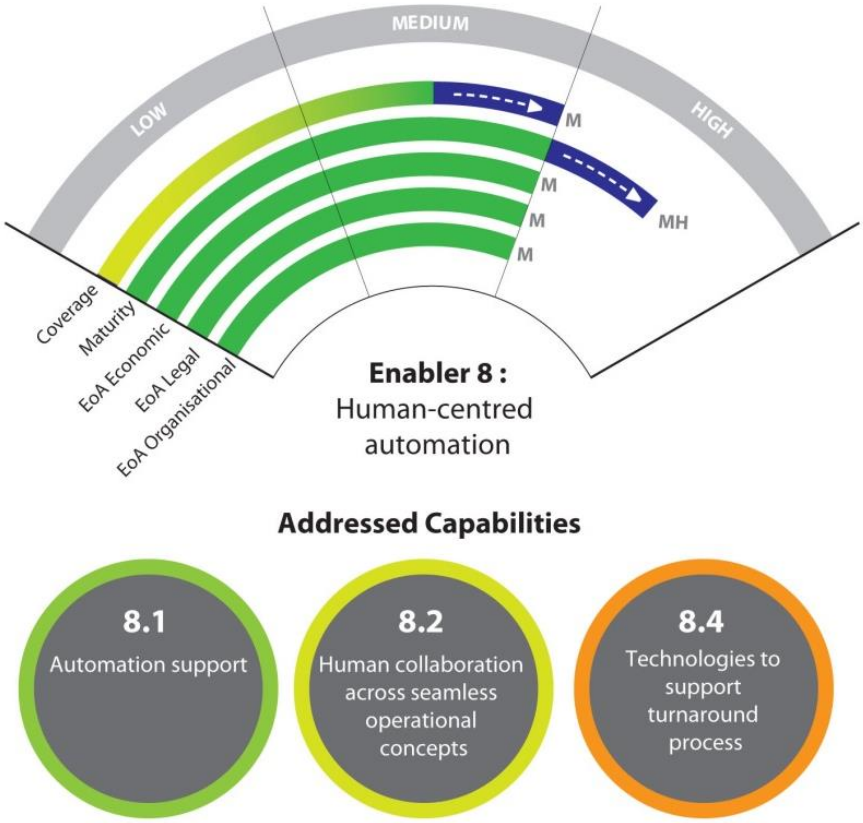
Enabler 7 (Resilience by design) includes 11 safety relevant capabilities.

- *Addressed*: **capability 7.2 (systematic methods for ensuring in-service experience) is newly addressed this year by research performed under SESAR WPE**. Capability 7.12 (reliability engineering of critical software) still has a low coverage, none of the projects assessed this year map to this capability. Parts of capabilities 7.1, 7.3, 7.5, 7.6 , 7.9 and 7.10 are covered. **All of these capabilities have coverage from research performed within the programmes considered by OPTICS in 2015**. Capability 7.10 (human factors and psycho-social issues in design and manufacturing is now reasonably well covered, **partly due to research performed under SESAR and SESAR WPE**.
- *Unaddressed capabilities*: capabilities 7.7 (multi-modal forums), 7.8 (availability of the suitably qualified and adaptable workforce and a framework which ensures the continued support to both legacy and emerging technologies), and 7.11 (airworthy aircraft is constantly in service with minimum deferred defects) are not addressed by research assessed by OPTICS in 2014 and 2015.
- *Unaddressed topics within addressed capabilities*: for 7.1 (feedback to design) the SESAR approach could be extended to other parts of the air transport system. For 7.3 (environmental hazards) some relevant environmental hazards are still lacking (e.g., fog, wind shear, thunderstorms). For 7.6 (improved survivability), crashworthiness is missing. For 7.9 (advanced systems engineering), dealing with large numbers of stakeholder requirements is missing. For 7.10 there is now an approach that could be adopted and tailored for industry.



Enabler 8 (Human-centred automation) includes 4 safety relevant capabilities.

- *Addressed*: **parts of capability 8.1 (automation support) are covered by projects from all programmes assessed by OPTICS this year**. The overall coverage of 8.1 has therefore increased and is now medium-high. **Capability 8.2 (human collaboration across seamless operational concepts) is newly addressed by SESAR projects assessed by OPTICS this year**. This year's assessment did not result in a change of coverage for capability 8.4 (technologies to support turnaround process).
- *Unaddressed capabilities*: capability 8.3 (preventive maintenance and system upgrades of automated systems) is not addressed by research assessed by OPTICS this year or last year.
- *Unaddressed topics within addressed capabilities*: the coverage of capability 8.4 could be increased by integration of existing solutions with airport and aircraft. It is furthermore noted that the scope of capability 8.1 is very wide, which complicates R&I initiatives and the monitoring by OPTICS. The utility of task analysis in other sectors is currently unaddressed.

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Enabler 9 (New crew and team concepts) includes 5 safety relevant capabilities.

- *Addressed*: **capability 9.1 (new collaborative team concepts across the whole ATS system) is newly addressed this year by research from the Future Sky Safety programme**. Parts of capabilities 9.2 (human performance envelope) and 9.3 (monitoring of team capacity) are addressed, **also by research assessed this year**.
- *Unaddressed capabilities*: capabilities 9.4 (CISM for organisations/teams) and 9.5 (passenger/ personnel culture) are not addressed by research assessed by OPTICS.
- *Unaddressed topics within addressed capabilities*: the research that addresses capabilities 9.1, 9.2 and 9.3 do not cover crews other than pilot and controllers, such as maintenance operators.

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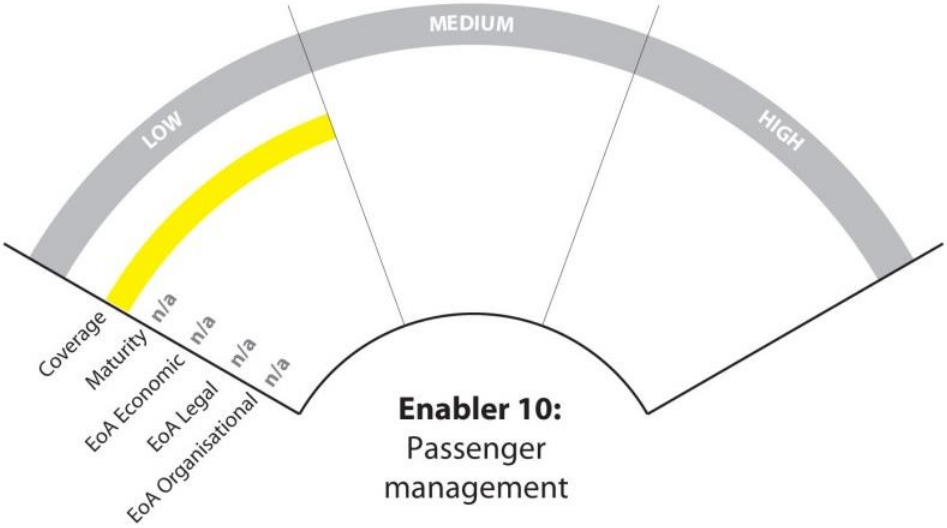

Enabler 10 (Passenger management) includes 3 safety relevant capabilities.

- *Addressed*: no capabilities of enabler 10 are addressed by the research assessed by OPTICS in 2014 and 2015.
- *Unaddressed capabilities*: all three safety relevant capabilities: 10.2 (management of human behaviours during emergencies), 10.4 (post-traumatic stress and psycho-social needs after distress), and 10.5 (passenger culture).
- *Unaddressed topics within addressed capabilities*: n/a.

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5.2. Expert workshop 2: From Hazard Management to Operational Resilience

This section summarized the results of the Second Expert Workshop organized by OPTICS. A full report is available online (OPTICS (2015b)). An analysis of the Expert Workshop outcomes resulted in a top ten of priorities for research directions for the four focal areas: autonomous systems, use of data, self-healing and weather. The top ten is structured around the following four 'driving forces' in aviation and aviation research today:

- UAS/RPAS integration into airspace is coming fast, but we are hardly prepared, and have an insufficient research basis for its integration.
- Real-time data analysis on human and system behaviour, including the performance of the human-automation team, should offer significant safety advantages.
- The necessity to improve the resilience of the air transportation system, and in particular the safety performance, as the socio-technical system grows in complexity.
- The integration of resources, knowledge and advanced technologies is now a must to ensure safe, fair and cost-effective aircraft operations under adverse weather conditions.

The resulting top ten of priorities for research directions is given below. The first four represent the top priority in each of the four focal areas.

1. Develop a new CONOPS that accommodates the rapidity and scale of developments occurring with RPAS/UAS and their impending integration into airspace. This new CONOPS must address issues ranging from legal (who is liable in case of an accident?) to regulatory (how must the operators and manufacturers account for safety and protection of the consumer?) to human performance (how can pilots and controllers manage the step-change in traffic complexity that may occur with UAS/RPAS?).
2. Develop real-time data analysis capability of human and automated system behaviour (e.g. pilots and aircraft subsystems; controllers and traffic management subsystems), and their interactions, that can detect precursors to adverse events and initiate protective measures before safety margins are affected.
3. Demonstrate the safety benefits to aviation and air transportation through the application of resilience in complex socio-technical systems. In particular determine a conceptual platform demonstrating resilience with associated models and metrics.
4. Increase the resilience of operation in adverse weather conditions by making possible shared understanding of weather hazards and cooperative building of weather awareness.
5. Derive a new and more agile V&V (Verification and Validation) approach for RPAS/UAS, one that includes in-service validation.
6. Develop advanced models of shared situation awareness and collaborative and dynamic decision-making for fully-integrated RPAS/UAS systems.
7. Determine the success factors in automation and its development cycle that lead to human trust in automation. Automation is key to future growth and safety, but if it is not trusted by the operators it will not be used/effective.

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8. Insights from data analysis should be fed back into design, but this is rarely done except in long time-frames. This has led to a gap between 'systems-as-designed' and 'systems-as-used'. A new, fast-track system for feeding back operational data into design needs to be developed.
9. Develop affordable technologies to go beyond current flight limitations in adverse weather conditions.
10. Use the weather knowledge in the decision chain to optimize the interest of each aviation actor while ensuring global safety and fairness.

Further analysis of these top priorities shows that there are three recurring themes:

Enabling future operations with advanced technology. This theme is seen under autonomous systems where the advanced technology is available, but where non-technical issues stand in the way of full spread implementation; what is an acceptable level of safety, who - or what - is accountable, how to regulate airspace access? The advanced technology might also require a complete redesign of how to operate. Under self-healing priorities human-automation-teaming is another example of advanced technology that requires rethinking of the concept of operations. Future developments pose a challenge on the way we assure aviation is safe. Autonomous systems developments require rethinking on how we verify and validate safety of these systems. Increased reliance on advanced software also poses challenges in the assurance of safety. It should be ensured that software engineers are qualified and do not rely on trial-and-error methods of software development.

Resilience. Making aviation resilient to non-nominal situations is a recurrent theme, which is underpinned by the reliance on the provision of comprehensive high quality operational data. It is needed to assure safety in an ever more complex environment. Resilience itself is subject to the study of fundamental questions such as what is understood by resilience within the complex socio-technical system that is the air transport system and how this system's behaviour may be modelled, measured and improved. For weather it is foreseen that technology can improve operations under bad weather conditions. Advanced sensors can be used to monitor system behaviour to self-correct in case of non-nominal operation.

Data and information. This is the most recurrent theme. Sharing data between stakeholders is believed to be a top priority. Constraints have to be overcome; harmonization, quality assurance, traceability of data, security etc. Advanced weather data can be collected to distribute weather information to relevant actors in order to increase weather hazard awareness. Enhanced weather information can be used in decision making processes for optimizing operations. Measuring human performance and using that information to improve both system design and aircraft operations is a clear research priority. Also in maintenance the use of data is foreseen to move to evidence-based maintenance, to take into account new difficulties related to new technology and use health-monitoring capabilities.

5.3. Gaps, bottleneck and priorities

In 2014 44 projects were assessed and mapped to capabilities of the SRIA. In 2015 an additional 63 projects are assessed. The addition of these new projects resulted in bridging some gaps, but there are still capabilities not addressed by any of the projects assessed in 2014 and 2015. Enabler 10 (passenger management) is still not addressed at all. There are also clear steps in the right direction, human factors in design was pinpointed as an issue from the 1st OPTICS expert workshop, but is now well-covered by capability 7.10. It is interesting to note that the exploratory research from SESAR WPE addresses some capabilities that are not addressed by the other programmes.

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Only for enablers 2 and 6 are all safety related capabilities addressed. Only enabler 1 has capabilities (two) that OPTICS considers to have a capability coverage score of 'high'. Enabler 1 also has the highest coverage score, namely 'medium-high'. A remaining gap for enabler 1 is that identification of safety performance indicators which will truly advance aviation safety. It is unlikely the coverage of an enabler will be classified as high, since that would mean the research covers the goals for 2020, 2035 and 2050. It would therefore be useful to segment the SRIA, so the enabler could reach high for the appropriate time period.

There are some clear gaps that overarch separate enablers. All of the research that is assessed by OPTICS focuses on aviation. No research looks into aspects of multi-modal transport - a research direction that is included in the SRIA. Given the maturity of research in aviation, it is the proper time to start research on safety of multi-modal transportation. Most research on equity of access to airspace focus on remotely piloted aircraft systems (RPAS). Other future aviation concept (e.g. personal aviation, commercial space flight) are taken into account far less. Research in the maintenance domain is also under-addressed by the research assessed by OPTICS in 2014 and 2015.

Last year only projects were assessed from the seventh framework programme. This year projects from four additional programmes were assessed. This showed that there seems to be a gap between near-term research which is close to implementation (e.g. the projects performed under SESAR) and research projects that can be seen as thought experiments that are unlikely to be implemented in the near or medium-near term.

From the ease of adoption assessments it becomes clear that there are commercial considerations that may be hindering industry-wide collaboration on safety research. It should be noted that with an increasing number of projects assessed, it becomes more difficult to define average ease of adoption scores. For 2016 OPTICS will therefore consider the need to cluster projects by topics and look at ease of adoption of those topic clusters, or use a more structured approach by putting projects in a matrix (ease of adoption classes vs score) for an optimized overview.

The Second OPTICS Expert Workshop also pinpointed several gaps in the SRIA. Although the SRIA foresees the need for a safety framework that ensures equity in access to airspace by all air vehicles, including RPAS/UAS (e.g. capability 3.5 - safe integration of e.g., non-commercial flights, personal air vehicles and UAS), it does not acknowledge that there might be a need to develop a new CONOPS to accommodate that integration.

Future verification and validation (V&V) needs pinpointed in the SRIA focus on the need for standardization, but do not highlight the needed derivation of new and more agile V&V approaches for RPAS/UAS that include in-service validation.

Another gap identified in the workshop is related to automation. Although this topic is extensively covered by the SRIA (e.g. capability 3.6 - adaptive automation allowing human intervention), the idea of determining success factors in automation and its development cycle that lead to human trust in automation is not yet covered by the SRIA.

Although needed research into improving aircraft maintenance is included in the SRIA, it does not contain the idea to move from process-based maintenance to evidence-based maintenance as identified in the self-healing workshop sessions.

A final gap in the SRIA is the lack of research related to the needed skills of software engineers. It is recommended to include in the SRIA research into the needed qualification of software engineers for safety critical application, producers of components (microprocessors etc.) and adapted system engineering approach. The idea to certify software engineers should also be explored.

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6. CONCLUSIONS AND RECOMMENDATIONS

The first part of this report has presented the results of a trial assessment conducted to better understand the impacts aviation safety research can have on society and the economy. OPTICS has trialled a methodology to address these impacts, based on a range of indicators and sources.

Indicators in the "Socio-Economic Needs and Expectations" category illustrate the overall social and economic well-being of the European society. The creation of jobs, the continuous improvement of safety levels or investments made in aviation safety research, for example, are aspects dealt with in this category. The second category "Environmental Considerations" traces the relation between environmental concerns and developments in aviation safety. This category focuses on the effects enhancements in one of these areas can have on the other and whether such cross-impacts are considered in research projects in either field. Indicators relating to "Industry Competitivity" cover aspects affecting the position of the European aviation industry in the worldwide market. The category aims at tracing whether research in aviation safety in Europe provides the industry with competitive advantages and thus supports the industry's leadership position. Aspects relating to the available research infrastructure as well as the level of education provided within the area of aviation safety are clustered in the fourth category "Capacity of EU Safety Research". There are also aspects such as the excellence of safety research within Europe and the strategic focus of aviation safety research covered here.

A central result from this preliminary assessment is that the public as well as aviation experts trust the air transport system to provide safe services. The feedback from project coordinators leads to the conclusion that results from previous projects are taken into account and that research is structured according to end user needs. Even though there are very few master programmes dedicated to aviation safety, coordinators were satisfied with the skills of the projects' personnel. Download statistics for safety related journals suggest that there is a worldwide interest for aviation safety research with no world region dominating.

Overall, the societal impact methodology has demonstrated 'proof of concept', and it will now be expanded to more projects in the remaining two years of the OPTICS work programme.

In 2015 OPTICS improved its state-of-the-art in safety research assessment by mapping an additional 63 safety-related research projects to the Strategic Research and Innovation Agenda (SRIA). Projects from the following programmes were considered: SESAR, SESAR WPE, Clean Sky, Future Sky Safety and FP7. Parallel to the project assessments, OPTICS organized in 2015 its 2nd Expert Workshop, attended by 50 experts in aviation safety.

The projects assessed in 2015 are more tightly coupled than the FP7 projects assessed in 2014 because of the common goal or research area of the programme they fall under: SESAR (ATM research), Future Sky Safety (aviation safety research) and Clean Sky (Environmental impact of aviation). The assessment of the individual projects within these programmes might not give a complete overview of the total impact of the programme. In 2016 the OPTICS team will study the possibility of including an assessment of a programme as a whole in the yearly synthesis of research.

The addition of new projects in the state-of-the-art assessment resulted in bridging gaps that were identified in 2014. A clear example is that human factors in design was pinpointed as an issue from the 1st OPTICS expert workshop, but is now well-covered. Every enabler - with the exception of enabler 10, which is not yet addressed by any project assessed by OPTICS - has additional coverage from projects assessed in 2015. The coverage for enabler 1 increased from low-medium to medium-high. The coverage of enablers 3, 5, 6, 7 and 8 increased from low-medium to medium. The coverage score of

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enablers 2 and 9 did not change. The maturity of research covering enabler 2 did increase, as did the ease of adoption of the research concepts.

Some of the enablers are now covered by ten or more projects. The synthesized scores of coverage, maturity and ease of adoption of SRIA capabilities and enablers are determined using expert opinion. The increased number of projects assessed makes it more challenging to come to consistent scores. The OPTICS team will therefore reassess its scoring methodology at the beginning of 2016 to assure consistency in the synthesis scores. Special attention will be paid to the ease of adoption score, which is sometimes difficult to compare between projects. For 2016 OPTICS will therefore consider the need to cluster projects by topics and look at ease of adoption of those topic clusters, or use a more structured approach by putting projects in a matrix (ease of adoption classes vs score) for an optimized overview.

There are still capabilities not addressed by any of the projects assessed in 2014 and 2015. There are also clear gaps that overarch separate enablers identified by the state-of-the-art assessment and by the expert workshop. These gaps are:

- No research looks into aspects of multi-modal transport - a research direction that is included in the SRIA. Given the maturity of research in aviation, it may be time to start research on safety of multi-modal transportation.
- Equity of access to airspace of future aviation concepts such as personal aviation and commercial space flight are taken into account in research far less than research on remotely piloted aircraft systems (RPAS). Furthermore, the need to develop a new CONOPS to accommodate integration of these concepts into current airspace is not yet acknowledged.
- Research in the maintenance domain is under-addressed by the research assessed by OPTICS in 2014 and 2015.
- There is sometimes a research void between near-term research which is close to implementation (e.g. the projects performed under SESAR) and research projects that can be seen as thought experiments that are unlikely to be implemented in the near or medium-near term.
- There is a need to derive new and more agile V&V approaches for RPAS/UAS that include in-service validation.

In the next two years OPTICS will extend its analysis to include national European safety-related research projects (2016) and international safety-related research projects (2017). In addition, OPTICS plans to update the assessments of projects for which substantial additional information becomes available. These activities will eventually determine whether the identified potential gaps are indeed gaps, or appear to be addressed after all.

This year's OPTICS work gave rise to possible improvements to the SRIA. OPTICS recommends to ACARE to include the following in an update of the SRIA:

- The need for research into determining success factors in automation and its development cycle that lead to human trust in automation. This would further increase coverage of automation in the SRIA.
- Research needs for a move from process-based maintenance to evidence-based maintenance.
- Research needs related to the required skills of software engineers.

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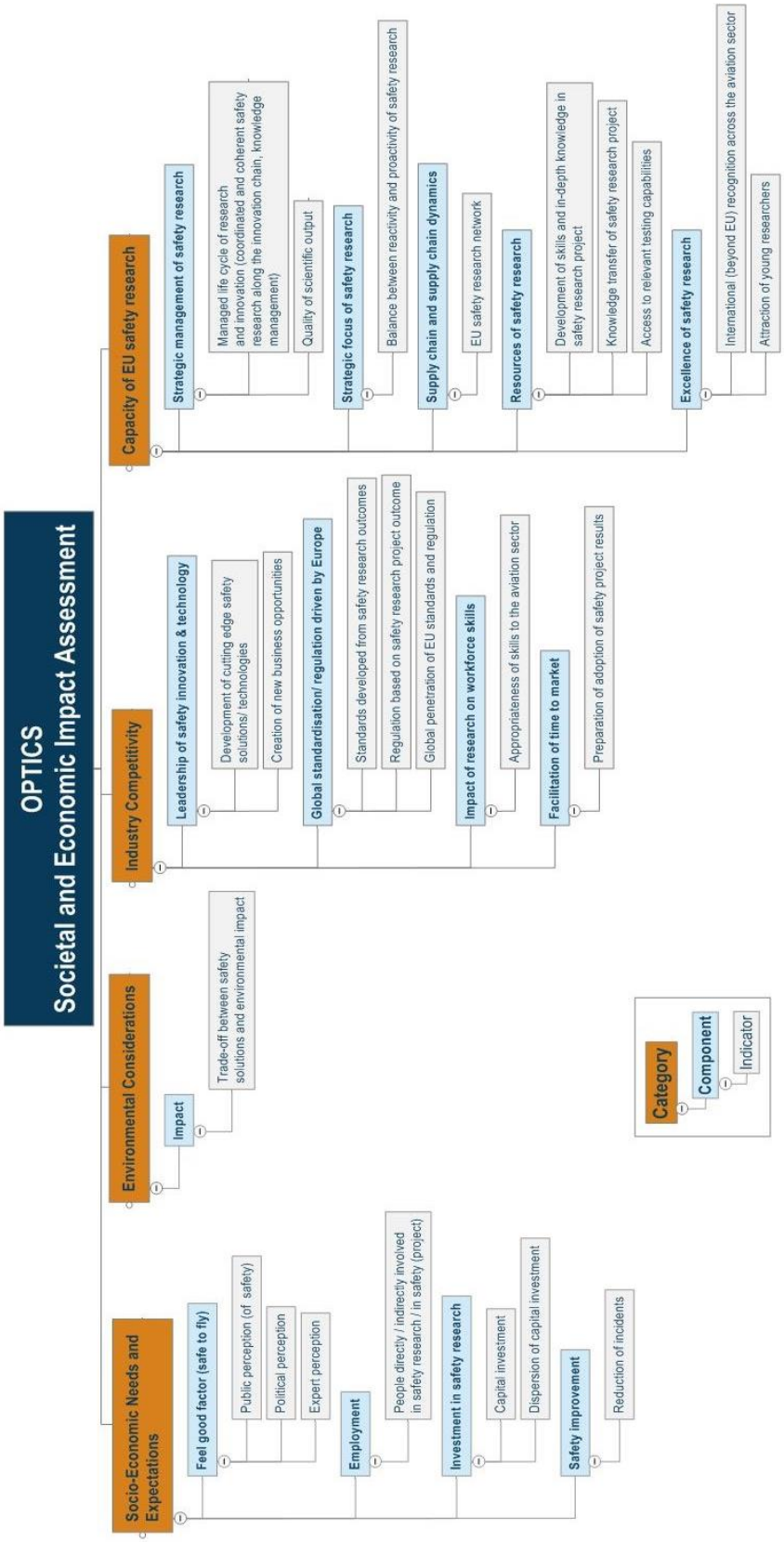
APPENDIX A – STRUCTURE OF INDICATORS



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APPENDIX B – TABLE INDICATING THE DIFFERENT INFORMATION SOURCES

optics
Observation Platform for Technical and Institutional Consolidation of Safety research

Societal and Economic Impact Assessment

Category	Component	Indicator	Metric	Source
Socio-Economic Needs and Expectations	Feel good factor (safe to fly)	Public perception	Qualitative	Interviews with public
			Qualitative	Internet search
		Political perception	Qualitative	Internet search
		Expert perception	Qualitative	ACARE WG 4
			Qualitative	ACARE SIB
			Qualitative	ACARE IRG
	Employment	People directly / indirectly involved in safety research / in safety (project)	Quantitative	ASD
			Quantitative	Project coordinator
			Quantitative	EREA
	Investment in safety research	Capital investment	Quantitative	Internet search
			Quantitative	OPTICS WS1 database
		Dispersion of capital investment	Quantiative	OPTICS WS1 database
	Safety improvement	Reduction of incidents	Quantitative	EASA
Environmental Considerations	Impact	Trade-off between safety solutions and environmental impact	Quantitative	Project coordinator
			Qualitative	Project coordinator
			Quantitative	Project coordinators (of Forum AE, Xnoise, CoreJetFuel)
Industry Competitivity	Leadership of safety innovation & technology	Development of cutting edge safety solutions/technologies	Qualitative (possibly quantitative)	Project coordinator
		Creation of new business	Quantitative	Project coordinator
			Quantitative	Project coordinator
	Global standardisation/ regulation driven by Europe	Standards developed from safety research outcomes	Quantiative and qualitative	Project coordinator
			Quantiative and qualitative	EUROCAE
			Quantiative and qualitative	ICAO
		Regulation based on safety research project outcome	Quantiative and qualitative	Project coordinator
			Quantiative and qualitative	EASA
			Quantiative and qualitative	FAA
		Global penetration of EU standards and regulation	Qualitative	EASA
			Qualitative	EASA
	Impact of research on workforce skills	Appropriateness of skills to the aviation sector needs	Qualitative	Project coordinators
			Qualitative	ASD
			Qualitative	EREA
	Facilitation of time to market	Preparation of adoption of safety project results	Qualitative	Project coordinator
			Qualitative	ASD
Capacity of EU safety	Strategic management of	Managed life cycle of research	Qualitative	EC

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Capacity of EU safety research	Strategic management of safety research	Managed life cycle of research and innovation (coordinated and coherent safety research along the innovation chain, knowledge management)	Qualitative	EC
			Qualitative	Project coordinators
			Qualitative	SJU
		Quality of scientific output	Quantitative	Project coordinators
	Strategic focus of safety research	Balance between reactivity and proactivity of safety research	Qualitative	Project coordinator
			Qualitative	EASA
			Qualitative	ACARE
	Supply chain and supply chain dynamics	EU safety research network	Qualitative	Project coordinator
			Qualitative	EREA
			Qualitative	ASD
			Qualitative	EASA
			Quantitative	Project coordinator
			Quantitative	Project coordinator
	Ressources of safety research	Development of skills and in-depth knowledge in safety research project	Quantiative and qualitative	Project coordinator
		Knowledge transfer of safety research project	Quantiative and qualitative	Project coordinator
		Access to relevant testing capabilities	Quantiative and qualitative	Project coordinator
	Excellence of safety	International (beyond EU) recognition across the aviation sector	Quantitative	Project coordinator
			Quantitative	Internet search
		Attraction of young researchers	Quantiative and qualitative	EASN
			Quantiative and qualitative	Internet search
			Quantiative and qualitative	Project coordinators
			Quantiative and qualitative	Internet search

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APPENDIX C – PUBLIC QUESTIONNAIRE

Public Perception

What is your preferred mode of transport for trips...

of 200 kms to 400 kms?

Mode	Comment (optional)

of 400 kms to 600 kms?

Mode	Comment (optional)

over 600 kms?

Mode	Comment (optional)

What are the most important keywords that come to your mind when you think about air transport?

Keyword	Comment (optional)
1	
2	
3	
4	

How often did you fly during the last two years?

☐ 0-2 ☐ 3-6 ☐ 7-16 ☐ 17+

Personal Information

Age ☐ 15-24 ☐ 25-34 ☐ 35-49 ☐ 50-64 ☐ 65+

Sex ☐ F ☐ M

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APPENDIX D – COORDINATOR QUESTIONNAIRE

Societal and Economic Impact Assessment

Composition of workforce engaged in research within the project
(excluding admin, management, etc)

1. How many researchers per partner are directly engaged in research and what is the main competence each project partner is contributing to your project?

Project partner	Number of researchers	Competence

2. Are there different teams/ departments/ chairs from the project partners involved in your project?

☐ Yes ☐ No

If yes, please indicate:

Project partner	Name or focus of team/ dept/ chair 1	Name or focus of team/ dept/ chair 2	Name or focus of team/ dept/ chair 3

For those partners where more than one team/ department/ chair is involved in the project: How many employees work in these teams/ departments/ chairs?

Project partner – specific department	Number of employees

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3. If there are any universities involved in your project: Are those universities providing specific curricula focusing on safety education in aviation?

☐ Yes ☐ No If yes, please elaborate on the nature of these classes:

Do advancements achieved throughout the project influence the curricula of these universities?

☐ Yes ☐ No If yes, please give short examples:

4. How is the workforce of the safety research project composed with respect to gender, nationality and educational background?

Please indicate the number of males and females:

Male	Female

Please list the different nationalities:

Please insert the total number of the highest professional qualification of the members of the research project:

Qualification	Number
Student	
Bachelor	
Master	
Diploma	
PhD	
Other	

5. How many phd thesis, master thesis and other thesis resulted/will result from the project?

Category	Number
Master thesis	
PhD thesis	
Other	

6. Did you have to recruit new personnel to cover all skills necessary to conduct the project?

☐ Yes ☐ No

If yes, did you encounter difficulties in recruiting personnel with appropriate skills?

☐ Yes ☐ No

If so, please elaborate briefly:

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7. Do you feel that universities are providing you with personnel that are sufficiently qualified to perform safety specific tasks within your project? Please elaborate.

8. How many experts beyond the project's core team are associated with the project (e.g. advisory board)?

9. How do you assure end user involvement in your project?

Research conditions and scientific output

10. Have you addressed or benefitted from any cross-cutting research with other safety critical sectors, i.e. medical, nuclear, oil & gas within the scope of your project?

☐ Yes ☐ No If yes, which sector, which topic:

11. Please indicate the number of publications as well as dissemination events related to the project.

	Number:
Conference papers	
Journal papers	
Citations	
Invited talks	
Dissemination events (workshops, conferences etc. organized by the project consortium)	
Other:	

12. If (a) project dissemination event(s) took place: Did representatives from outside the EU participate in this (these) event(s)?

☐ Yes ☐ No ☐ Not applicable

If yes, what percentage of the audience did they approximately represent?

%

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13. Has the project received an invitation to...

...participate in an international (within EU) safety event?

☐ Yes ☐ No If yes, how often?

...present the project at an international (within EU) safety event?

☐ Yes ☐ No If yes, how often?

...participate in an international (outside EU) safety event?

☐ Yes ☐ No If yes, how often?

...present the project at an international (outside EU) safety event?

☐ Yes ☐ No If yes, how often?

14. Are the project's scientific or technical deliverables published with confidentiality restrictions?

☐ Yes ☐ No

If yes, please indicate the percentage of restricted scientific or technical deliverables, i.e. excluding administrative, management, etc %

15. Are/ will the scientific and or technical results and deliverables (be) publicly available upon project conclusion?

☐ Yes ☐ No

If yes, how do you (plan to) make them available?

16. Does the project require any testing facilities?

☐ Yes ☐ No

If yes, are the necessary testing facilities available?

☐ Yes ☐ No

If yes, how do you ensure access?

If no, how do you cope with the restraint?

17. Is your research oriented more towards short term or long term safety goals?

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☐ Short term goals ☐ Long term goals

Please specify the split of project budget oriented towards...

...short term goals: ____ %
...long term goals: ____ %

Please specify the time horizon envisaged for the in-service application of project results.

Short term goals: Year 20____
Long term goals: Year 20____

18. Which goals from EU strategic visions and initiatives, i.e. FP 2050 and ACARE SRIA, are addressed by your research project?

____

19. Does the research addressed in the project build upon previous knowledge?

☐ Yes ☐ No

If yes, please identify the related projects and topic areas, or other sources:

____

If yes, how important do you consider this contribution to the success of your research?

☐ very important ☐ important ☐ of little importance ☐ unimportant

Please provide an indication of the level of TRL's addressed within the project/topic area:

TRL start ____

TRL end ____

Towards market introduction

20. Does the project foresee the delivery of a business case with the results of the research project?

☐ Yes ☐ No

If yes, please describe the application briefly:

____

If yes, please provide a brief description of how the project is preparing the adoption of project results by the market?

____

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21. Has the research resulted in any direct spin-offs, e.g commercial venture, product, research department, unit, team?

☐ Yes ☐ No

If yes, please describe the nature of the spin-off(s) briefly. To which aspect of the project does it (do they) relate? Is it (are they) implemented or planned?

22. Please indicate the number of patents that have been developed in relation to the project and describe them briefly.

23. Have the results from the project contributed to the development of any new safety standards?

☐ Yes ☐ No

If yes, please describe the standard(s) briefly and highlighting their applicability (technical/ processual area & global/ local).

24. Do you consider certification requirements in relation to the application of the results from the project?

☐ Yes ☐ No

If yes, do you do so in preparation for the adoption of a developed solution by the market or because of other reasons? Please elaborate.

25. Do you consider the impact of research results upon the current regulatory framework?

☐ Yes ☐ No

If yes, what aspects? Please elaborate.

26. Have the application of your research results contributed to the elaboration of international safety regulations?

☐ Yes ☐ No

If yes, please briefly describe the areas influences by your findings and highlight in which ways your project affected / would affect the regulation.

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Environmental aspects

27. Does your research project consider...

...explicit environmental impacts, i.e. environmental considerations is a project objective?

☐ Yes ☐ No

If yes, please describe the explicit impacts.

...implicit environmental impacts, i.e. environmental considerations is not a project objective?

☐ Yes ☐ No

If yes, please briefly describe the positive side effects upon the environment.

General comments

28. Is there anything else you would like to add?

29. Please share with us any problems you encountered or feedback you might have.

APPENDIX E – APPROACH OF STATE-OF-THE-ART ASSESSMENT

This section presents the approach followed in analysing the state-of-the-art of aviation safety research and providing strategic recommendations for reaching the safety related goals. It is based on the approach as initially described in OPTICS D1.3 (OPTICS (2014)) and improvements and practical deviations made in the eventual application in 2014 and 2015. The approach combines (cf. Figure 26):

- A bottom-up approach, in which the OPTICS team assesses in a structured way how individual R&I projects contribute to elements of the SRIA; and
- A top-down approach of expert workshops centred on specific aviation safety R&I fields, in which experts with an overview over the field identify gaps in research being performed and new research opportunities.

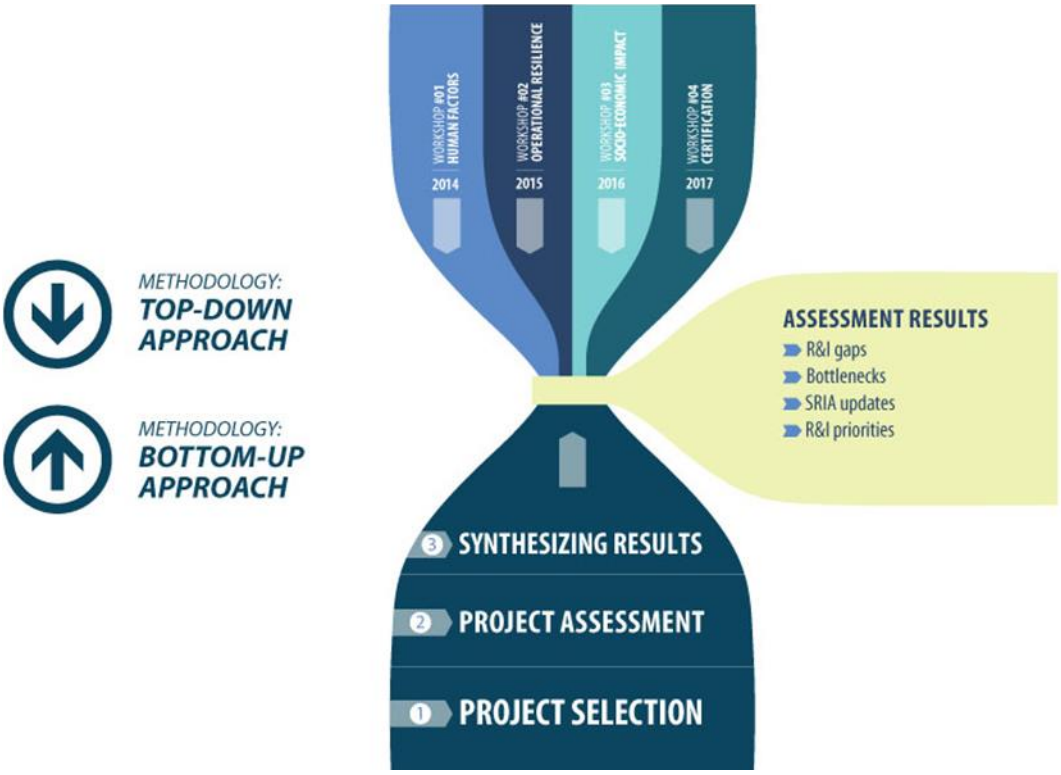

Figure 26: Overview of the approach followed. The bottom-up view is developed from individual project assessments. The top-down view is developed by experts overlooking the field in expert workshops.

The projects assessments are performed each year using a three step approach:

1. Selection of projects.
2. Assessment of projects.
3. Synthesising project assessment results.

The fourth step is the identification of gaps in R&I research, bottlenecks for the implementation of research results, possibilities for SRIA updates and priorities in R&I to be pursued. In this step the bottom-up and top-down approach are combined.

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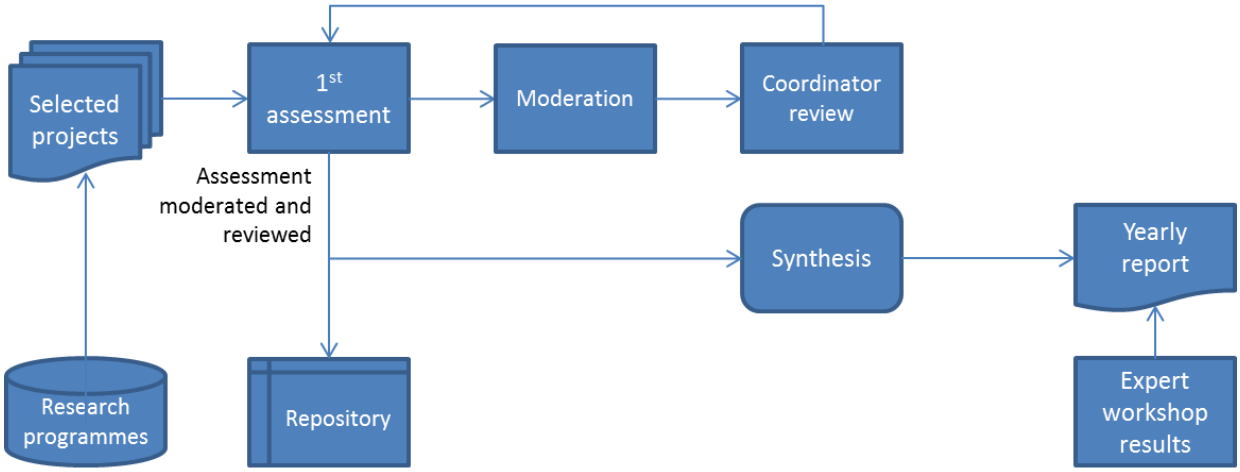

Figure 27: Flow diagram of the OPTICS methodology

Figure 27 shows a flow diagram of the OPTICS methodology. The pivotal steps of the methodology are further described below.

a. Selection of projects

Different types of projects are divided over the years of OPTICS as follows:

- Year 1: FP7 projects with an explicit aviation safety part (projects that have aviation safety improvement as primary objective);
- Year 2: FP7 project with an implicit aviation safety part (projects targeting other objectives than safety, in which safety is identified as a crucial issue and managed), SESAR, SESAR WPE, Future Sky Safety and Clean Sky projects;
- Year 3: also include national research projects; and
- Year 4: also include international research projects.

The FP7 projects with an implicit safety part and the SESAR WPE projects are selected for assessment based on a succinct review of their abstract and main objectives. The relevant SESAR and Clean Sky projects are selected in coordination with the programme. For Future Sky Safety all 5 projects dedicated to a specific safety topic are assessed.

b. Assessment of projects

Each selected project is mapped onto one or more of the safety-related capabilities of SRIA Volume 2. A maximum of five capabilities is selected per project to avoid a dilution effect, whereby a project might seem to link to many capabilities but is unlikely to deliver strongly on any one of them. Next, each capability is assessed with respect to the following metrics:

1. Contribution to the capability. This metric evaluates which part of the scope of a capability is addressed by the scope of the R&I project.
2. Maturity. This metric considers the level of maturity of the research results of an R&I project, considering a simplified lifecycle of R&I. This provides an indication of the progress towards the targeted delivery to the aviation system, and what remains to be achieved.
3. Ease of adoption. This metric represents the perceived complexity of what is still required to implement the innovation considered into the aviation system. Three aspects are considered:

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a. Economic: this evaluates whether the costs of introducing the research results are high in comparison with the benefits;
b. Legal: this evaluates the extent to which there are legal constraints that remain to be solved; this also considers certification issues; and
c. Organisational: this evaluates the extent to which there are organisational, institutional or political constraints for adoption.

The adopted classification schemes, which all use a three-point scale (Low, Medium, High), are given at the end of this section.

It is stipulated that OPTICS is not evaluating the intrinsic values of projects but matching projects to SRIA capabilities. Moderation of the initial assessment of projects is always done by a partner not involved in the project being assessed. The OPTICS methodology also involves other experts from one partner organisation not directly involved in one specific project. Finally the project coordinator can always propose an amendment to the SRIA coverage assessment during the coordinator review phase. The OPTICS team tries to maintain a high ethical standard throughout its work, not favouring any particular Projects or Programmes other than with respect to their intrinsic safety value. The process followed in obtaining final project assessment results is given in the flow diagram shown in Figure 28.

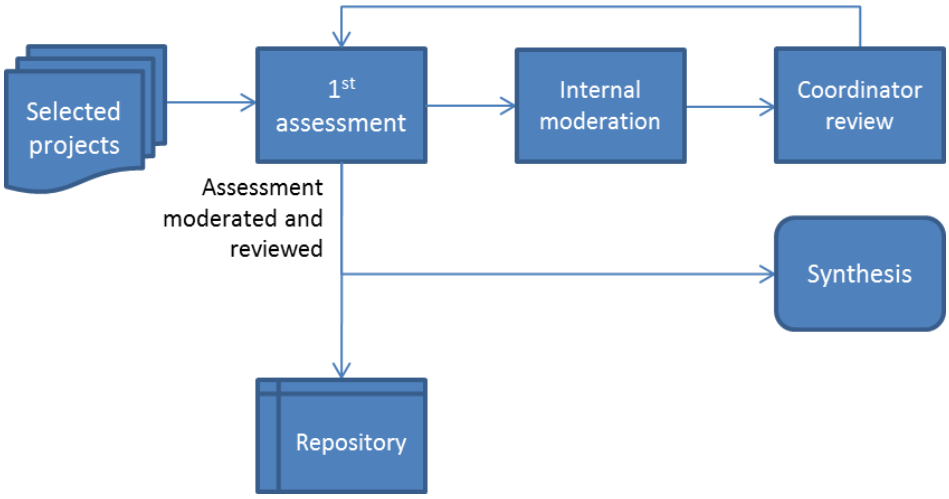

Figure 28: Detail of the methodology flow diagram showing the review loop.

c. *Synthesising project assessment results*

The status of each safety-related capability and enabler of the SRIA is assessed using the project assessment results. The metrics used are related to those considered in the project assessments, but here a five-point scale is used (Low, Low-Medium, Medium, Medium-High, High):

- Coverage of the capability/ enabler. This metric evaluates to which extent the projects mapped on a capability/ enabler jointly address its full scope.
- Average maturity: This metric evaluates the weighted average level of maturity of the research results for the capability or enabler considered. Here, weighted means that the maturity of projects with higher contribution to this capability or enabler has larger weight than the maturity of projects with lower contribution.
- Average ease of adoption: This metric similarly evaluates the weighted average ease of adoption level. Also here three aspects are considered (economic, legal and organisational).

d. *Identification of gaps, bottlenecks and priorities*

From the synthesised project assessment results and the expert workshop results conclusions are drawn. In these conclusions the results of both activities are combined. These conclusions entail gaps in research being performed including new research opportunities, bottlenecks for the implementation of research results, possibilities for SRIA updates and priorities in the research avenues that should be pursued. These conclusions give a flavour of the realisation of the SRIA and accordingly of the safety goals of Flightpath 2050.

e. *Classification schemes*

This subsection presents the classification schemes used for the assessment of each R&I project for an individual capability, and for the associated syntheses at the levels of capabilities and enablers.

Contribution to capability: The classification scheme for assessing the contribution of a certain R&I project to a certain capability is as follows:

- High: the project addresses the full scope of the capability;
- Medium: the project addresses a significant part of the scope of the capability; and
- Low: the project addresses a small part of the scope of the capability.

Maturity: The classification scheme for assessing the maturity of the contribution of a certain R&I project to a certain capability is presented in Table 3.

Table 3: Classification scheme for evaluating maturity

Score	Lvl	Technological readiness	General readiness	Example indicators for maturity
Low	1	Scientific research begins to be translated into applied research and development. The research is limited to paper studies of basic principles of the technology.	A need is identified to solve a problem. Research is limited to paper studies of the problem, offering basic ideas for a solution.	Identification and specification of the problem. Academic impact: • Papers in leading and respected journals • Presentations to academic audiences • Ongoing debate with other researchers
	2	Once basic principles are observed, practical applications are formulated. The concept of the application is defined and characteristics are described. There is no need for proof or detailed analysis to support the assumptions. Research is limited to analytic studies.	Once the basic idea is determined, practical applications are formulated. The concept of the application is defined and characteristics are described. Research is still limited to paper studies.	
Medium	3	Active Research and Development is initiated with analytical and laboratory studies. The technical feasibility is demonstrated in proof of concept studies. The application for the technology results in the development of a system. Future research is likely to be impacted	The concept is translated into product and functional descriptions e.g. new procedures, methodologies, management systems. The benefits and technical feasibility are assessed in paper studies.	Applied research, lab-testing and academic crossover impact: • Interdisciplinary contribution to academic research

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Score	Lvl	Technological readiness	General readiness	Example indicators for maturity
		by this development.		• Generation of new research questions
	4	Standalone components of the new system are validated in a laboratory environment. Experiments are carried out with integrated subsystems. Research has identified potential impediments for implementation, e.g. regulatory constraints.	The new concept is tested in case studies. Research shows that there are no major problems for actual implementations, e.g. regulatory constraints.	
High	5	Thorough testing of prototyping (system, subsystems and components) in a representative environment. Basic technology elements are integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.	Concept is tested in representative environment, case study results are verified. Concept is picked-up by a wider range of disciplines, e.g. policy makers make draft regulations.	Operational tests, policy and end-user crossover impact: • Constructive academic-policy crossover • Policy feedback into research • Policy white papers and policy reports • Constructive academic-end-user crossover • Feedback from end-users into research
	6	Thorough testing of prototyping (system, subsystems) in a full-scale representative environment. Technology is partially integrated with existing systems. Engineering feasibility is fully demonstrated in actual system application.	The concept is deployed under testing condition at a selected number of pilot customers. Full feasibility is demonstrated.	
Out of scope of OPTICS	7	Prototype is at or near scale of the operational system, with most functions available for demonstration and test in an operational environment.	The concept is deployed in specific parts of the aviation system.	*Not applicable* *(out of scope of OPTICS)*
	8	End of system development. System is fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios.	The concept is successfully deployed in multiple parts of the aviation system and does not need further development. The idea is embraced by rule-making bodies and the use is recommended.	

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Score	Lvl	Technological readiness	General readiness	Example indicators for maturity
	9	Actual application of the system in its final form and under mission conditions. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.	The concept is implemented throughout the total aviation system and, if applicable, mandated by rulemaking bodies.	

Ease of adoption: The classification scheme for assessing the Ease of Adoption of the research results of a certain R&I project in a certain capability is presented in Table 4:

Table 4: Classification scheme for evaluating Ease of Adoption

Score	Economic	Legal	Organisational
Low	The costs of adoption are very large, e.g. due to high technical complexity of the innovation.	There are major legal constraints that need to be solved before adoption. Resolving these constraints requires a significant effort.	There are major organisational, institutional or political constraints for adoption by aviation stakeholders; in terms of e.g., operational, infrastructural or social limitations. Resolving these constraints would take a significant effort.
Medium	The adoption will require investments that are not significantly high considering the benefits (safety and other) brought by the innovation.	There are minor legal constraints that must be solved before adoption.	There are organisational, institutional or political constraints for adoption by aviation stakeholders. Resolving these constraints will take time but is rather straightforward.
High	The costs involved in adopting the innovation are low compared to the benefits (safety and other) brought by the innovation.	The innovation fits in the current legal framework. Adoption is therefore easy from a legal point of view.	Aviation stakeholders are keen to adopt, because of the perceived benefits. Any constraints are minor only.

Coverage of capability/ enabler

The *coverage* of the capability is assessed using the following classification:

- High: the projects address the full scope of the capability;
- Medium: the projects address a significant part of the scope of the capability; and
- Low: the projects address a small part of the scope of the capability.

The classification of enablers is similar.

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APPENDIX F - SYNTHESIS PER ENABLER

Enabler	***1***	**System-wide Safety Management Systems**

Description: "The identification and implementation of a Safety Management System to operate throughout the whole chain of Air Transport activities."

Capabilities	Projects	Coverage of capability	Maturity	Ease of adoption
1. Understanding the safety related influence factors on the overall air transport system	*ASCOS, MAN4GEN MAREA SESAR-AIM*	*Medium*	*Medium*	*M-M-M*
2. Implementation of an operational risk management system	*ASCOS, PROSPERO, FSS P4*	*Medium-High*	*Medium*	*H-L-M*
3. Transport (multi-modal) safety governance	*Not addressed by research assessed in OPTICS D2.1*			
4. Safety Management Systems integrated with Business Managements systems	*FSS P5*	*Low*	*Low*	*H-H-L*
5. Effective and efficient safety regulations and procedures	*Not addressed by research assessed in OPTICS D2.1*			
6. Safety framework that ensures equity in access to airspace by all air vehicles	*ERAINT ULTRA SESAR Steering the safe integration of RPAS*	*Medium*	*Low*	*M-M-M*
7. Positive corporate safety culture within organisations	*FSS P5*	*High*	*Low*	*L-H-L*
8. Common safety risk management policy across all sectors of transport	*Not addressed by research assessed in OPTICS D2.1*			
9. Development of tools, metrics and methodologies to assess and pro-actively manage current and emergent risks	*ELSA SESAR-SRM*	*Medium-High*	*Medium-High*	*M-M-M*
10. The pro-active identification of the potential hazards resulting from climate change and other external hazards	*WEZARD*	*Medium*	*High*	*H-H-H*
11. Safety performance indicators are systemically linked to safety outcomes	*ASCOS, PROSPERO, FSS P5*	*High*	*Medium*	*H-L-MH*

Coverage of enabler

The coverage of the enabler is assessed as *Medium-High*, since of the 11 relevant capabilities, 8 are addressed to a certain extent, while the other 3 relevant capabilities are not addressed.

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There is research into the implementation of Safety Management Systems and supporting risk models and safety culture to operate throughout the whole chain of Air Transport activities. Some projects actually cover the total aviation system, while other focus on a specific domain or risk area. *Classification: Medium-High*
Maturity On average the research is in the phase of prototyping. Actual deployment under testing conditions is rare. *Classification: Medium*
Ease of adoption • Since this enabler covers mostly processes, economic ease of adoption is fairly high. • The legal ease of adoption is *Medium*, the main issues are in the field of data ownership, data use and data protection. • Organisational constraints can arise due to the complexity of a total aviation system approach and the number of stakeholders involved. *Economic: Medium-High* *Legal: Medium* *Organisational: Medium*
Potential gaps A part of the enabler is not addressed. This considers capabilities related to multi-modal transport (1.3, 1.8), and safety regulations and procedures (1.5). Potential gaps within the addressed capabilities are interdependencies of transport nodes (1.1, 1.2); the integration of new air vehicles or operations other than RPAS (1.6); the actual ways for pro-active identification of the potential hazards resulting from external hazards (1.10); and indicators of societal perception of safety (1.11).
Bottlenecks The main bottlenecks are identified for the use of Safety Performance Indicators (SPIs) covering the total aviation system. These bottlenecks are related to data ownership, data use and data protection, and regulatory acceptance of the SPIs.

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Enabler	***2***	**Safety Radar**

Description: "Innovative methods, processes and services which ensure the real time detection of deviations in safe performance within the total Air Transport System."

Capabilities	Projects	Coverage of capability	Maturity	Ease of adoption
1. Behaviour analysis of people within the system (e.g. abnormal behaviour, mobility patterns etc.) to identify hazards to safety.	*AIRCRAFTFIRE, SESAR/ECTL – Separation Performance Visualiser*	*Low-Medium*	*Medium*	*MH-MH-M*
2. Behaviour analysis of airspace and airport use.	*PROSPERO, COMPASS, SESAR/ECTL – Flight Plan Hotspot Visualizer, SESAR STAM 13.2.3*	*Medium*	*Medium-High*	*M-H-M*
3. Pro-active identification of the external hazards, development of models which enable the identification of their probability and impact.	*HAIC*	*Low*	*Low*	*M-M-M*

Coverage of enabler

Capability 2-1: The coverage of capability 2-1 is assessed as “Low-Medium”, mainly because the projects that contribute to this capability focus on specific stakeholders in specific situations, whereas other stakeholders and situations are not addressed so far.
Capability 2-2: The SESAR projects FPHV and STAM provide information for tactical and strategic deconflicting of air traffic flows, thus focussing on ANSPs, whereas PROSPERO incorporates all ATS stakeholders but on a more generic level. Therefore the coverage is assessed as “Medium”.
Capability 2-3: Only one project contributes to this capability: HAIC, addressing the phenomenon of high-altitude icing. The coverage of capability is assessed as “Low” accordingly.
All of the capabilities of the enabler are addressed by the minimum of one project. The average coverage of the enabler is assessed as “Low-Medium”.

Classification: *Low-Medium*

Maturity

Three of the projects are in a rather mature state or even planned to be deployed. Therefore maturity is qualified as “Medium”.

Classification: *Medium*

Ease of adoption

The economic ease of adoption is assessed as “medium”, since two of the projects (AIRCRAFTFIRE, PROSPERO) are based on software for simulations and the acquisition of data, respectively. In contrast to the benefits, the investments are assumed to be minor. The projects “Separation Performance Visualiser”, “Flight Plan Hotspot Visualiser”, STAM require tailoring to individual ANSPs. But despite the benefit with respect to safety there is also a benefit with respect to airspace capacity that can be expected which has a positive impact on the economic ease of adoption. Therefore it is

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qualified as “Medium-High”. There are hardly any legal burdens expected. Organizational ease of adoption is “Medium” for all capabilities” Economic: *Medium* Legal: *Medium-High* Organizational: *Medium*
Identified gaps or bottlenecks • The SESAR projects “Separation Performance Visualiser”, “Flight Plan Hotspot Visualiser”, STAM are in a mature state but cover only the ATM part. There is a need to expand to the airport and airline part as well. • The research does not yet provide means for a real-time safety radar function (determining safety vulnerabilities 15min to 3h ahead). • Especially capability 2.3 has a low coverage, other external hazards apart from high-altitude icing of the aircraft must be considered, e.g. thunderstorms, turbulence, volcanic ash.

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Enabler	***3***	**Operational mission management systems and procedures**

Description: "Operational mission management systems and procedures. Protection and responses which enable hazard risk management through appropriate tools including atmospheric models enabling the optimisation of trajectories to ensure hazard and collision avoidance throughout all flight phases and on the surface."

Capabilities	Projects	Coverage of capability	Maturity	Ease of adoption
1. Models which facilitate the mission planning through the identification & prevision of meteorological and other environmental hazards affecting flight safety	*DELICAT, WEZARD, UFO, A-PIMOD, IMET*	*Medium-High*	*Medium*	*MH-M-M*
2. Predictive & Real Time complexity assessment modelling capability which supports accurate mission planning	*ELSA, SESAR 4.7.2*	*Medium*	*Low-Medium*	*MH-H-M*
3. Systems and new traffic services coupled with on-board sensor technology to ensure hazard avoidance in-flight and on the ground, e.g. detect adverse atmospheric conditions and traffic proximity, wild life, FOD.	*DELICAT, HAIC, JEDI ACE, MOTA, ProGA, DANIELA, STORM, MYCOPTER, FSS P3, WINFC*	*Medium*	*Medium*	*M-M-M*
4. Commercial Space operations merged safely with traditional flight operations and airspace structures	*Not addressed by research assessed in OPTICS*			
5. The safe access and integration of non-commercial flights, personal air vehicles and UAS to airspace	*PPLANE, ERAINT, ProGA, ULTRA, MYCOPTER, CARE, GARDEN*	*Medium*	*Medium*	*M-LM-LM*
6. Intelligent, adaptive automation systems which ensure the human can intervene for safe recovery	*PPLANE, ALICIA, MOTA, MYCOPTER, SESAR 4.8, SESAR 4.8.1 (ACAS-X),FSS P6*	*Medium*	*Medium*	*M-M-M*
7. Innovative safety concepts providing a benefit in maximising usage of resources (runways, airspace, parking)	*AAS, ALICIA, UFO, SESAR 6.8.1, SESAR 6.7.1, SESAR APV-SBAS 5.6.3, CARE, GARDEN, CK_CONCORDE*	*Medium*	*Medium-High*	*M-MH-MH*
8. Secure, resilient and integrated CNS systems which ensure seamless, global coverage and are robust to failures of individual components	*AGEN*	*Low*	*Low*	*M-H-H*

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9. Integrated search and rescue capabilities, rapid and appropriate intervention	*Not addressed by research assessed in OPTICS*
10. All flight objects are uniquely and positively identified, tracked, monitored and neutralised if threatening	*Not addressed by research assessed in OPTICS*
11. Globally networked organisational structures identified and implemented to support safety and/or security crisis management with intelligent decision making support under high work load and stress	*Not addressed by research assessed in OPTICS*
12. Security intervention methods, tools, technologies and processes to neutralise active threat	*Out of scope of OPTICS*

Coverage of enabler

Of the 12 relevant capabilities, 7 are addressed by projects assessed in OPTICS. The coverage of each of these 7 capabilities is on average *Medium,* since most contributing projects focus on a specific part of the capability. The coverage of the enabler is therefore assessed as *Medium*.

Classification: Medium

Maturity

The average maturity of the technologies addressed related to enabler 3 is *Medium*. Several tests are performed either in case studies or in representative environment.

Classification: Medium

Ease of adoption

The average ease of adoption of the enabler is *Medium* on each of the three dimensions:

- Economic: the adoption will require investments that are not significant.
- Legal: there are legal constraints that must be solved, related to reduced wake vortex separation, liability issues, and so on. On average these are *Medium*.
- Organisational: There are organisational, institutional or political constraints for adoption by aviation stakeholders. Some will be solved with training but others are related to new stakeholder roles. Resolving most will take time but is rather straightforward.

Economic: Medium
Legal: Medium
Organisational: Medium

Potential gaps

- Several capabilities are not addressed. These consider access for commercial space operations, non-commercial flights, personal vehicles, UAS, and SAR flights (3.4 & 3.9), tracking of all flying objects (3.10), globally networked organisational structures identified and implemented to support safety crisis management (3.11) and security intervention methods, tools, technologies and processes to neutralise active threat (3.12).
- Within the addressed capabilities, a potential gap is associated to the avoidance of environmental hazard types that remain unaddressed, e.g. volcanic ash (3.1 and 3.3). The following hazard types are addressed: wake vortex, wind shear, high altitude ice crystals, and

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clear air turbulence. There is a lack of validated use of data from aircraft (3.2). There is room for improvement in the coverage of hazard avoidance on the ground and networking of sensor systems (3.3), and there is room for improvement within the average maturity of research into the safe access and integration of non-commercial flights, personal air vehicles and UAS to airspace (3.5). Within 3.6 the research assessed is rather fragmented, and there is not a unifying consideration of how far automation should go, with relevant stakeholder input (pilots, flying public, airframe manufacturers). For 3.7 it is noted that there is a gap between near-term research such as SESAR and thought experiments that are unlikely to be implemented in the medium term.
Bottlenecks Bottlenecks are expected to be in regulations allowing reduced wake vortex separation such as proposed by UFO and aircraft operators who are under-represented in the research currently assessed (3.1). In the PPLANE project radically new concepts are expected to face potential legal and organisational bottlenecks (3.5).

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Enabler	***4***	**System Behaviour Monitoring and Health Management**

Description: "Systems which enable the proactive detection of degraded and abnormal situations and optimised healing".

Capabilities	Projects	Coverage of capability	Maturity	Ease of adoption
1. Continuous health management of airports and airspace.	*SCALES SPAD*	*Low-Medium*	*Low*	*H-M-M*
2. Global surveillance and vehicle monitoring capabilities which ensure the tracking and location of air vehicles throughout the mission and initiate SAR in case of serious incidents and accidents	*Not addressed by research assessed in OPTICS D2.1*			
3. Innovative Health Management systems and Maintenance processes and tools, including self-healing capabilities, which ensure critical systems and technologies remain operationally sound	*AISHA II, TRIADE, LAYSA, ALAMSA, JEDI ACE, DOTNAC, IAPETUS*	*Medium*	*Medium*	*M-M-MH*

Coverage of enabler

Of the three relevant capabilities, two are partially addressed by the projects assessed in OPTICS year 1 and 2. The coverage of the addressed enabler is *Low* to *Medium* with most current efforts devoted to improving health monitoring capabilities for sensors to drive maintenance activities (capability 4.3). The other capability (4.1) is only partially addressed by the projects assessed in 2015 (SCALES and SPAD). The research is limited to:

1. Checking current resilience level by providing indicators as early warnings signs and as measures to quantify the potential for the resilience of the ATM system, so without improving it continuously (by health management)
2. Detecting automation degradation rather than off-nominal conditions due to general degraded and abnormal situations.

Elements which are currently missing for capability 4.1 are the application domains airports and airspace.

Classification: Low-Medium

Maturity

The average maturity is Low-Medium, with some projects delivering a proof of concept.

Classification: Low-Medium

Ease of adoption

The ease of adoption is *Medium-High* regarding economic and organisational impact. Legally, certification issues are critical; such systems will imply changes in procedures (maintenance).

Economic: Medium-High
Legal: Medium
Organisational: Medium-High

Potential gaps

• Capability 4.2 (global surveillance) is not addressed by the projects assessed in OPTICS in 2014 and 2015. • Potential gaps within Capability 4.3 are related to investigating health management and self-healing for air vehicle operations in flight and traffic management; and overcoming current limits in fast and efficient implementation of health management faced with critical situations (e.g., weight, real time constraints, reliability, and resilience). • A gap to be filled is represented by the need to guarantee reliability and security for these kinds of systems (health management) which are vulnerable to risks (due to technological limits or malevolent attacks).
Bottlenecks The main potential bottleneck lies in applying the proposed approaches to complex systems such as airports and airspace. This implies data protection and coordination among different actors.

Enabler	***5***	**Forensic Analysis**

Description: "Tools, methodologies and processes which aim to automate the capture and analysis of aviation accidents, incidents and occurrences. Further improve the efficient identification of trends and emergent vulnerabilities aiming to mitigate the risks to aviation safety and security through design. The application in current and new developments of technology, system designs and operations and necessary requirements and regulations and their effects on human performance."

Capabilities	Projects	Coverage of capability	Maturity	Ease of adoption
1. Systematic analysis of safety data	*SVETLANA, FSS P3, FSS P4*	*Medium*	*Medium*	*MH-M-M*
2. Systematic analysis of security data	*Out of scope of OPTICS*			
3. New sensor technology to capture key safety data	*Not addressed by research assessed in OPTICS*			

Coverage of enabler

Of the two relevant capabilities, one is partly addressed (5.1), which has *Medium* coverage. The coverage of the enabler is assessed to be *Medium.*

It is noted that the sensor technology of Capability 5.3 is not mentioned on lower levels in the SRIA, and that Enabler 5 may not require it. Also, 5-3 and 5-1 show large overlap.

Classification: *Medium*

Maturity

All the contributing projects have *Medium* maturity.

Classification: *Medium*

Ease of adoption

The ease of adoption is identical to that of the addressed capability. The main issues in ease of adoption are in the field of data ownership and protection, dealing with many stakeholders, and investments to be made without direct pay-off. Legal obstacles to obtaining valid data have to be overcome.

Economic: *Medium-High*
Legal: *Medium*
Organisational: *Medium*

Potential gaps

The main parts of this enabler are not addressed. This particularly considers:

- a fully integrated means of capturing safety data of all stakeholders across the ATS (including e.g. general aviation); this may also involve improvement of the associated safety culture and processes; and
- the use of these captured safety data by all stakeholders.
- There is not yet research assessed that is dedicated to the identification of emergent vulnerabilities.

Furthermore, ACARE is suggested to re-consider Capability 5-3. A possible improvement is to dedicate Capability 5.3 to the development of the database and to transferring data to this database; and dedicating Capability 5-1 to the use of these data by all stakeholders.

Bottlenecks

The main bottlenecks are issues regarding data ownership and data protection, and on stakeholders data reliability.

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Enabler	*6*	**Standardisation and Certification**

Description: Innovative approach to standardisation, certification and approval processes. Advanced methodologies including simulation tools applied to compliance demonstration of safety / security requirements at component, product, system and system of systems level, including human, social and technical aspects, leading to efficiency and shorter time to market of new products, services and operations. Improved methodologies for standardised approval and licensing.

Capabilities	Projects	Coverage of capability	Maturity	Ease of adoption
1. Common framework for Certification / Approvals which embrace new technologies and their integration within the systems to be certified and the use of new technologies and methods in the certification / approval processes.	*EXTICE, HIRF SE, MISSA, SCARLETT, ADDSAFE, AIM2, AIRCRAFTFIRE, SMAES, ASCOS, HAIC, RECONFIGURE, ALIAS 1&2, ESTOLAS, DAEDALOS, HYPSTAIR, RECREATE, RESEARCH, IMPSHIELDA, IMPSHIELDB, IMPSHIELDC, IMPTEST*	*Medium*	*Medium*	*MH-M-MH*
2. Common roadmap between EU and other aviation leaders, leading to international standards for security technologies and processes.	*Out of scope of OPTICS*			
3. Common certification approach for security systems	*Out of scope of OPTICS*			
4. Methods and tools which facilitate the verification of the global standardisation, certification and approvals processes are all joined up at air transport systems level.	*PICASSO, SUPRA*	*Medium*	*Medium*	*MH-M-MH*

Coverage of enabler

The two relevant capabilities are both addressed. Several elements are addressed, but potential gaps exist, specifically in addressing systems inter-dependencies, human factors, and several segments of aviation (e.g., general aviation).

Classification: Medium

Maturity

Average maturity in both addressed capabilities is *Medium*. The project results have already contributed to update industry standards but in several areas further developments and validation are required prior to industrialisation.

Classification: Medium

Ease of adoption

Reduction in design or maintenance times and direct costs is a key incentive for the adoption but several constraints (e.g. 'learning curve') and organisational challenges remain to be addressed. Organisation
culture (resistance to change) is not addressed in general in listed research projects.

Economic: Medium-High

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Legal:	*Medium*
Organisational:	*Medium-High*

Potential gaps

The main potential gaps within the relevant Capabilities 6.1 and 6.4 are associated to:

- Several segments of total aviation system not addressed (e.g. light aircraft)
- Use of large operational data sets feeding risk models
- Impact of organisational changes need to be addressed

Bottlenecks

There are various constraints for adoption, but no major bottlenecks were identified.

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Enabler	***7***	**Resilience by Design**

Description: Methodologies and tools, products and services which ensure the air transport system is resilient by design and operation to current and predicted safety and security threat and hazard evolution. [IT security concepts resilient against cyber-attacks throughout the global aviation system.]

Capabilities	Projects	Coverage of capability	Maturity	Ease of adoption
1. Systematic methods for ensuring results of safety/security analysis are fed back into design process	*PROSPERO, MISSA, SESAR SRM, ASHICS*	*Medium*	*Medium-High*	*MH-M-M*
2. Systematic methods for ensuring in-service experience is fed back into the design and manufacturing process	*ELSA*	*Medium*	*Low*	*H-H-H*
3. Current and emergent environmental hazards are characterized and understood, and accurately mitigated in the design.	*HIRF-SE, WEZARD, HAIC, RESILIENCE2050, JEDI ACE, COMPASS, STORM, ENDLESS RUNWAY, EXTICE*	*Medium*	*Medium*	*M-MH-MH*
4. Current and emergent security hazards are characterized and understood, and accurately mitigated in the design	*Out of scope of OPTICS*			
5. Improved resilience through the introduction of new technology or improved system designs.	*(see Appendix G for a detailed synthesis of capability 7.5)*	*Medium*	*Medium*	*MH-M-MH*
6. New materials, new manufacturing techniques, and design approaches which improve the survivability (active and passive measures) of transported people and goods (e.g. new cabin designs)	*LAYSA, AIRCRAFT-FIRE, SMAES, HYPMOCES, FANTASSY, MAAT, FSS P7, FLYBAG, FLYBAG II, IASS*	*Medium*	*Medium*	*M-M-MH*
7. Coordination forums between the various interested parties, including other transport means, when designing ATS in a multi-modal context.	*Not addressed by research assessed in OPTICS*			
8. Availability of the suitably qualified and adaptable workforce and a framework which ensures the continued support to both legacy and emerging technologies	*Not addressed by research assessed in OPTICS*			
9. A methodology and toolset for advanced Systems Engineering,	*MISSA, SESAR Safety Register, ASHICS,*	*Medium*	*Medium*	*H-MH-MH*

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to help address both the necessary complexity of designs, and the need to manage a large number of stakeholder requirements, as well as allowing safety and security requirements to be integrated into the design from the earliest stages. (e.g.. counterfeit parts)	*MAREA, SCALES, PICASSO*			
10. The application of human factors and psycho-social issues in design and manufacturing.	*HUMAN, SAFAR, MAN4GEN, A-PIMOD, ODICIS, ARISTOTEL, SESAR Ref Material & Case, MOTA*	*Medium-High*	*Medium-High*	*MH-MH-MH*
11. Airworthy aircraft is constantly in service with minimum deferred defects	*Not addressed by research assessed in OPTICS*			
12. Reliability engineering of critical software	*SCARLETT*	*Low*	*Medium*	*H-M-M*

Coverage of enabler

Eight out of eleven relevant capabilities are addressed, with the coverage of these capabilities typically being *Medium* and in one case *Medium-High*. Many of the projects aim to advance engineering and analysis capability, including Human Factors in design, all of which are cornerstones of Resilience by design.

Classification: *Medium*

Maturity

The maturity of almost each addressed capability is *Medium*; hence the average maturity of this enabler is *Medium*.

Classification: *Medium*

Ease of adoption

- Some of the projects require changes to systems (including aircraft systems), whereas others are mainly concerned with processes, however in some cases there are economic incentives. The economic aspects are therefore considered *Medium-High*.
- Legal aspects are considered to be overall *Medium*, as changes to certification etc. are required but these should be feasible.
- For organizational aspects, most of the outputs would be of obvious benefit to organizations, so that impediments in this area should be more easily overcome.

Economic: *Medium-High*
Legal: *Medium*
Organizational: *Medium-High*

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Potential gaps • Capabilities 7.7 (multi-modal forums), 7.8 (Availability of the suitably qualified and adaptable workforce and a framework which ensures the continued support to both legacy and emerging technologies), and 7.11 (Airworthy aircraft is constantly in service with minimum deferred defects) are not addressed. • Within the addressed capabilities: for 7.1 (feedback to design) the SESAR approach could be extended to other parts of the ATS, supported by concepts from MISSA and PROSPERO. For 7.3 some relevant environmental hazards are still lacking (e.g., fog, wind shear, thunderstorms). For 7.6, crashworthiness is missing. For 7.9, dealing with large numbers of stakeholder requirements is missing. For 7.10 (application of HF and psycho-social issues in design and manufacturing), there is now an approach that could be adopted and tailored for industry.
Bottlenecks There are various constraints for adoption, but no major bottlenecks were identified.

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Enabler	***8***	**Human-centred automation**

Description: "Human-centred automation"

Capabilities	Projects	Coverage of capability	Maturity	Ease of adoption
1. Automation supports human in both normal and degraded operations; allocation of functions between human and machine is optimised in order to maximise situation awareness, support decision-making, and enhance performance execution	*PPLANE, ALICIA, ACROSS, MAN4GEN, A-PIMOD, ARISTOTEL, BRAINFLIGHT, ODICIS MOTA, MUFASA NINA, SAFECORAM, SPAD SESAR A-CWP 6.9.2, SESAR Guidance on Human Centred Automation 16.5.1, SESAR Guidance on Impact of Future Systems in Selection, Training, Competence and Staffing Requirements 16.4.3 & 16.5.4 MYCOPTER, RECREATE, FSS P6, CK_TACTIC*	*Medium-High*	*Medium*	*M-M-M*
2. Information systems support human collaboration across seamless operational concepts throughout the ATS (air & ground)	*SESAR A-CWP 6.9.2, SESAR Human Performance Reference Material and Human Performance Case 16.6.5*	*Medium*	*High*	*M-M-M*
3. Preventive Maintenance and system upgrades of automated systems and information management systems are facilitated through automated processes and adapted human support systems	*Not addressed by research assessed in OPTICS*			
4. Aircraft, airport and ground handling technologies are integrated to support people in the turnaround process and links to other transport modes	*AAS*	*Low*	*High*	*M-H-M*

Coverage of enabler

The research assessed in OPTICS addresses three of the 4 relevant capabilities, only Capability 8.3 remains unaddressed. Capability 8.1 has *Medium to High* coverage, Capability 8.2 has *Medium* coverage, and Capability 8.4 has *Low* coverage, with a single project contributing. For Capability 8.1 research focuses both on air and ground operations, while Capability 8.2 covers only ground

operations and Capability 8.4 only pilots and cockpit operations. The average contributions coverage is *Medium.*
The R&I needs of this enabler mixes different elements such as diverse target users, industrial segment, different expected research outcomes (including principles, philosophy, guidelines, methods, techniques, concepts, role description, task analysis, and so on).
Such a wide area is almost impossible to cover for the research.

Classification: Medium

Maturity
The average maturity of the enabler is *Medium-High*, as it has a balanced set of High maturity projects (SESAR A-CWP 6.9.2, SESAR Human Performance Reference Material and Human Performance Case 16.6.5, MAN4GEN etc.), long-term research oriented projects (BRAINFLIGHT, MYCOPTER, NINA, PPLANE, MOTA) with *Low* maturity, and other contributing projects with *Medium* maturity.

Classification: Medium-High

Ease of adoption
On average, the ease of adoption is *Medium* for each dimension. The classifications vary per contributing project. The ease of adoption of the enabler is mixed, since the projects deal with different aspects of Human-Centred Automation. The economic one is the most consistent one, at the *Medium* level with the rationale that the proposed innovations will bring high costs, but also high benefits. The classification of organisational ease of adoption is particularly varying for the contributing projects.

Economic: Medium
Legal: Medium
Organisational: Medium

Potential gaps
The fact that Capability 8.3 (preventive maintenance and system upgrades of automated systems) is still unaddressed forms a potential gap, as the low coverage of Capability 8.4, where integration of existing solutions with airport and aircraft should be sought.
It is furthermore noted that the scope of Capability 8.1 is very wide, which complicates R&I initiatives and the monitoring by OPTICS.
The utility of task analysis in other sectors needs to be explored.

Bottlenecks
The main bottlenecks are as follows:

- No consolidation of past research, with a fragmented community going into different directions. No good view on what's achieved. This especially applies to methods and techniques, to key research results like task analysis or human performance envelope, to expected benefits from new concepts.
- Bottlenecks w.r.t. adoption of research results are: Legal aspects of automation appear to be a bottleneck and should be addressed. The impact of automation of human roles is still a bottleneck and should be addressed. Certification processes are to be consolidated for adaptive automation concepts.

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Enabler	***9***	**New Crew and Team Concepts**

Description: "New Crew and Team Concepts"

Capabilities	Projects	Coverage of capability	Maturity	Ease of adoption
1. New collaborative team concepts will embrace the whole ATS system, enhancing collaboration across professional roles and between different organisations	*FSS P5*	*Low*	*Low*	*M-H-L*
2. Optimisation of the 'Human performance envelope' through better job design and management, to reduce current problems of fatigue, vigilance, poor decision making and loss of situation awareness or loss of control	*SUPRA, MAN4GEN, BRAINFLIGHT ERAINT, FSS P6*	*Medium*	*Medium*	*M-M-M*
3. Monitoring of crew/team capacity and corrective measures	*ACROSS, A-PIMOD, ARISTOTEL NINA*	*Medium*	*Medium*	*M-L-LM*
4. Services address critical incident stress and psycho-social needs of crew/team/organisation following major disruption or disaster	*Not addressed by research assessed in OPTICS*			
5. Diverse dimensions of passenger and personnel culture are understood, so that system change can positively influence cultural evolution and consequently foster system effectiveness in relation to safety and security goals.	*Not addressed by research assessed in OPTICS*			

Coverage of enabler

Three of the 5 relevant capabilities are addressed by research assessed in OPTICS; the unaddressed ones are Capability 4 and Capability 5. Two out of three addressed capabilities have *Medium* coverage, with the research focus being mainly on pilots and cockpits and only one ATM research project for each of the addressed Capability. The third one has *Low* coverage, and it is addressed by just one project.

The R&I needs of this enabler mixes different elements such as diverse target users, industrial segments, and research outcomes (i.e. guidelines, methods, knowledge). Such a wide area is almost impossible to cover for the research.

Classification: Low-Medium

Maturity

The average maturity of the enabler is *Medium,* and the projects focus only on a limited part of the capability (e.g., situational awareness, loss of control, or workload).

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Classification: *Medium*
Ease of adoption The ease of adoption varies per project, since the projects deal with different aspects of Human Performance, using not comparable approaches. • The economic one is most consistent, average *Medium* (high costs, high benefits). • The legal ease of adoption varies more, mostly depending on the certification complexity for the proposed concepts. The average is *Low-Medium*. • Organisational ease of adoption includes low and high classifications. Organisational barriers are expected for the radical changes (as for the adaptive automation proposed in A-PIMOD or ACROSS for single pilot) and for the changes that require coordination and agreement among different parties (as the monitoring technologies for ATM operators in NINA), while high acceptability is expected for more incremental changes (as the support to detect and correct undesired pilot behaviour proposed in ARISTOTEL, or the improvements delivered by MAN4GEN). *Economic:* *Medium* *Legal:* *Medium* *Organisational:* *Low-Medium*
Potential gaps A significant part of this enabler is not addressed, in particular the Capabilities regarding passenger/ personnel culture (9.5) and CISM for organisations/ teams (9.4). Furthermore there are potential gaps in research for the other Capabilities. For these capabilities a potential gap is that other crews than pilots and controllers, such as maintenance operators are not yet covered. For Capability 9.2 determining the exact potential gaps is not straightforward, since the R&I needs are not fully clear; e.g., are they a check-list or merely examples, and is there a model behind it? This capability may be split in three or four areas covering technologies, concepts, methods, and possibly human resources / training (cf. Enabler 8)
Bottlenecks • Whereas the average ease of adoption is lowest in the legal area, the ease of adoption is even lower in the organisational area for some projects. The associated main bottleneck is in the acceptance by operators of the solutions, e.g., operators' opposition against being monitored, and opposition against different team concepts (e.g. single pilot operations). • No consolidation of past research, with a fragmented community. This especially applies to the Human performance envelope capability (9.2), and to methods and tools to monitor crew capacity (9.3).

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Enabler	***10***	**Passenger Management**

Description: "Passenger Management"

Capabilities	Projects	Coverage of capability	Maturity	Ease of adoption
1. Improved prediction of terrorist threats	*Out of scope of OPTICS.*			
2. Management of human behaviours during emergencies	*Not addressed by research assessed in OPTICS D2.1*			
3. Ability to safely control disruptive behaviour	*Out of scope of OPTICS.*			
4. Services address post-traumatic stress and psycho-social needs of passengers and public following major disruption or disaster	*Not addressed by research assessed in OPTICS D2.1*			
5. Diverse dimensions of passenger culture are understood	*Not addressed by research assessed in OPTICS D2.1*			

Coverage of enabler

No safety research projects have yet been identified that contribute to one or more of the three relevant capabilities of this enabler.

Classification: *Low*

Maturity

No contributing projects yet identified.

Classification: *Not applicable*

Ease of adoption

No contributing projects yet identified.

Economic: *Not applicable*
Legal: *Not applicable*
Organizational: *Not applicable*

Potential gaps

The three relevant capabilities all remain unaddressed by research assessed in OPTICS D2.1. These consider management of human behaviours during emergencies (10.2), services addressing post-traumatic stress and psycho-social needs of passengers and public following major disruption or disaster (10.4) and understanding diverse dimensions of passenger culture 10.5).

Bottlenecks

No bottlenecks identified since no relevant research was identified in OPTICS D2.1.

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APPENDIX G - SYNTHESIS PER CAPABILITY

Enabler	***1***	**Capability**	***1***

Description: "Understanding the safety related influence factors on the overall air transport system and its connections with other transport nodes."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
ASCOS	*Medium*	*Medium*	*M-L-L*
MAN4GEN	*Low*	*Medium*	*M-M-H*
MAREA	*Medium*	*Low*	*H-H-H*
SESAR-AIM	*Medium*	*High*	*M-H-M*

Coverage

ASCOS addresses this capability by outlining a proposed safety assessment methodology suitable to deal with the total aviation system and its entire lifecycle, and includes a process to identify emergent risks. The development of an integrated risk management framework building on a set of models for the various actors of the total aviation chain and addressing cross-boundary hazards and risk issues does not seem to be fully covered by ASCOS. MAN4GEN considers a specific safety related influence factor: factors that lead to the loss of situational awareness after unexpected events. MAREA developed a modelling approach that can deal with the complexity of the future ATM. The SESAR –AIM project developed a model for part of the ATS (focus on air traffic management risks) that has been adopted by a number of ANSP in their risk management process. The projects reviewed do not include research into an ATS wide system risk model. Current research does not consider other transport nodes.

Classification: Medium

Maturity

ASCOS and MAN4GEN have *Medium* maturity. ASCOS aims to provide a prototype safety assessment methodology and MAN4GEN includes demonstrations in a full flight simulator. MAREA has *Low* maturity. SESAR-AIM has been adopted by a number of ANSP's and is actively used and has therefore a *High* maturity. Considering that both projects have a *Medium* coverage, the average maturity is assessed as *Medium*.

Classification: Medium

Ease of adoption

For safety assessment methodologies covering the total aviation system, data collection and processing complexity is high. There may be constraints due to confidentiality of data, legal issues, union considerations, etc. Due to the fragmentation of EU aviation, the complexity of a total aviation system approach and the number of stakeholders, the organisational complexity of an overall safety assessment methodology is high. ASCOS covers this capability much more than MAN4GEN (covering the total system, versus covering only loss of situational awareness). Due to the *Low* maturity of MAREA the Ease of adoption is hard to judge at this early stage. SESAR-AIM provides a methodology that needs to be fed with local data. This may incur some cost for the organisation. No legal and organisational issues are foreseen for SESAR-AIM.

Economic: Medium
Legal: Medium
Organisational: Medium

Potential gaps and bottlenecks

- No identified project considers connections with other transport modes

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- Most projects focus on one specific domain of the total aviation system. Only ASCOS considers the total system, but does not cover cross-boundary hazards and risk issues.

Enabler	***1***	**Capability**	***2***

Description: "Implementation of an operational risk management system which demonstrates the ability of the ATS to anticipate, react, respond and recover with respect to safety threats within a multi-modal transportation system."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
ASCOS	*Medium*	*Medium*	*H-L-H*
PROSPERO	*Medium*	*Medium*	*M-L-L*
FSS P4	*High*	*Medium*	*H-L-M*

Coverage

The coverage of this capability is assessed as *Medium-High.* The development of an operational risk management system across the whole ATS is the core of the PROSPERO and FSS P4 project; this is further enhanced by the development of a process for safety performance measurement in ASCOS. It is stated that "It is not clear if the proposed solution goes beyond the management of known hazards" (PROSPERO) and "ASCOS does not seem to fully define the main aspects of a risk management platforms that will provide the capability of an early warning system to, inter alia, (i) detect unsafe trends; (ii) suggest safety improvement areas; (iii) reach all those involved". The connections with other transport nodes are not covered.

Classification: Medium-High

Maturity

The projects intend to demonstrate a prototype risk assessment system.

Classification: Medium

Ease of adoption

The economic ease of adoption is *High*: costs are only related to processes, overall no high investments needed. Legal "barriers [are] expected due to confidentiality of data, unions, etc." Organisational barriers are "due to the fragmentation of EU aviation, its complexity and number of stakeholders".

Economic: High
Legal: Low
Organisational: Medium

Potential gaps and bottlenecks

The interdependencies of transport nodes introducing risk elements are not considered.
There are bottlenecks due to issues with multi-modal use of safety data.

Enabler	***1***	**Capability**	***4***

Description: "Safety Management Systems integrated with Business Management systems."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
FSS P5	*Low*	*Low*	*H-H-L*

Coverage

FSS P5 represents a significant but limited start in this direction, as the concept will likely need to evolve if it is successful.

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Classification: *Low*

Maturity
This is a new approach, and although its target is TRL4, we will have to wait and see if it achieves this level of maturity since Dashboards and their integration into business management represent a novel approach.

Classification: *Low*

Ease of adoption
The cost of implementation is low, and at the moment no legal impediments are identified. However there is as yet insufficient organisational 'pull', so this needs to be built up by FSS as the programme of work develops.

Economic: *High*
Legal: *High*
Organisational: *Low*

Potential gaps and bottlenecks
The step towards integration of SMS in Business Managements system needs still to be taken, a limited start in this direction is occurring.

Enabler	***1***	**Capability**	**6**

Description: "Safety framework that ensures equity in access to airspace by all air vehicles. E.g. UAS, LTA"

Contributing projects	Contribution to capability	Maturity	Ease of adoption
ERAINT	*Low*	*Medium*	*M-L-L*
ULTRA	*Medium*	*Low*	*H-H-H*
SESAR Steering the Safe Integration of RPAS	*Medium*	*Low*	*M-M-M*

Coverage
ERAINT addresses only RPAS and safety is only addressed in terms of workload. ULTRA addressed safe integration of RPAS in the air transport system and developed a roadmap. In SESAR demonstrations are performed paving the way for standardisation work on detect-and-avoid, command and control link, etc. For the 2020 timeframe RPAS is the main vehicle type to be considered in the capability (others are e.g. LTA, commercial space operations, personalized air transport, single manned commercial flight). Therefore the projects cover an important part of the capability. The topics addressed in the projects are limited (only IFR en-route). The total coverage is judged to be *Medium*.

Classification: *Medium*

Maturity
ERAINT has conducted fast time simulations. ULTRA developed a roadmap and as such does not provide solutions. Within SESAR, 9 demonstrations were conducted that provide a basis for standardisation work. The two projects with medium coverage have a low maturity, resulting in a weighted maturity of *Low*.

Classification: *Low*

Ease of adoption
Economic: *Medium* as the costs will likely be very high, but there are potentially high benefits. Legal: a whole new set of regulations and processes will be required. It is expected however that legal

issues will be solved due to the very strong pressure from RPAS operators. Organisational: it involves the coordination of many stakeholders, a score of *Medium* is chosen because of the *Medium* score of the SESAR project which has *Medium* coverage. (It is noted that de high ease of adoption of ULTRA has low impact on the overall score, because ULTRA develops a roadmap with does in itself not pose challenges to adopt - the work foreseen to meet the roadmap does).

Economic: *Medium*
Legal: *Medium*
Organisational: *Medium*

Potential gaps and bottlenecks
Consider other vehicle types apart from RPAS (e.g. LTA, commercial space operations, personalized air transport, single manned commercial flight). For RPAS, also consider other aspects of the operation (VFR, near/on the airport etc.). Finally, all demonstrations and work to date have not targeted the incorporation of large numbers of other vehicles.

Enabler	***1***	**Capability**	**7**

Description: "Positive corporate safety culture within organisations is infused at all levels across the air transport system."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
FSS P5	*High*	*Low*	*L-H-L*

Coverage
This is a major aim of the entire P5 Project, and the Project is targeting airlines (e.g. EasyJet) and airports (e.g. Luton, Milan) as well as Airbus.

Classification: *High*

Maturity
The approach has already been tried and tested in ATM, and so is being exported into airline/manufacturer segments. It is currently being tailored to other aviation segments.

Classification: *Low*

Ease of adoption
There will be cost implications with surveys etc. since this would impose another activity on the ATS. No legal impediments are foreseen, though Just Culture will need to be adopted across the ATS. There may be organisational sluggishness in adopting safety culture simply due to an intense period of competitiveness against cost pressures.

Economic: *Low*
Legal: *High*
Organisational: *Low*

Potential gaps and bottlenecks
Lack of unified model for Safety Culture showing the relations between national, organisational and professional culture.

Enabler	***1***	**Capability**	***9***

Description: "Development of tools, metrics and methodologies to assess and pro-actively manage current and emergent risks in a multi-modal door-to-door environment. Data integration across the transport system links system antecedents to safety outcomes enabling calculation of quantitative risk assessments and measurement of risk reduction."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
ELSA	*Low*	*Low*	*H-H-H*
SESAR-SRM	*High*	*High*	*M-M-M*

Coverage
ELSA has explored some innovative safety metrics, using the correlation between traffic data and safety nets data. Only one indicator (safety nets metric) and one correlation have been explored, and hence the coverage is low. SESAR-SRM provides a framework for method, tools and metrics which covers the whole ATS (with a focus on ATM and the design/validation stages). Although SESAR-SRM has a *High* contribution, it is judged that complete coverage is not yet achieved because multi-modal aspects are not yet considered.

Classification: Medium-High

Maturity
ELSA conducted one case study with real data. SESAR-SRM constructed a framework that can be applied to the whole ATS and is already put to use by two ANSP's

Classification: Medium-High

Ease of adoption
Although hard to assess at this moment, there seem to be no major obstacles as the innovation is methodological and can be implemented by one organisation with no coordination needs, using existing data. The reference material provided by SESAR-SRM can be adopted without having to overcome major costs, or legal or organisational obstacles. There is however considerable expertise needed as well as regulatory acceptance. As SESAR-SRM covers most of the capability, the scores are strongly influenced by this project.

Economic: Medium
Legal: Medium
Organisational: Medium

Potential gaps and bottlenecks
- SESAR SRM is not yet adapted to other transport modes or integration across transport modes.

Enabler	***1***	**Capability**	***10***

Description: "The pro-active identification of the potential hazards resulting from climate change and other external hazards, development of models which enable the identification of their probability and impact"

Contributing projects	Contribution to capability	Maturity	Ease of adoption
WEZARD	*Medium*	*High*	*H-H-H*

Coverage
WEZARD addresses a roadmap regarding weather hazards. Other external hazards are not considered. No models are developed to identify probability and impact of the hazards.

Classification: Medium

Maturity
WEZARD's roadmap for weather hazards has *High* maturity since it was accepted by the main actors in the Air Transport System and paved the way for follow-up projects.

Classification: High

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Ease of adoption
There are no foreseen economic, legal or organisational constraints for adoption of WEZARD's roadmap.

Economic: *High*
Legal: *High*
Organisational: *High*

Potential gaps and bottlenecks
The single project addressing this capability (WEZARD) develops a roadmap. No research is conducted that aims to find actual ways for the pro-active identification of the potential hazards resulting from climate change and other external hazards.

Enabler	***1***	**Capability**	***11***

Description: "Safety performance indicators are systemically linked to safety outcomes, allowing measurement of system safety performance. Credible measurement of progress towards 2050 targets becomes possible."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
ASCOS	*High*	*Medium*	*H-L-H*
PROSPERO	*Low*	*Low*	*M-L-M*
FSS P4	*High*	*Medium*	*H-L-M*

Coverage
Indicators relating to safety are well developed in ASCOS and will be developed in FSS P4. The developed SPIs are not yet linked however to all available accident models in order to link these SPIs to all credible safety outcomes. PROSPERO will develop SPIs mainly for airlines and airports. Research into indicators of societal perception of safety is currently lacking.

Classification: *High*

Maturity
Indicators are in development. The indicators developed in ASCOS are validated, while the indicator research in PROSPERO is still exploratory. P4 will develop a prototype Risk Observatory integrating SPI tailored to industry needs.

Classification: *Medium*

Ease of adoption
Development of indicators does not constitute large economic barriers. The *Low* score for 'Legal' is because "it is expected that difficulties will arise in obtaining the relevant data and regulatory acceptance". There may be organisational reluctance if SPI can impact reputation of an organisation.

Economic: *High*
Legal: *Low*
Organisational: *Medium-High*

Potential gaps and bottlenecks
- Research into indicators of societal perception of safety is currently lacking.
- Bottlenecks due to obtaining and using relevant safety data and regulatory acceptance.

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Enabler	***2***	**Capability**	***1***	

Description: "Behaviour analysis of people within the system (e.g. abnormal behaviour, mobility patterns etc.) to identify hazards to safety."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
AIRCRAFTFIRE	*Low*	*Low*	*H-M-M*
SESAR/ECTL – Separation Performance Visualiser	*Medium*	*High*	*M-H-M*

Coverage

The focus of the project AIRCRAFTFIRE is on the simulation of emergency evacuations of aircraft cabins in case of fire. A software tool ("Exodus") is used to simulate passengers´ behaviour during the evacuation. No information is given on the psychological validity of the software tool. The project "Separation Performance Visualiser" analyses air traffic controller behaviour. In particular their separation management interventions. The two projects look at behaviour analysis of two stakeholders within the ATS (i.e. passengers and ATC). They focus on special safety-relevant issues (emergency evacuation of aircraft, en route traffic conflicts), whereas other stakeholders (e.g. pilots) or situations (e.g. health risk of pilots or passengers) are not addressed.

Classification: *Low-Medium*

Maturity

The software tool used in the project AIRCRAFTFIRE is based on assumptions made how passengers behave during an emergency situation. In contrast to this, the project "Separation Performance Visualiser" makes use of more reliable Human-in-the-loop (HIL) simulations

Classification: *Medium*

Ease of adoption

The economic ease of adoption is qualified as "Medium-High" mainly because of the costly post-processing that is needed in the "Separation Performance Visualiser"-project. Generally no legal implications are expected.

Economic: *Medium-High*
Legal: *Medium-High*
Organizational: *Medium*

Identified gaps or bottlenecks

- Not all stakeholders in the Air Transport System are considered in the research assessed.

Enabler	***2***	**Capability**	***2***	

Description: "Behaviour analysis of airspace and airport use."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
PROPSERO	*High*	*Low*	*L-L-L*

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COMPASS	*Medium*	*Medium*	*M-H-H*
SESAR/ECTL – Flight Plan Hotspot Visualiser	*Medium*	*High*	*H-H-M*
STAM 13.2.3	*Medium*	*High*	*M-H-H*

Coverage
The contribution of the project PROSPERO is assessed as "High", as the operational monitoring of airport and airline is one of the main activities. The project "Flight Plan Hotspot Visualiser", even though not real time capable, analyses flight plans and therefore airspace and airport use prior to actual operations (strategic), whereas the STAM project helps to detect and resolve conflicts in the short-term (tactical). COMPASS can help to detect safety-relevant situations that might arise due to the complexity of the system. Therefore the capability is partly covered by these projects.

Classification: *Medium*

Maturity
In the project PROSPERO the data acquisition to enable a full demonstration is at a conceptual stage. In the COMPASS project, simulations were conducted. The project "Flight Plan Visualiser" is being used in SESAR validation exercises and STAM is planned to be deployed in 2018. A weighed maturity "Medium-High" is used.

Classification: *Medium-High*

Ease of adoption
The project PROSPERO is based on data analysis. Since the acquisition of this data across the air transport system is impeded by legal, confidentiality, unions, etc., major changes to culture and regulations will be required. For FPHV there are no economic or regulatory burdens foreseen. The development of software in order to bring the results of the COMPASS project will need some investment.

Economic: *Medium*
Legal: *High*
Organizational: *Medium*

Identified gaps or bottlenecks

- The FPHV and the STAM project contribute to the coverage of the capability and both are in a very mature state. The focus of these projects is on ATM only. Other stakeholders should be included.
- The research does not yet provide means for a real-time safety radar function (determining safety vulnerabilities 15min to 3hrs ahead).

Enabler	***2***	**Capability**	***3***	

Description: "Pro-active identification of the external hazards, development of models which enable the identification of their probability and impact."

Contributing projects	Contribution to capability	Maturity	Ease of adoption

HAIC	*Low*	*Low*	*M-M-M*

Coverage
The project HAIC aims at the development of detection and awareness technologies to avoid icing at high altitudes. Other possible external hazards like e.g. volcanic ash, thunderstorms, severe weather, etc. are not addressed.

Classification: *Low*

Maturity
Since only one project contributes to the capability, the maturity is assessed as “low”.

Classification: *Low*

Ease of adoption
The ease of adoption for the project HAIC is assessed as *Medium* for economic, legal and organizational aspects. Although the findings of HAIC might be useful for other projects that aim at the identification of external hazards, the overall ease of adoption with respect to the capability is assesses as low for all areas.

Economic: *Medium*
Legal: *Medium*
Organizational: *Medium*

Identified gaps or bottlenecks

- Only one project contributes to the capability that focuses on a small part of potential external hazards, namely high altitude icing. Other potential hazards like, volcanic ash, thunderstorms, clear air turbulence etc. are not addressed.

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Enabler	***3***	**Capability**	***1***	

Description: **"**Models which facilitate mission planning through the identification & provision of meteorological and other environmental hazards affecting flight safety".

Contributing projects	Contribution to capability	Maturity	Ease of adoption
DELICAT	*Low*	*Medium*	*M-M-M*
WEZARD	*Medium*	*High*	*H-H-H*
UFO	*Low*	*High*	*M-L-M*
A-PIMOD	*Medium*	*Medium*	*H-H-M*
IMET	*High*	*Low*	*M-M-M*

Coverage

Five projects address Capability 3.1. DELICAT addresses one type of hazard (clear air turbulence at medium range), WEZARD develops a roadmap for weather hazards, UFO focuses on wake vortex, A-PIMOD on cockpit design and IMET on taking into account atmospheric model output. Identification of certain other hazard types and development of a forecast model are not addressed.

Classification: Medium-High

Maturity

Most projects include flight tests and/ or validation of models. IMET is a paper study, making use of real data.

Classification: Medium

Ease of adoption

Economic: adoption will require investments that are not significant.
Legal: there are legal constraints that must be solved before adoption; for reduced wake-vortex separation this may involve significant effort.
Organisational: Resolving the organisational, institutional and political constraints for adoption by aviation stakeholders will take time but is rather straightforward.

Economic: Medium-High
Legal: Medium
Organisational: Medium

Potential gaps and bottlenecks

Hazard types other than wake vortex, wind shear, high altitude ice crystals, and clear air turbulence remain unaddressed (e.g, volcanic ash).
Bottlenecks are expected to be in regulations allowing reduced wake vortex separation such as proposed by UFO.
Aircraft operators are under-represented in the research currently assessed.

Enabler	***3***	**Capability**	***2***	

Description: **"**Predictive & Real Time complexity assessment modelling capability which supports accurate mission planning"

Contributing projects	Contribution to capability	Maturity	Ease of adoption
ELSA	*Low*	*Low*	*H-H-M*
SESAR Separation tasking in en-route trajectory	*Medium*	*Medium*	*M-H-M*

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based environment 4.7.2			

Coverage
The Air Traffic simulator developed by ELSA is partially addressing only the predictive complexity assessment to support mission planning.
It is likely the SESAR conflict detection tools, not seen as operationally critical at this time, may become more useful as new airspace design concepts (FABs, Free Routeing, "Sectorless") become operational. At the moment tools such as IFACTS offer most potential at the tactical level, allowing denser and more complex operations with the same level of safety.

Classification: Medium

Maturity
The ELSA Air Traffic simulator has been developed for research purposes and operational applications have not been explored.
Instantiations of SESAR en-route trajectory tools are already operational in at least one ANSP.

Classification: Low-Medium

Ease of adoption
The use of the ELSA Air Traffic simulator to assess complexity of different operational scenarios might require coordination with other organizations depending on the spatial scale it is intended to work on. The cost of these systems is not high, however what is needed is tailoring to each air traffic centre and even each sector, in order to gain most utilisation. No issues with certification or legal are foreseen, other than demonstrating that its integration into the platform and its performance are within certain parameters.

For the SESAR research it can be said that adoption of the radical and novel ideas will require significant investments. There are only minor legal constraints. Resolving organisational, institutional and political constraints will take time but is rather straightforward.

Economic: Medium-High
Legal: High
Organisational: Medium

Potential gaps and bottlenecks
No validated use of data from aircraft

Enabler	***3***	**Capability**	***3***

Description: **"**Systems and new traffic services coupled with on-board sensor technology to ensure hazard avoidance in-flight and on the ground, e.g. detect adverse atmospheric conditions and traffic proximity, wild life, FOD."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
DELICAT	*Low*	*Medium*	*M-M-M*
HAIC	*Medium*	*High*	*M-M-M*
JEDI ACE	*Low*	*Medium*	*M-M-M*
MOTA	*Low*	*Medium*	*M-L-M*
ProGA	*Low*	*Medium*	*M-M-M*
DANIELA	*Medium*	*Medium*	*M-H-M*
STORM	*Medium*	*Medium*	*L-H-L*
MYCOPTER	*Low*	*Low*	*L-L-L*

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FSS P3	*Low*	*Medium*	*L-H-H*
WINFC	*Medium*	*Medium*	*M-M-H*

Coverage
The first three projects that address capability 3.3 each address one hazards element: ice crystals (HAIC, JEDI ACE) or clear air turbulence (DELICAT). The project MOTA addresses the human-machine-interactions rather than technology (i.e. coupling with on-board sensor technology). The contribution of ProGA is Low, since it addresses only one hazard (other airborne traffic) and only GA, while DANIELA's is *Medium* as it does not cover hazard avoidance on the ground.
Then the contribution of STORM is Medium because it focuses on one type of environmental hazard (icing condition). MYCOPTER project focus on the definition of a personal air vehicle. The safe integration of these new personal air vehicles in the air transport system was not studied in detail. FSS P3 focuses on one specific hazard: runway excursion. WINFC is working on data fusion to provide awareness related to un-forecast weather hazards and traffic hazards.

Classification: Medium

Maturity
Most projects include flight tests and/ or validation of models.

Classification: Medium

Ease of adoption

Economic: the adoption will require investments that are not significant.
Legal: there are minor legal constraints that must be solved before adoption.
Organisational: Resolving organisational, institutional and political constraints will take time but is rather straightforward.

Economic: Medium
Legal: Medium
Organisational: Medium

Potential gaps and bottlenecks
Most of the projects currently assessed do not cover hazard avoidance on the ground.
Networking of sensor systems underexposed in assessed research.

Enabler	***3***	**Capability**	***5***

Description: **"**The safe access and integration of non-commercial flights, personal air vehicles and UAS to airspace".

Contributing projects	Contribution to capability	Maturity	Ease of adoption
PPLANE	*Low*	*Low*	*M-L-L*
ERAINT	*Medium*	*Medium*	*M-L-L*
ProGA	*Medium*	*Medium*	*M-M-M*
ULTRA	*Medium*	*Low*	*H-H-H*
MYCOPTER	*Low*	*Low*	*L-L-L*
CARE	*Low*	*High*	*M-M-H*
GARDEN	*Low*	*High*	*M-M-H*

Coverage
PPLANE considers the safety of specific novel operations; not of the integration. ERAINT addresses

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only RPAS. Safety is only addressed in terms of workload. ProGA project only addresses trajectory planning for GA. The contribution of ULTRA is *Medium* because it is a CSA project that defined a roadmap for the safe integration of RPAS in the air transport system but it did not provide solutions for the capability. The MYCOPTER project focuses on the definition of a personal air vehicle although the safe integration of these new personal air vehicles in the air transport system was not studied in detail.

Classification: Medium

Maturity

PPLANE explores radical and novel ideas resulting in a comprehensive view on the possibility to develop such a personnel air transport system. Fast time simulations have been performed within ERAINT and 2 real-time simulations were performed on 4 different traffic scenarios In ProGA. However, the ULTRA project did not perform tests of the proposed approaches and scenarios and only proof of concepts tests and simulations were performed in MYCOPTER. CARE and GARDEN work on developing new IFR flight procedures based on the use of GNSS for rotorcraft enabling rotorcraft to reach busy airports fully independently of the airplane traffic operating from or to active runways.

Classification: Medium

Ease of adoption

Economic: adoption of the radical and novel ideas will require large investments, but the benefits brought by the innovations can be significant.
Legal: there are large legal implications related to automation.
Organisational: the changes include new stakeholder roles.

Economic: Medium
Legal: Low-Medium
Organisational: Low-Medium

Potential gaps and bottlenecks

Efforts have been made to address this capability with 4 more projects than in previous assessment but there is still room for improvement. The average maturity of the research is relatively low. It will take time before the results become operational, while deployment of RPAS is imminent. Bottlenecks are expected to be in potential legal and organisational issues of radically new concepts, such as considered in PPLANE.

Enabler	***3***	**Capability**	***6***	

Description: **"**Intelligent, adaptive automation systems which ensure the human can intervene for safe recovery".

Contributing projects	Contribution to capability	Maturity	Ease of adoption
PPLANE	*Low*	*Low*	*M-L-L*
ALICIA	*Medium*	*Medium*	*M-M-M*
MOTA	*Medium*	*Medium*	*M-L-M*
MYCOPTER	*Low*	*Low*	*L-L-L*
SESAR Enhanced Safety Nets for En Route and TMA Operations - 4.8 -	*Medium*	*High*	*M-H-M*
SESAR Ground and Air Safety Nets 4.8.1 (ACAS-	*Medium*	*High*	*M-H-M*

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X)			
FSS P6	*Low*	*Low*	*L-M-H*

Coverage
PPLANE identifies the need for the development of automation for small aircraft. ALICIA addresses a new cockpit concept. Non-commercial operations are not considered. In MOTA the multi agent system can handle constraints specified on the ground control interface. No more info was about MYCOPTER. Both SESAR projects will improve performance in a limited set of situations but ACAS-X will also deliver fewer nuisance alerts, provide better risk ratio, and better compatibility with automated responses to RAS. FSS P6 will consider where the best human-automation partnerships lie. The automation is only in the cockpit, not across other ATS segments.

Classification: Medium

Maturity
Maturity is *Low* in PPLANE; test beds are developed in ALICIA. MOTA's maturity is not clear from the available information but it seems to target the delivery of a prototype with related simulation studies. In MYCOPTER proof of concepts tests and simulations were performed. SESAR Enhanced Safety Nets for En Route and TMA Operations is already deployed in certain ANSPs.

Classification: Medium

Ease of adoption
Economic: investments and benefits will be significant.
Legal: there are minor legal constraints that must be solved before adoption.
Organisational: Resolving the organisational and institutional constraints will take time but is rather straightforward.

Economic: Medium
Legal: Medium
Organisational: Medium

Potential gaps and bottlenecks
Bottlenecks are expected to be in potential legal and organisational issues of a radically new concept as considered in PPLANE. In ACAS-X, the use of bearing info gets rid of some classes of nuisance alerts which are still not deployed but validated.
The research assessed is rather fragmented, there is not a unifying consideration of how far automation should go, with relevant stakeholder input (pilots, flying public, airframe manufacturers).

Enabler	***3***	**Capability**	***7***

Description: **"**Innovative safety concepts providing a benefit in maximising usage of resources (runways, airspace, parking)".

Contributing projects	Contribution to capability	Maturity	Ease of adoption
AAS	*Low*	*High*	*M-H-M*
ALICIA	*Low*	*Medium*	*M-M-M*
UFO	*Low*	*High*	*M-L-M*
ENDLESS RUNWAY	*Medium*	*Medium*	*L-L-L*
SESAR Enhanced Runway Throughput via Flexible and Dynamic use of Wake Vortex Separations 6.8.1	*Medium*	*High*	*M-H- H*

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SESAR Airport Safety Nets Project 6.7.1	*Medium*	*High*	*M- H-H*
SESAR APV-SBAS 5.6.3	*Medium*	*High*	*H-H-H*
CARE	*Medium*	*High*	*M-M-H*
GARDEN	*Medium*	*High*	*M-M-H*
CK_CONCORDE	*Medium*	*Medium*	*M-H-M*

Coverage

AAS focuses on the ground segment, ALICIA contributes somewhat through a new cockpit concept, and UFO aims to increase runway use through monitoring wake vortex and wind shear. ENDLESS RUNWAY could improve the efficiency of the usage of runways, but it does not contribute to the usage of other parts of the air transport system such as the airspace. SESAR's 6.8.1 guarantees safe introduction of separation modes enabling runway throughput in windy conditions. SESAR's 6.7.1 measures are believed to have a significant impact on reducing runway and taxiway risks, but is designated *Medium* as it only focuses on this part of the aviation risk spectrum. Last but not least, CFIT from SESAR APV-SBAS will be more useful for low-medium density airports and/or mountainous areas. CARE and GARDEN work on developing new IFR flight procedures based on the use of GNSS for rotorcraft enabling rotorcraft to reach busy airports fully independently of the airplane traffic operating from or to active runways. The CONCORDE project aims at experimenting on a novel Flight Management System (FMS) function that proposes to introduce strict time constraints in the trajectory in order to give the ATC a powerful tool to cope with separation issues.

Classification: Medium

Maturity

In most projects tests and simulations have been performed in representative environment and also some deployments have occurred.

Classification: Medium-High

Ease of adoption

Economic: the adoption will require investments that are not significant.
Legal: there are minor legal constraints that must be solved before adoption.
Organisational: Resolving organisational, institutional and political constraints will take time but is rather straightforward.

Economic: Medium
Legal: Medium-High
Organisational: Medium-High

Potential gaps and bottlenecks

There is a gap between near-term research such as SESAR, and thought experiments that are unlikely to be implemented in the medium term.

Enabler	***3***	**Capability**	***8***	

Description: **"**Secure, resilient and integrated CNS systems which ensure seamless, global coverage and are robust to failures of individual components".

Contributing projects	Contribution to capability	Maturity	Ease of adoption
AGEN	*Low*	*Low*	*M-H-H*

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Coverage The redundancy of CNS systems is addressed, but seamless global coverage and system resilience are not. *Classification:* *Low*
Maturity The concept of application is defined, but research is still limited to paper studies. *Classification:* *Low*
Ease of adoption Economic: adoption will require relatively limited investments. Legal: there are minor legal constraints. Organisational: There are minor organisational, institutional or political constraints. *Economic:* *Medium* *Legal:* *High* *Organisational:* *High*
Potential gaps and bottlenecks The projects assessed do not address system resilience and seamless global coverage.

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Enabler	***4***	**Capability**	***1***

Description: "Continuous health management of airports and airspace".

Contributing projects	Contribution to capability	Maturity	Ease of adoption
SCALES	*Medium*	*Medium*	*H-M-M*
SPAD	*Low*	*Low*	*H-H-H*

Coverage

This capability is partially covered. One project (SCALES) addresses developing a framework to detect early warning indicators, to monitor performance of the system and its environment affecting operation to facilitate anticipation and responses to disturbances (risks and opportunities).
The other project, SPAD addresses how to monitor automation degradation and how to contain it with design solutions

Classification: Low-Medium

Maturity

The maturity is *Low*, partially improved by the four cases studies included in the SCALES Framework, increasing knowledge by the observations of everyday operations. A web tool is accessible.
A simulator to validate the proposed models was developed in SPAD, so without significantly contributing to increase the maturity of the technology.

Classification: Low

Ease of adoption

Economic: *High* as the proposed innovation is both methodological and implemented by a framework which can improve the awareness about the Critical infrastructure (airports and airspace: system and its environment).
Legal and Organisational issues are *Medium* as there may be issues of data protection and coordination among different organisations using the system.
For SPAD, the innovation is methodological. No major obstacles are foreseen for the economic, legal, organisational ease of adoption.

Economic: High
Legal: Medium
Organisational: Medium

Potential gaps and bottlenecks

A gap is represented by the need to guarantee reliability and security for these kinds of systems (health management) which are vulnerable to risks (due to technological limits or malevolent attacks).
The main potential bottleneck is in applying the proposed approaches to complex systems as airports and airspace.

Enabler	***4***	**Capability**	***3***

Description: "Innovative Health Management systems and Maintenance processes and tools, including self-healing capabilities, which ensure critical systems and technologies, remain operationally sound".

Contributing projects	Contribution to capability	Maturity	Ease of adoption
AISHA II	*Medium*	*Medium*	*M-M-M*
TRIADE	*Medium*	*Low*	*H-M-M*
LAYSA	*High*	*Medium*	*M-M-H*

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ALAMSA	*Medium*	*High*	*M-M-H*	
JEDI ACE	*Low*	*Medium*	*M-M-M*	
DOTNAC	*Low*	*Medium*	*H-H-M*	
IAPETUS	*Medium*	*Medium*	*M-M-H*	

Coverage

This capability is partially covered. One project (ALAMSA) addresses self-healing by developing thermo-reversible self-healing materials. Two projects (LAYSA, JEDI ACE) address self-healing in terms of anti-icing. IAPETUS contributes to the development of an innovative maintenance process based on the utilization of new composite materials. The other projects (AISHA II, TRIADE, DOTNAC) investigate health monitoring to feed production and/or maintenance, and focus on cost saving rather than self-healing.

Classification: Medium

Maturity

The average maturity is *Medium*, considering that most projects will deliver proofs of concept. (AISHA II foresees full scale testing of the laboratory results; TRIADE develops a neural network software-computing tool; LAYSA manufactures a demonstrator; ALAMSA will include an experimental campaign on small-scale components and full-scale aircraft structures; JEDI ACE will result in validated design concepts and lab-scale prototypes; DOTNAC includes implementation and experiments on test-cases)

Classification: Medium

Ease of adoption

Economic: Costs of investments are significant, but benefits can be as well.
Legal: The certification issues are to be managed.
Organisational: The stakeholders are generally keen to adopt the proposed technologies.

Economic: Medium
Legal: Medium
Organisational: Medium-High

Potential gaps and bottlenecks

The main potential gap is in self- healing, which is so far addressed only by developing thermo-reversible self-healing materials.

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Enabler	**5**	**Capability**	**1**	

Description: "Systematic analysis of Safety data (incident reports, flight data etc.) is utilised by stakeholders due to improved capture technologies, processes and safety culture across the ATS, which includes the General Aviation and Rotorcraft operators."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
SVETLANA	*Medium*	*Medium*	*M-M-L*
FSS P3	*Medium*	*Medium*	*H-H-H*
FSS P4	*Medium*	*Medium*	*H-L-M*

Coverage

SVETLANA covers a flight data management technology focused on processing routinely large amounts of data. FSS P3 systematic analysis of flight data targets only one type of accident (runway excursion).

FSS P4: the prototype risk observatory will be a facilitator for a common EU database in use to capture and interrogate safety related incidents; P4 will study the analysis of heterogeneous sources, alerting mechanisms, exchange of data and data capture mechanisms. Lacking is a fully integrated means of capturing safety data of all stakeholders across the ATS (including e.g. general aviation, and improvement of safety culture and processes.

Classification: Medium

Maturity

The maturity of the covered part is *Medium*.

Classification: Medium

Ease of adoption

The main issues in ease of adoption are in the field of data ownership and protection, dealing with many stakeholders, and investments to be made without direct pay-off. Legal obstacles to obtaining valid data have to be overcome.

Economic: Medium-High
Legal: Medium
Organisational: Medium

Potential gaps and bottlenecks

- Potential gap: a fully integrated means of capturing safety data of all stakeholders across the ATS (including e.g. general aviation), and improvement of e.g., safety culture and processes.
- Potential gap: use of the captured safety data by all stakeholders.
- Bottleneck: Issues regarding data ownership and protection. Potential issues in obtaining reliable data

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Enabler	**6**	**Capability**	**1**

Description: Common framework for Certification / Approvals which embrace new technologies and their integration within the systems to be certified and the use of new technologies and methods in the certification / approval processes.

Contributing projects	Contribution to capability	Maturity	Ease of adoption
EXTICE	*Medium*	*Medium*	*M-L-H*
HIRF SE	*Medium*	*Medium*	*H-M-H*
MISSA	*Medium*	*High*	*M-M-M*
SCARLETT	*Low*	*Medium*	*H-M-M*
ADDSAFE	*Low*	*Medium*	*H-M-H*
AIM2	*Low*	*High*	*H-L-M*
AIRCRAFTFIRE	*Medium*	*Medium*	*H-M-M*
SMAES	*Medium*	*Medium*	*M-M-H*
ASCOS	*Medium*	*Medium*	*M-M-M*
HAIC	*Medium*	*High*	*H-M-H*
RECONFIGURE	*Low*	*Medium*	*H-M-H*
ALIAS 1&2	*Low*	*Medium*	*M-H-M*
ESTOLAS	*Low*	*Low-Medium*	*H-M-H*
DAEDALOS	*Low*	*Low*	*H-M-H*
HYPSTAIR	*Low*	*Low*	*H-M-H*
RECREATE	*Low*	*Medium*	*M-M-L*
RESEARCH	*Low*	*Medium*	*L-H-H*
IMPSHIELDA	*Low*	*Medium*	*M-M-M*
IMPSHIELDB	*Low*	*Medium*	*M-M-M*
IMPSHIELDC	*Low*	*Medium*	*M-M-M*
IMPTEST	*Low*	*Medium*	*M-M-M*

Coverage

Most of the sixteen listed projects address very specific domains of airworthiness certification. ALIAS 1&2 are on liability issues related to complex automation. MISSA and ASCOS however address generic certification processes up to aircraft level or even Air Transport System-level safety assessment. RECREATE studies new air transport designs and therefore includes research on operational certification. The overall coverage is not obtained; it remains unclear how large operational datasets becoming available may contribute to certification processes, and several segments of total aviation system are not addressed (e.g. light aircraft and rotorcraft). The IMPSHIELD and IMPTEST projects address the design, manufacturing and testing of shielding concepts to protect the aircraft from damage by failing rotating engine components. Data coming from the testing will be used to validate numerical models that can be used for certification activities.

Classification: Medium

Maturity

The proposed methodological framework (model-based) to tackle key technological challenges for aircraft design and airworthiness certification (e.g. modularity, complex system, system of systems) is not yet fully matured. But early linkage to industry standards (e.g. ARP 4761, ARP4754) allows a stepped approach.

Classification: Medium

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Ease of adoption
The 'learning-curve' for aircraft / equipment manufacturing industries to deploy new design methods (such as model-based development assurance) is significant, nevertheless reduction in certification costs or time-to-market or maintenance costs is a strong incentive.
The adoption by safety regulators is progressive following the update cycle for underlying industry standards.

Economic: *Medium-High*
Legal: *Medium*
Organisational: *Medium-High*

Potential gaps and bottlenecks
Potential gaps are the use of large operational data sets, and addressing several segments of the total aviation system (e.g., light aircraft, rotorcraft).

Enabler	**6**	**Capability**	**4**

Description: Methods and tools which facilitate the verification of the global standardisation, certification and approvals processes are all joined up at air transport systems level.

Contributing projects	Contribution to capability	Maturity	Ease of adoption
PICASSO	*Low*	*Medium*	*H-M-H*
SUPRA	*Medium*	*Medium*	*M-M-M*

Coverage
Some specific areas are covered (e.g., a simulator for training loss of control), but a significant part of the capability remains unaddressed, a particular area is the operational approval processes for changes to automation.

Classification: *Medium*

Maturity
Experiments are included, but e.g., the use of SUPRA results for certification has not yet been addressed.

Classification: *Medium*

Ease of adoption
Benefits from reductions of costs or organisational constraints represent key incentives to move towards the adoption of the capability. But the challenges to evolve safety oversight from current methods (fragmented) towards a unified framework are significant.

Economic: *Medium-High*
Legal: *Medium*
Organisational: *Medium-High*

Potential gaps and bottlenecks
A large part of the capability is unaddressed, specifically an overall approach to standardisation and the use of large operational datasets to support approval processes.

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Enabler	***7***	**Capability**	***1***	

Description: Systematic methods for ensuring results of safety / security analysis are fed back into the design process

Contributing projects	Contribution to capability	Maturity	Ease of adoption
PROSPERO	*Medium*	*Low*	*M-M-M*
MISSA	*Medium*	*High*	*M-M-M*
SESAR SRM	*Medium*	*High*	*H-H-M*
ASHICS	*Low*	*Medium*	*H-M-M*

Coverage

Four projects, with overall *Medium* coverage for this capability. SESAR SRM enables results to be fed back into the design process but only focuses on ATM. Support is also available in particular from PROSPERO which aims for a system change loop, providing "design solutions", and MISSA, which proposes safety assessment models tightly linked with design.

Classification: Medium

Maturity

Two projects have *High* maturity, one *Medium* and one *Low*, so *Medium/High* is selected.

Classification: Medium-High

Ease of adoption

No significant impediments foreseen for these projects**.**

Economic: Medium-High
Legal: Medium
Organizational: Medium

Potential gaps and bottlenecks

A systematic method for ensuring that results of safety analysis are fed back into the design process is now available, and needs to be extended to other parts of the ATS. During such adaptation, benefits from PROSPERO and MISSA could be integrated.

Enabler	***7***	**Capability**	***2***	

Description: Systematic methods for ensuring in-service experience is fed back into the design and manufacturing process

Contributing projects	Contribution to capability	Maturity	Ease of adoption
ELSA	*Medium*	*Low*	*H-H-H*

Coverage

ELSA is focused on ATM therefore the coverage of this capability is *Medium.*

Classification: Medium

Maturity

The Maturity is rated *Low*.

Classification: Low

Ease of adoption

Ease of adoption is rated *High*.

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Economic: *High*
Legal: *High*
Organizational: *High*

Potential gaps and bottlenecks
There is room for additional focus in this area as there is only one Project with a Medium Contribution and Low Maturity.

Enabler	***7***	**Capability**	**3**	

Description: Current and emergent environmental hazards are characterized and understood, and accurately mitigated in the design.

Contributing projects	Contribution to capability	Maturity	Ease of adoption
HIRF-SE	*Medium*	*Medium*	*H-M-H*
WEZARD	*Medium*	*High*	*H-H-H*
HAIC	*Medium*	*High*	*H-M-M*
RESILIENCE 2050	*Low*	*Low*	*unknown*
JEDI ACE	*Low*	*Medium*	*M-M-M*
EXTICE	*Low*	*Medium*	*L-M-H*
COMPASS	*Medium*	*Medium*	*M-H-H*
STORM	*Medium*	*Medium*	*L-H-L*
ENDLESS RUNWAY	*Low*	*Medium*	*L-L-L*

Coverage
Nine projects address Capability 7.3. Four consider icing (HAIC, JEDI ACE, STORM, EXTICE), one electromagnetic interference (HIRF-SE), one a weather hazard roadmap (WEZARD), one considers resilience in ATM (RESILIENCE2050), one considers wind issues on take-off and landing (ENDLESS RUNWAY), and one considers providing early warnings of adverse events (weather) to operators (COMPASS). Other environmental hazards such as wind shear, turbulence, low visibility and thunderstorms remain unaddressed.

Classification: *Medium*

Maturity
Overall the maturity of these projects is *Medium*.

Classification: *Medium*

Ease of adoption
No significant issues are expected, except for ENDLESS RUNWAY, which is a radical new concept, and STORM, which has significant cost implications. As accidents continue to happen due to weather effects (e.g. icing), the case for improvement is strong.

Economic: *Medium*
Legal: *Medium-High*
Organizational: *Medium-High*

Potential gaps and bottlenecks
Several hazards (fog or low visibility, wind shear, turbulence and thunderstorms) are not addressed but are significant in safety terms.

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Enabler	***7***	**Capability**	**5**	

Description: Improved resilience through the introduction of new technology or improved system designs.

This capability has a very wide scope, and many projects contribute to it. For a better assessment, this capability has been divided into 5 sub-capabilities:

Sub-capabilities	Projects	Coverage of capability	Maturity	Ease of adoption
7.5.1 Improved resilience through advanced systems integration.	*MISSA, SCARLETT, ADDSAFE, ARISTOTEL, MAN4GEN, RECONFIGURE, RESILIENCE2050, ODICIS,RESEARCH, FSS P3, WINFC*	*Medium*	*Medium*	*MH-M-MH*
7.5.2 Safe design of future/novel aircraft concepts	*PPLANE, SAFAR, SAFUEL, AGEN, HYPMOCES, BRAINFLIGHT,DAEDALOS, FSS P7*	*Medium*	*Low-Medium*	*M-M-M*
7.5.3 Improved resilience through research into new/ improved sensor technology	*AISHA II, GREEN-WAKE, HISVESTA, TRIADE, ON-WINGS, SAFUEL, JEDI ACE, IAPETUS, DOTNAC, NINA, FSS P7*	*Medium*	*Medium*	*M-M-M*
7.5.4 Improved resilience through research into new improved materials which improve safety through product lifecycle	*LAYSA, AEROMUCO, ALAMSA, JEDI ACE, BOPACS, DAEDALOS, IMPSHIELDA, IMPSHIELDB, IMPSHIELDC, IMPTEST*	*Medium-High*	*Medium*	*M-M-MH*
7.5.5 Improved resilience through Improved manufacturing techniques/ technologies	*ACCENT,BOPACS, CORSAIR, DAEDALOS, IAPETUS*	*Medium*	*Medium-High*	*MH-M-H*

Coverage
Four sub-capabilities have *Medium* coverage, one sub-capability has *Medium-High* coverage.

Classification: Medium

Maturity
Average maturity is *Medium*.

Classification: Medium

Ease of adoption
Most contributing projects have at least Medium ease of adoption on all three scales. There are exceptions in sub-capabilities 7.5.2 (all related to highly novel concepts for which research is of low maturity) and 7.5.3 (related to certification and training for reduced wake vortex separation

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operations and certification of novel sensors).

Economic: *Medium-High*
Legal: *Medium*
Organisational: *Medium-High*

Potential gaps and bottlenecks
Potential gap: There are unaddressed topics in each of the five sub-capabilities.
Bottleneck: issues related to highly novel concepts for which research is of low maturity.

Enabler	***7***	**Sub-capability**	**5.1**

Description: Improved resilience through advanced systems integration.

Contributing projects	Contribution to capability	Maturity	Ease of adoption
MISSA	*Medium*	*High*	*M-M-M*
SCARLETT	*Low*	*Medium*	*H-M-M*
ADDSAFE	*Low*	*Medium*	*H-M-H*
ARISTOTEL	*Medium*	*Medium*	*M-M-H*
MAN4GEN	*Low*	*High*	*M-H-H*
RECONFIGURE	*Low*	*Medium*	*H-M-H*
RESEARCH	*Low*	*Medium*	*L-H-H*
RESILIENCE2050	*Medium*	*Low*	*Not*
ODICIS	*Low*	*Medium*	*M-M-M*
FSS P3	*Low*	*Low*	*H-H-H*
WINFC	*Low*	*Low*	*M-M-H*

Coverage
The coverage is good. Projects cover: assessment framework for systems, standardised, modular avionics scalable for different applications, fault detection and diagnosis technology. Three projects cover improved systems and information to manage abnormal situations, one covers ATM system resilience and one standardised cockpit displays. Most projects have a low contribution to the capability.

Classification: *Medium*

Maturity
The average maturity of these projects is *Medium*

Classification: *Medium*

Ease of adoption
Ease of adoption is for all projects on all three scales at least *Medium*.

Economic: *Medium-High*
Legal: *Medium*
Organisational: *Medium-High*

Potential gaps and bottlenecks
Potential gap: Unaddressed part of the sub-capability.
Bottleneck: None (no projects with *Low* ease of adoption).

Enabler	***7***	**Sub-capability**	**5.2**

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Description: Safe design of future/novel aircraft concepts

Contributing projects	Contribution to capability	Maturity	Ease of adoption
PPLANE	*Low*	*Low*	*M-L-L*
SAFAR	*Low*	*High*	*M-M-M*
SAFUEL	*Low*	*Medium*	*M-M-M*
AGEN	*Medium*	*Low*	*M-H-H*
HYPMOCES	*Medium*	*Low*	*L-L-L*
BRAINFLIGHT	*Medium*	*Low*	*M-L-L*
DAEDALOS	*Medium*	*Medium*	*H-M-H*
FSS P7	*Low*	*Low*	*M-H-H*

Coverage
Broad coverage. Two projects cover future small or personal air transport concepts, one covers safer fuel systems for new generation of aircraft, one covers improved navigation and guidance, one covers hypersonic aircraft escape systems, one covers pilot neural interfaces, one covers assessment of dynamic loads in sizing of components, and one covers novel materials to reduce fire risks.

Classification: Medium

Maturity
Most projects are in an early concept stage.

Classification: Low-Medium

Ease of adoption
The overall ease of adoption is at least Medium for most projects on all three scales. The exceptions are all associated with research of low maturity: the radically new PPLANE concept, the use of morphing in escape systems for hypersonic transport aircrafts in HYPMOCES, and HYPMOCES's concept for brain control of aircraft.

Economic: Medium
Legal: Medium
Organisational: Medium

Potential gaps and bottlenecks
Potential gap: Unaddressed part of the sub-capability.
Bottleneck: Possible bottlenecks regarding highly novel concepts, for which the research is in low maturity.

Enabler	***7***	**Sub-capability**	**5.3**

Description: Improved resilience through research into new/ improved sensor technology

Contributing projects	Contribution to capability	Maturity	Ease of adoption
AISHA II	*Low*	*Medium*	*M-M-M*
GREEN-WAKE	*Medium*	*Medium*	*M-L-L*
HISVESTA	*Medium*	*Medium*	*M-L-H*
TRIADE	*Medium*	*Medium*	*H-M-M*
ON-WINGS	*Medium*	*High*	*M-M-M*
SAFUEL	*Low*	*Medium*	*M-M-M*
JEDI ACE	*Low*	*Medium*	*M-M-M*

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IAPETUS	*Medium*	*Medium*	*M-M-H*
DOTNAC	*Low*	*Medium*	*H-H-M*
NINA	*Low*	*Medium*	*M-L-L*
FSS P7	*Medium*	*Low*	*M-M-M*

Coverage
Coverage is good with a number of areas being addressed: two projects cover ice protection, one covers accurate altitude measurement, one is an advanced non-destructive inspection technique, one a fuel sensor, one aimed at wake vortex monitoring, one advanced structural monitoring systems and a smart tag to fit within composite layers for a number of measurements, one project advanced composite patch repair technology, and one cabin air quality.

Classification: Medium

Maturity
The average maturity of these projects is *Medium*.

Classification: Medium

Ease of adoption
Ease of adoption is at least Medium for most projects on all three scales. The exceptions are due to certification and training for reduced wake vortex separation operations (legal, economic) and certification of novel sensors.

Economic: Medium
Legal: Medium
Organisational: Medium

Potential gaps and bottlenecks
Potential gap: Unaddressed part of the sub-capability.
Bottlenecks: Certification and training for reduced wake vortex separation operations (legal, economic) and certification of novel sensors.

Enabler	***7***	**Sub-capability**	**5.4**

Description: Improved resilience through research into new improved materials which improve safety through product lifecycle.

Contributing projects	Contribution to capability	Maturity	Ease of adoption
LAYSA	*Medium*	*Medium*	*M-M-H*
AEROMUCO	*Low*	*Medium*	*H-M-M*
ALAMSA	*Medium*	*High*	*M-M-H*
JEDI ACE	*Low*	*Medium*	*M-M-M*
BOPACS	*Medium*	*High*	*M-M-H*
DAEDALOS	*Medium*	*Medium*	*H-M-H*
IMPSHIELDA	*Low*	*Medium*	*M-M-M*
IMPSHIELDB	*Low*	*Medium*	*M-M-M*
IMPSHIELDC	*Low*	*Medium*	*M-M-M*
IMPTEST	*Low*	*Medium*	*M-M-M*

Coverage
The projects offer broad coverage: one project is developing self-healing technologies, seven (of which four are the related IMPSHIELD and IMPTEST projects) are developing novel protections systems for surfaces, icing and luggage explosives. One project covers the assessment of dynamic

loads in sizing of components. One project develops a technology to join composite structures avoiding the use of fasteners.

Classification: *Medium-High*

Maturity
The average maturity of these projects is *Medium*.

Classification: *Medium*

Ease of adoption
Ease of adoption is on all three scales at least *Medium* for all projects.

Economic: *Medium*
Legal: *Medium*
Organisational: *Medium-High*

Potential gaps and bottlenecks
Potential gap: Unaddressed part of the sub-capability.
Bottleneck: None (no projects with *Low* ease of adoption).

Enabler	***7***	**Sub-capability**	**5.5**

Description: Improved resilience through Improved manufacturing techniques/ technologies.

Contributing projects	Contribution to capability	Maturity	Ease of adoption
ACCENT	*Medium*	*Medium*	*H-M-H*
BOPACS	*Medium*	*High*	*M-M-H*
CORSAIR	*Medium*	*High*	*M-M-H*
DAEDALOS	*Medium*	*Medium*	*H-M-H*
IAPETUS	*Medium*	*Medium*	*M-M-H*

Coverage
5 Projects contribute to this capability: ACCENT develops adaptive control of manufacturing processes which could result in a safety benefit if applied to critical parts. BOPACS develops a technology to join composite structures avoiding the use of fasteners. CORSAIR develops a cold spray repair technology making it possible to repair a wider range of defects. DAEDALOS develops methods and procedures to determine dynamical loads. IAPETUS develops an advanced composite patch repair technology.

Classification: *Medium*

Maturity
The average maturity of the three projects is *Medium-High*.

Classification: *Medium-High*

Ease of adoption
Ease of adoption is on all three scales at least *Medium* for all projects.

Economic: *Medium-High*
Legal: *Medium*
Organisational: *High*

Potential gaps and bottlenecks
Potential gap: Unaddressed part of the sub-capability.

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Bottleneck: None (no projects with *Low* ease of adoption).

Enabler	***7***	**Capability**	**6**	

Description: New materials, new manufacturing techniques, and design approaches which improve the survivability (active and passive measures) of transported people and goods (e.g. new cabin designs)

Contributing projects	Contribution to capability	Maturity	Ease of adoption
LAYSA	*Low*	*Medium*	*M-M-H*
AIRCRAFTFIRE	*Medium*	*Medium*	*H-M-M*
SMAES	*Low*	*Medium*	*M-M-H*
HYPMOCES	*Low*	*Low*	*L-L-L*
FANTASSY	*Low*	*Low*	*L-L-L*
MAAT	*Low*	*Medium*	*L-L-L*
FSS P7	*Medium*	*Low*	*M-H-H*
FLYBAG	*Medium*	*Medium*	*M-H-M*
FLYBAG II	*Medium*	*High*	*H-H-H*
IASS	*Medium*	*Medium*	*M-M-H*

Coverage
Both external and in-cabin aspects of survivability are addressed, related to fire, emergency ditching, and escape from supersonic aircraft. Other elements, e.g., crashworthiness are not addressed.

Classification: *Medium*

Maturity
Average maturity is *Medium* of these projects.

Classification: *Medium*

Ease of adoption
The results of some of the projects may provide cost-savings, and organisations are motivated to address some of the sources of risk considered. Legal issues may be more challenging, e.g. for engine components.

Economic: *Medium*
Legal: *Medium*
Organizational: *Medium-high*

Potential gaps and bottlenecks
Certain critical elements of survivability remain unaddressed (e.g., crashworthiness). This aspect deserves further attention.

Enabler	***7***	**Capability**	**9**	

Description: A methodology and toolset for advanced Systems Engineering, to help address both the necessary complexity of designs, and the need to manage a large number of stakeholder requirements, as well as allowing safety and security requirements to be integrated into the design from the earliest stages. (e.g., counterfeit parts)

Contributing projects	Contribution to capability	Maturity	Ease of adoption
MISSA	*Medium*	*Medium*	*M-M-M*
PICASSO	*Low*	*Medium*	*H-M-H*

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SESAR Safety Register	*Medium*	*High*	*H-H-M*
ASHICS	*Low*	*Medium*	*H-M-M*
MAREA	*Low*	*Low*	*H-H-H*
SCALES	*Medium*	*Medium*	*H-M-M*

Coverage
There are six Projects contributing to this Capability, with overall a Medium contribution. MISSA deals with new safety assessment activities part of the certification process; SESAR Risk Register ensures risks are categorised, acted upon and not forgotten; SCALES and MAREA focusing Resilience Engineering, and ASHICS on change management. PICASSO improves system engineering for Non-destructive testing applications. Overall, the approach is currently able to deal with system safety requirements, but not a "large number of stakeholder requirements".

Classification: Medium

Maturity
The projects have *Medium* maturity.

Classification: Medium

Ease of adoption
Economic factors are favourable for large or complex systems; legal factors are *Medium*, and organisational factors are *Medium* due to training requirements for engineers.

Economic: High
Legal: Medium-High
Organizational: Medium-High

Potential gaps and bottlenecks
Dealing with large numbers of stakeholder requirements.

Enabler	***7***	**Capability**	**10**

Description: The application of human factors and psycho-social issues in design and manufacturing.

Contributing projects	Contribution to capability	Maturity	Ease of adoption
HUMAN	*Medium*	*Low*	*H-H-M*
SAFAR	*Low*	*High*	*M-M-H*
MAN4GEN	*Low*	*High*	*M-H-H*
A-PIMOD	*Medium*	*Medium*	*M-M-M*
ODICIS	*Medium*	*Medium*	*M-M-M*
ARISTOTEL	*Medium*	*High*	*M-M-H*
SESAR Human Performance Reference Material & Case	*High*	*High*	*H-H-M*
MOTA	*Low*	*Medium*	*M-L-M*

Coverage
Eight projects address Capability 7.10. The focus in these projects is primarily on the flight deck, but thanks to SESAR and its Human Performance approaches in ATM, this Capability can now be considered *Medium-High*.

Classification: Medium-High

Maturity
The average maturity is *Medium-High*.

Classification: *Medium-High*

Ease of adoption
The average rating is *Medium-High* for all three dimensions. With new designs of cockpits and new displays, etc., cost and certification can be difficult.

Economic: *Medium-High*
Legal: *Medium-High*
Organizational: *Medium-High*

Potential gaps and bottlenecks
Potential gaps: There is an opportunity to harmonise a Human Factors approach across the ATS design and manufacturing system, as was raised in the first OPTICS Workshop in 2014.

Enabler	***7***	**Capability**	**12**

Description: Reliability engineering of critical software

Contributing projects	Contribution to capability	Maturity	Ease of adoption
SCARLETT	*Low*	*Medium*	*H-M-M*

Coverage
The SCARLETT project deals with digital avionics equipment that includes software; it does not focus on the reliability. Coverage is thus considered *Low*.

Classification: *Low*

Maturity
First prototypes have been developed. A follow-up project (ASHLEY) will improve the maturity of the approach.

Classification: *Medium*

Ease of adoption
Economic: there is a strong incentive to use the second generation of Integrated Modular Avionics (IMA2G) that SCARLETT aims to identify, since the aircraft would need less equipment (computers, networks), and aircraft operators would need to buy fewer spare parts. Despite these economic advantages, there are open issues on certification aspects and changes needed to occur at the inter-organisational level.

Economic: *High*
Legal: *Medium*
Organizational: *Medium*

Potential gaps and bottlenecks
The main potential gap is that software reliability is not addressed.

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Enabler	***8***	**Capability**	***1***	

Description: "Automation supports human in both normal and degraded operations; allocation of functions between human and machine is optimised in order to maximise situation awareness, support decision-making, and enhance performance execution".

Contributing projects	Contribution to capability	Maturity	Ease of adoption
PPLANE	*Low*	*Low*	*M-L-L*
ALICIA	*Medium*	*Medium*	*M-M-M*
ACROSS	*Medium*	*Medium*	*M-M-M*
MAN4GEN	*Medium*	*High*	*M-H-H*
A-PIMOD	*Medium*	*Low*	*H-H-M*
ARISTOTEL	*Medium*	*Medium*	*M-M-H*
BRAINFLIGHT	*Medium*	*Low*	*M-L-L*
ODICIS	*Low*	*Medium*	*M-M-M*
MOTA	*Low*	*Medium*	*M-L-M*
MUFASA	*Low*	*Low*	*H-H-H*
NINA	*Medium*	*Medium*	*M-L-L*
SAFECORAM	*Low*	*Low*	*H-M-M*
SPAD	*Low*	*Low*	*H-H-H*
SESAR A-CWP 6.9.2	*Medium*	*High*	*M-M-H*
SESAR Guidance on Human Centred Automation 16.5.1	*Low*	*Medium*	*M-M-M*
SESAR Guidance on Impact of Future Systems in Selection, Training, Competence and Staffing Requirements 16.4.3 & 16.5.4	*Low/Medium*	*High*	*M-M-M*
MYCOPTER	*Low*	*Low*	*L-L-L*
RECREATE	*Low*	*Medium*	*M-M-L*
FSS P6	*Low*	*Low*	*L-M-H*
CK_TACTIC	*Medium*	*Medium*	*M-M-H*

Coverage

Capability 8.1 shows a good balance of projects covering pilots and cockpit, and projects looking at controllers and ATM automation. Two projects - SESAR Guidance on Human Centred Automation 16.5.1, and SESAR Guidance on Impact of Future Systems in Selection, Training, Competence and Staffing Requirements 16.4.3 & 16.5.4 - seem to look at the total system.

With respect to the performance support, it has to be noted that some specific situations are analysed in more detail (e.g., situation awareness, high workload), while others are not considered (e.g. fatigue). CK_TACTIC is looking at a more generic decision support tool for pilots in off-nominal scenarios. Better integration of operators (air and ground) and automation is investigated, automation for mission management is not considered in any project. Maintenance operators are still missing. Two projects are oriented to non-professional pilots (PPlane and MYCOPTER) and investigate automation increase in personal aerial vehicles.

Classification: Medium-High

Maturity

Most projects are still research and long-term oriented, with Low to Medium maturity for projects delivering systems and testing them in simulators. Only MAN4GEN – with tests being performed - and SESAR A-CWP 6.9.2 – ready for pre-implementation validation - are at High level of maturity.

Classification: *Medium*

Ease of adoption

The cost of adoption is generally *Medium*.

Economic: most projects have both high investments balanced with high pay off.

Legal: The legal ease of adoption varies from *Low* to *High* over the projects according to the expected complexity of the certification process. The main issues are for the innovative concepts of BRAINFLIGHT, MYCOPTER, NINA and PPLANE, where significant legal constraints and extensive certification processes are expected.

Organisational: Organisational ease of adoption also varies much. It is *High* for projects addressing non-controversial aspects of automation (improve training, deal with undesired couplings between operators and automation) and for methodological innovations, *Medium* for projects proposing more extensive changes to cockpit concepts or in ground-control interfaces, and *Low* for concepts expected to encounter strong operators' oppositions (reduced crew operations, high levels of automation).

Economic: *Medium*
Legal: *Medium*
Organisational: *Medium*

Potential gaps and bottlenecks

- Maintenance segment and respective operators are not addressed.
- It is not clear how to fit together the outcomes of industrial projects (e.g. *High*er maturity) with more research-driven ones (e.g. *Low*er maturity). It is not clear if there is duplication or complementarity, as it may be the case when the same issue is addressed with two different approaches.
- The mechanism to make the transition from research to ATS-wide operational implementation is not clear for this capability.
- Commercial aspects may be hindering industry-wide collaboration.

Enabler	***8***	**Capability**	***2***	

Description: "Information systems support human collaboration across seamless operational concepts throughout the ATS (air & ground)".

Contributing projects	Contribution to capability	Maturity	Ease of adoption
SESAR A-CWP 6.9.2	*Medium*	*High*	*M-M-H*
SESAR Human Performance Reference Material and Human Performance Case 16.6.5	*Medium*	*High*	*H-H-M*

Coverage

There are two projects covering Capability 8.2, and both of them focussing ATM operations (one of them only on tower). Seamless human collaboration doesn't seem really addressed. The task analysis approach in SESAR could easily be adapted industry-wide for defining information requirements in interfaces.

Classification: *Medium*

Maturity

Both projects show high maturity, as ACWP is at pre-implementation validation (EOCVM V3) and HPRM task analyses have been ratified.

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Classification: *High*

Ease of adoption
The cost of adoption is generally *Medium*.
Economic: some costs can be associated with tailoring of A-CWP to the local airport conditions, while the use of task analyses doesn't imply additional costs.
Legal: As for the economic EOA, A-CWP has to go through some certification prior to implementation, even if no specific hurdles are anticipated; no legal issues are foreseen for task analyses.
Organisational: easier operator acceptance is foreseen for A-CWP than for task analyses.

Economic: *Medium*
Legal: *Medium*
Organisational: *Medium*

Potential gaps and bottlenecks
- Seamless human collaboration doesn't seem really addressed, as the proposed systems apply just to one type of operator and to normal operations.
- The utility of task analysis in other sectors needs to be explored.

Enabler	***8***	**Capability**	**4**

Description: "Aircraft, airport and ground handling technologies are integrated to support people in the turnaround process and links to other transport modes"

Contributing projects	Contribution to capability	Maturity	Ease of adoption
AAS	*Low*	*High*	*M-H-M*

Coverage
Integration of ground handling technologies is covered, but the main parts of this capability is not addressed (e.g., integration with aircraft and airport, link to other transport modes).
Classification: *Low*

Maturity
Tests have been performed in full-scale representative environments, on 3 airports.
Classification: *High*

Ease of adoption
Economic: *Medium*; costs involved (e.g., equipping vehicles with new technology) are not deemed to be very significant. The benefits are only for ground handling accident types.
Legal: *High*, no legal implications are foreseen.
Organisational: *Medium*, vehicle drivers have to be trained in the usage of new equipment.
Economic: *Medium*
Legal: *High*
Organisational: *Medium*

Potential gaps and bottlenecks
- Potential gaps are the integration of aircraft and airport, and the link to other transport modes.
- The main bottleneck is the number of stakeholders to be involved for a fully integrated solution, especially when addressing other transport modes.

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Enabler	***9***	**Capability**	***1***

Description: "New collaborative team concepts will embrace the whole ATS system, enhancing collaboration across professional roles and between different organisations."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
FSS P5	*Low*	*Low*	*M-H-L*

Coverage
The capability is only addressed by one project which has a low contribution to the capability. FSS P5 represents a significant but limited start in this direction, as the concept will likely need to evolve if it is successful.

Classification: Low

Maturity
Since the use of safety culture for behaviour modification proposed by P5 is still in a relatively low state of maturity, the maturity of this capability is rated with *Low*.

Classification: Low

Ease of adoption
There will be some cost implications in new training and also potential applications relating to safety information flow inside and between organisations. At the moment the organisational 'pull' for this is relatively low, although some organisations may prove to be early adopters.

Economic: Medium
Legal: High
Organisational: Low

Potential gaps and bottlenecks

- Safety culture aspects are covered by FSS P5, new team concepts (for example collaboration between teams for different organizations) need still to be explored.

Enabler	***9***	**Capability**	***2***

Description: "Optimisation of the 'Human performance envelope' through better job design and management, to reduce current problems of fatigue, vigilance, poor decision making and loss of situation awareness or loss of control"

Contributing projects	Contribution to capability	Maturity	Ease of adoption
SUPRA	*Medium*	*High*	*M-M-M*
MAN4GEN	*Medium*	*High*	*M-M-H*
BRAINFLIGHT	*Medium*	*Low*	*M-L-L*
ERAINT	*Low*	*Medium*	*M-L-L*
FSS P6	*Low*	*Low*	*L-M-H*

Coverage
The capability is addressed mainly in the area of pilots and cockpit, with a focus on some specific situations (e.g., loss of control, situation awareness, high workload). For example, MAN4GEN addresses reduction of problems of loss of situation awareness or loss of control, and BRAINFLIGHT

extensive automation and the impact on aspects as situation awareness and decision-making. The only ATM-related project has a very narrow and specific focus on human factors with respect to the RPAS operator, and on RPAS in-flight contingencies. Other operators and accident types are generally not addressed. FSS P6 focuses on mapping the relationships between key performance factors. It is only expected to find some principal relations, and it focuses on pilots only.

Classification: Medium

Maturity
The results of MAN4GEN and SUPRA have been tested in simulators, and the project ERAINT has *Medium* maturity. BRAINFLIGHT and FSS P6 have a Low maturity.

Classification: Medium

Ease of adoption
Economic: the costs for the innovation proposed in SUPRA are manageable; MAN4GEN, BRAINFLIGHT, ERAINT and FSS P6 involve high investments balanced with high pay-off.
Legal: Ease of adoption varies from *Low* to *Medium* according to the expected complexity of the certification process. BRAINFLIGHT is the *Low* one; the proposed innovative concepts will have to face with major legal constraints to be solved before adoption. ERAINT is *Low* as well, as a whole new set of regulations and processes will be required to RPAS to operate under an IFR-ATM environment. For FSS P6 there may be legal accountability issues to consider with respect to automation failure.
Organisational: almost all aviation stakeholders recognise the benefits of innovations proposed by MAN4GEN. For SUPRA there are some issues w.r.t. training. ERAINT is ranked as *Low* because of the need of coordinating many stakeholders. BRAINFLIGHT ranks the same, as brain sensors could encounter pilots' opposition. For FSS P6 organisational pull may pave the way - eventually - for single pilot operations.

Economic: Medium
Legal: Medium
Organisational: Medium

Potential gaps and bottlenecks
- The human performance envelope is not considered as a whole, and aspects other than loss of control, situation awareness, and high workload are not addressed (e.g. fatigue).
- Main area of interest is pilots and cockpit, ATM is almost unexplored and maintenance is not addressed at all.

Enabler	***9***	**Capability**	**3**

Description: "Monitoring of crew/team capacity and corrective measures."

Contributing projects	Contribution to capability	Maturity	Ease of adoption
ACROSS	*Medium*	*Medium*	*M-L-L*
A-PIMOD	*Medium*	*Medium*	*L-L-L*
ARISTOTEL	*Medium*	*High*	*M-M-H*
NINA	*Medium*	*Medium*	*M-L-L*

Coverage
This capability is addressed for specific pilot- and cockpit-related items: a system for crew workload and crew incapacitation (ACROSS), adaptive automation using real time inferences about the pilot state and mental picture (A-PIMOD), detection of pilots' undesired behaviour and identification of

corrective measures (ARISTOTEL). Only one project addressed the ATM sector and controllers' capacity; NINA proposes a set of neuro-physiological indicators to monitor ATCOs workload, expertise, and level of cognitive control. Other areas are not addressed. *Classification: Medium*
Maturity ARISTOTEL will perform tests and has *high* maturity but contributes less to this capability than A-PIMOD, ACROSS and NINA which all have *Medium* contribution. *Classification: Medium*
Ease of adoption Economic: *Medium*; even the most radical concepts lead to high safety benefits. Legal: barriers are expected, with extensive certifications for the proposed concepts and privacy issues to be addressed for neurometrics measures (NINA). Organisational: barriers are expected for the radical changes (as for the adaptive automation proposed in A-PIMOD or ACROSS for single pilot) and for the changes that require coordination and agreement among different parties (as the monitoring technologies for ATM operators in NINA), while high acceptability is expected for more incremental changes (as the support to detect and correct undesired pilot behaviour proposed in ARISTOTEL). *Economic: Medium* *Legal: Low* *Organisational: Low-Medium*
Potential gaps and bottlenecks • The main potential gaps are areas other than pilots and controllers, such as maintenance operators. • In the projects assessed fatigue is not directly addressed. • Bottlenecks are that there is no consolidation of past research, with a fragmented community; and acceptance by operators of the solutions, e.g., operators opposition against being monitored, and opposition against different team concepts (e.g., single-pilot operations).

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