optics

OPTICS Final Report

IS EUROPEAN AVIATION SAFETY RESEARCH DELIVERING?

Observation Platform for Technological and Institutional Consolidation of Research in Safety

Preface

The OPTICS project set out in 2013 to determine if Europe was doing the right aviation safety research to deliver us towards a safer future, in accordance with the goals cited in Europe's vision for aviation, Flightpath 2050. Four years later the team has analysed 243 safety research projects from all over Europe, and indeed, many of these projects are moving us in a safer direction, whether focusing on adverse weather, drones, Human Factors or Resilience.

As well as analysing research projects and programmes, OPTICS ran an annual two-day workshop, where between forty-five and seventy-five experts discussed and evaluated research priorities, and came up with a 'Top Ten' hit-list of urgent and strategic research needs. Several of those identified priorities have since been funded by the European Commission, and the resultant research projects are ongoing at the time of writing this final report.

Having answered the question, that we are – broadly speaking – doing the right research, OPTICS turned to several harder questions. How do we compare with other major research players such as the US and China? Is the funded research helping to resolve Europe's top aviation safety risks? And is the research-to-industry business model working well?

There are lessons to be learned from the answers to these questions, and Europe needs to become more strategic in its safety research, and 'tighten up' its business model. But overall the review is positive, and Europe will no doubt continue to carry out world class safety research, preparing us for the challenges that lie ahead in aviation. This report shows that Europe is already on a good track.

This is the final report for OPTICS, but it is not the end of the story, as a further project called OPTICS2 is about to start and will enlarge the scope, focusing also on aviation security research. It is envisaged that in the next four years, some of the refinements suggested in this current report may come to fruition, leading to an improved aviation safety and security research framework in Europe, enabling safe and secure travel for all, whether inside Europe's borders or beyond.

Barry Kirwan,
EUROCONTROL
OPTICS Project Coordinator

Consortium

Acknowledgments

OPTICS reports both to its funder, the European Commission, and to the Advisory Council for Aviation Research & Innovation in Europe (ACARE), via a multi-stakeholder group known as Working Group 4 (WG4), which focuses on Safety & Security. Throughout the past four years the European Commission and ACARE WG4 have helped steer OPTICS in the right direction. Without their support, OPTICS would not have been possible. Particular thanks goes to the OPTICS Advisory Board, and to the OPTICS Project Team members.

optics

OPTICS Final Report

IS EUROPEAN AVIATION SAFETY RESEARCH DELIVERING?

Observation Platform for Technological and Institutional Consolidation of Research in Safety

OPTICS

Navigating towards safety goals of Flightpath 2050

The Advisory Council for Aviation Research and Innovation in Europe (ACARE) has provided Europe with a vision for aviation. To identify a pathway towards this vision, called Flightpath 2050, ACARE developed the Strategic Research and Innovation Agenda (SRIA), a roadmap providing guidance on what is required, as well as when it is required, and how it can be delivered via Research and Innovation (R&I) activities.

The SRIA goals are challenging: ensuring that Europe maintains its competitive edge in the global market through sustainable investment in R&I activities, and assuring that aviation achieves the highest levels of safety and security throughout the whole air transport system. A number of projects have been funded to see if we are on the right track towards Flightpath 2050. One such project is OPTICS.

Are we doing the right safety research?

OPTICS is a Coordination and Support Action of the European Commission, working in close co-operation with ACARE on the topic of safety. It provides a comprehensive evaluation of relevant safety research & innovation in aviation and air transport. The main objective of the project is assessing if Europe is performing the right safety research and if the research is delivering the expected benefits to society.

Each year OPTICS assessed projects from different research programmes in order to deliver a global view of the state of aviation safety research by 2017.

2014

STATE-OF-THE-ART IN SAFETY RESEARCH
First release, FP7 projects

PROJECT REPOSITORY
First release

METHODOLOGICAL FRAMEWORK

Workshop #1
HUMAN FACTORS

2015

STATE-OF-THE-ART IN SAFETY RESEARCH
Second release, SESAR, SESAR WP-E, Future Sky Safety, Clean Sky projects

PROJECT REPOSITORY
Second release

Report on
PRELIMINARY MARKET AND SOCIETAL IMPACT ASSESSMENT

Workshop #2
HAZARD MANAGEMENT

2016

STATE-OF-THE-ART IN SAFETY RESEARCH
Third release, National Projects

PROJECT REPOSITORY
Third release

Workshop #3
DO POLITICS AND SAFETY MIX WELL?

2017

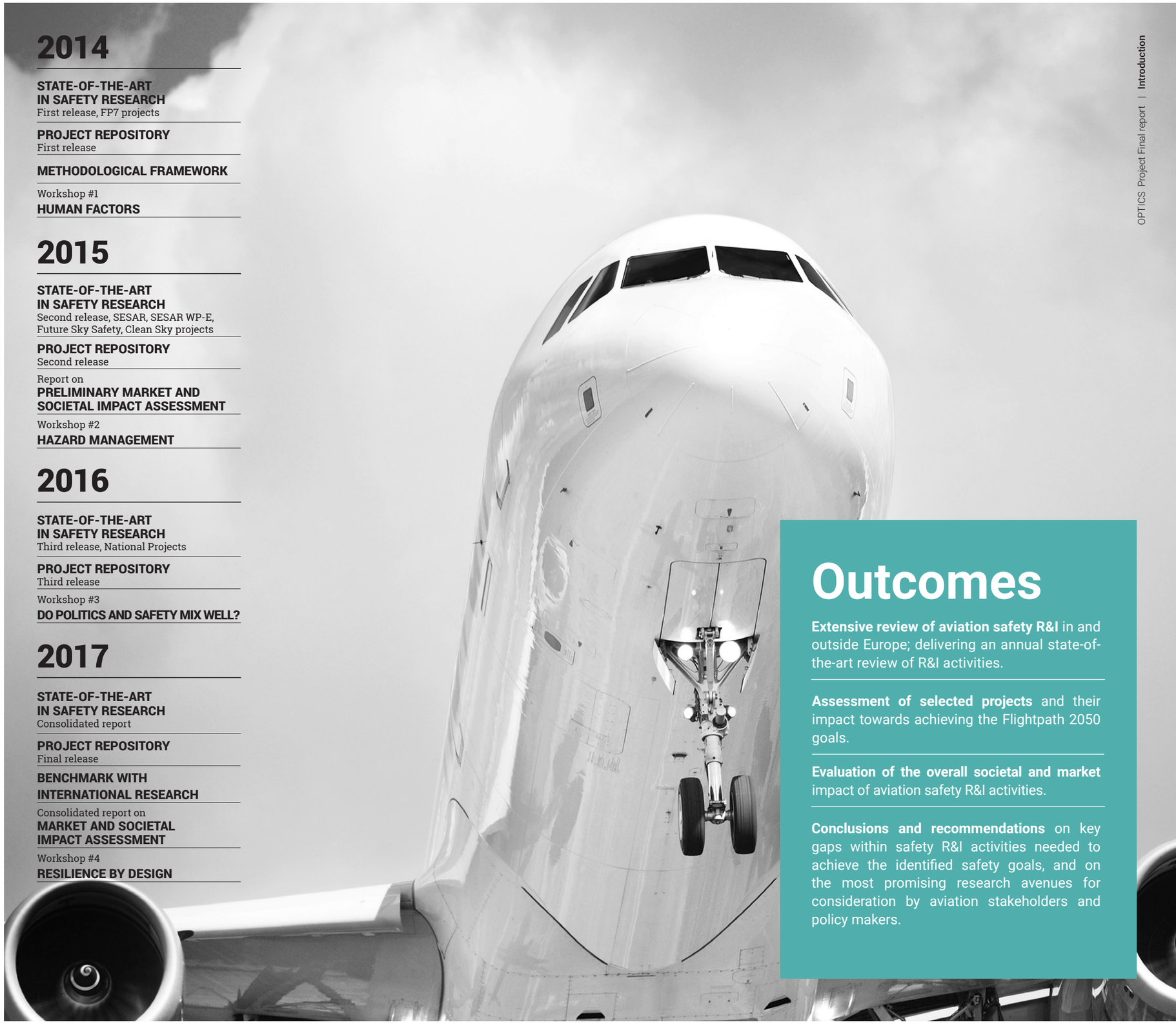
STATE-OF-THE-ART IN SAFETY RESEARCH
Consolidated report

PROJECT REPOSITORY
Final release

BENCHMARK WITH INTERNATIONAL RESEARCH

Consolidated report on
MARKET AND SOCIETAL IMPACT ASSESSMENT

Workshop #4
RESILIENCE BY DESIGN



Outcomes

Extensive review of aviation safety R&I in and outside Europe; delivering an annual state-of-the-art review of R&I activities.

Assessment of selected projects and their impact towards achieving the Flightpath 2050 goals.

Evaluation of the overall societal and market impact of aviation safety R&I activities.

Conclusions and recommendations on key gaps within safety R&I activities needed to achieve the identified safety goals, and on the most promising research avenues for consideration by aviation stakeholders and policy makers.

HOW OPTICS WORKS

The Flightpath 2050 Safety Goals will be achieved by realising four overall Clusters of R&I activities:

#1
SOCIETAL EXPECTATIONS CONCERNING AVIATION SAFETY

Reassuring the public and regulators it is safe to fly via proper safety governance.

#2
AIR VEHICLE OPERATIONS AND TRAFFIC MANAGEMENT

Operating all aspects of the air transport system safely.

#3
DESIGN, MANUFACTURING, CERTIFICATION

Delivering intrinsically safe aviation systems.

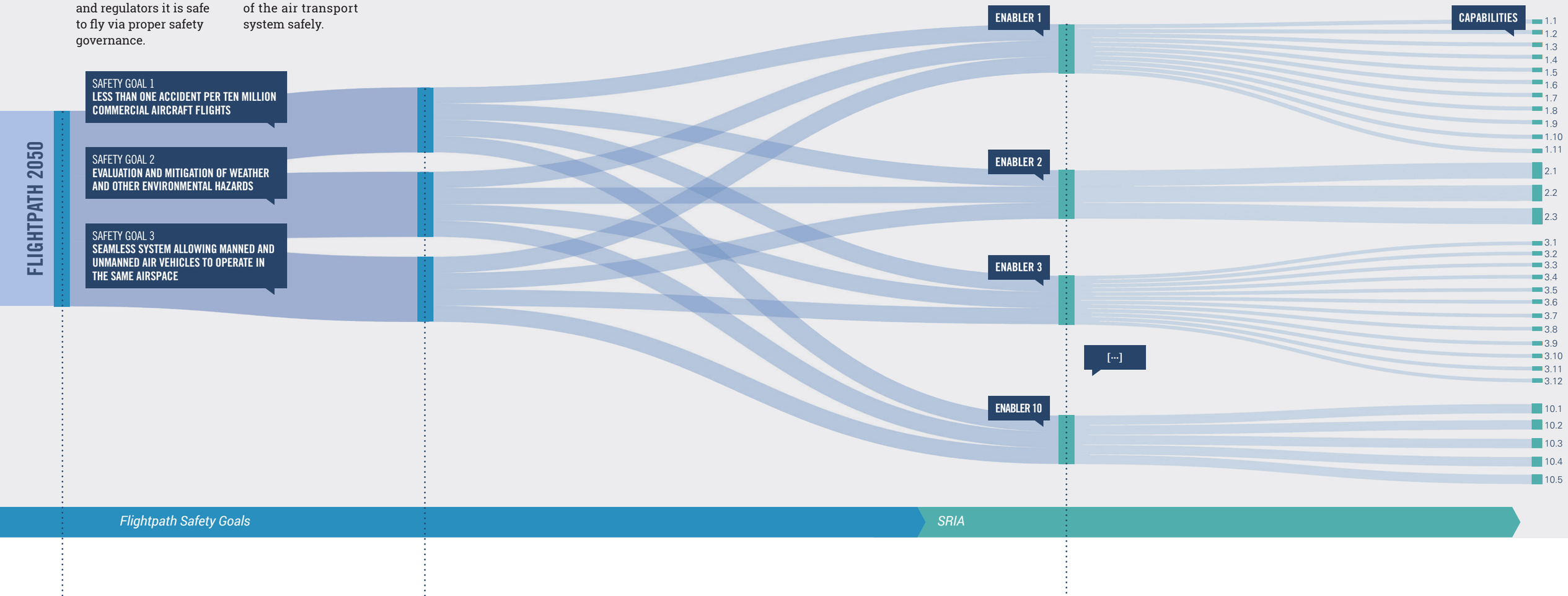
#4
HUMAN FACTORS

Ensuring that all human elements, including passengers, work together safely.

This is the vision: if we can design, build and certify safer aircraft and air traffic management systems, if we can operate them in safer ways, and if we can optimise the human element on the ground and in the air, we will achieve the goal of one accident in ten million flights, even while ensuring equity in access to airspace for all aviation applications and operations under all weather conditions. The question is whether the research we are funding and executing is helping us achieve this vision. But this vision is too high-level to evaluate if safety research is progressing in the right direction.

The four Clusters are broken down into ten more concrete **Safety Enablers.** These Enablers are the key properties of the future system that will deliver the safety goals of 2050, such as a system-wide safety management system (SMS), resilient system designs, and properly balanced human-centred automation. If we achieve these Enablers, we deliver the vision and we will be able to meet the safety goals. Because the Enablers are still high-level, covering broad areas of safety research and engineering, and safety-related disciplines, each Enabler is further broken down into a number of 'bite-sized' **Capabilities**, which are more manageable as research objectives. It is then possible to compare ongoing R&I activities to the Capabilities and see where there is research serving them, where it brings the expected benefits to society, and where there are gaps, and hence answer the questions that OPTICS poses:

Are we doing the right research? Are we doing the research right?



LOOKING BOTH WAYS

OPTICS is like a magnifying lens, seeing all the way from the Safety Goals through the Clusters to the Enablers and finally down to the level of Capabilities.

But looking through a lens is not enough, it is sometimes necessary to step back and see the broader picture. For this reason OPTICS has adopted a twofold approach to evaluate safety R&I activities in aviation and air transport, in order to assess if the right research is being conducted and if research is delivering the expected benefits to society.

The bottom-up project-based assessment focuses on how safety R&I projects and programmes cover the SRIA Capabilities – and hence the Enablers, Clusters and goals – and allows the identification of research strengths and gaps, as well as bottlenecks or constraints affecting research progress. But there is always the chance that the SRIA is missing a relevant research avenue. The bottom-up assessment is therefore complemented by top-down workshops in which aviation experts with an overview of safety R&I identify issues and opportunities. The experts can look at the SRIA, or completely ignore it, and simply tell us where they think the research priorities lie. Most of the assessment effort in OPTICS was bottom-up, since assessing projects takes time, whereas a three day top-down workshop can yield a prioritised list of top ten research issues in a particular area relatively quickly. The workshops were carried out at Cluster level based on specific research topics, incorporating a focus on Enablers within that Cluster.

These results from bottom-up and top-down processes were then reviewed and compiled to provide strategic recommendations to the EC and ACARE via an annual 'State-of-the-Art' report, including suggested corrective actions and priorities.

TOP-DOWN APPROACH

From experts to priorities and gaps

This approach is structured around workshops with aviation safety experts, used to identify major R&I priorities, issues, and opportunities for new research. Each workshop has a specific topic, selected amongst critical elements for aviation safety and mapped onto the SRIA Volume 2.

BOTTOM-UP APPROACH

From projects to SRIA

Structured assessment of how R&I projects contribute (individually and cumulatively) to elements of the SRIA Volume 2.

Metrics for the assessment:

- Contribution to SRIA
- Maturity of the results
- Ease of adoption of the innovation *(economic, legal/regulatory and organisational)*

Assessment results

- Safety R&I gaps and bottlenecks
- Recommended priorities in safety R&I
- New avenues of research
- Updated SRIA
- Strategic recommendations to EC and ACARE, including suggested corrective actions

ARE WE DOING **THE RIGHT RESEARCH?**

The best way to gain an overview of whether we are moving in a good direction towards the 2050 safety goals is at Enabler level.

The state of each Enabler is defined by **five criteria**:

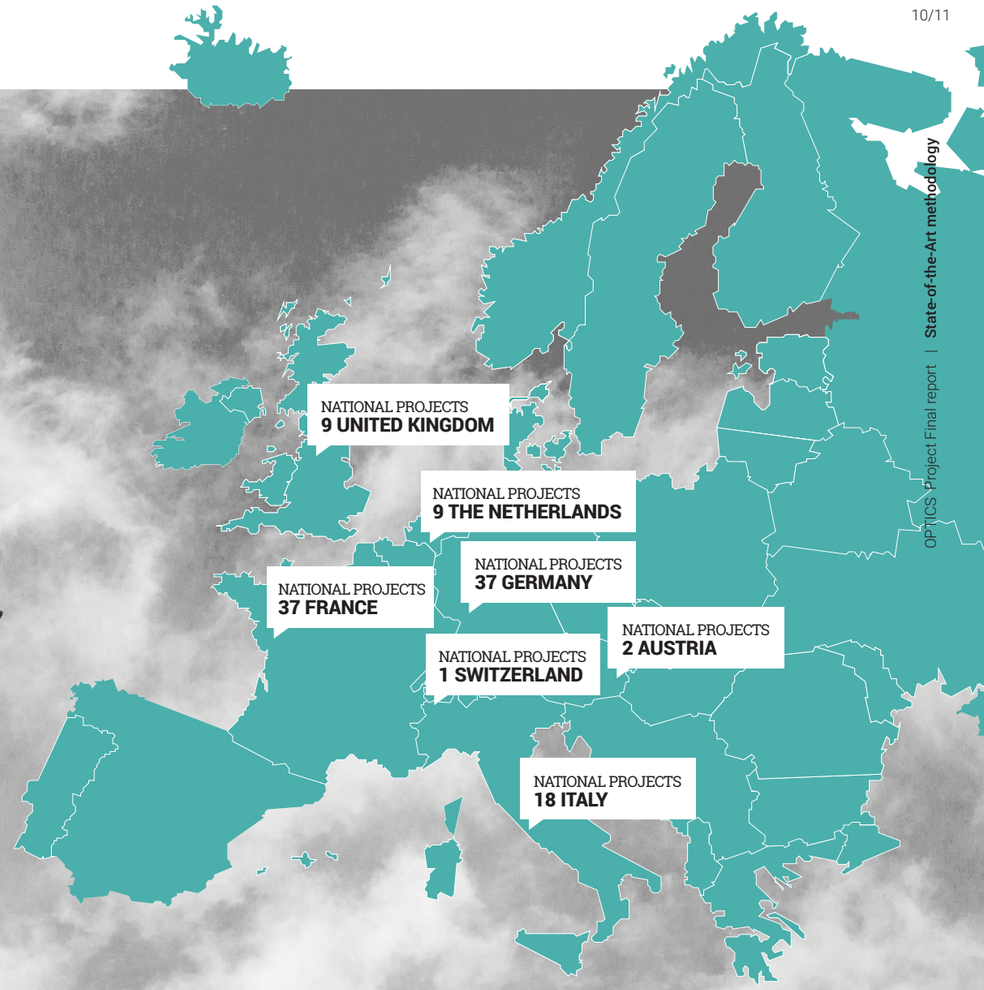
Coverage is the key criterion that indicates the degree to which research is addressing the full scope of the Enabler. OPTICS found that two Enablers are doing well, seven reach a reasonable level of coverage by research, while one Enabler is completely unaddressed. This picture is encouraging, especially considering the SRIA 2030/2050 targets, but research on Passenger Management is largely missing.

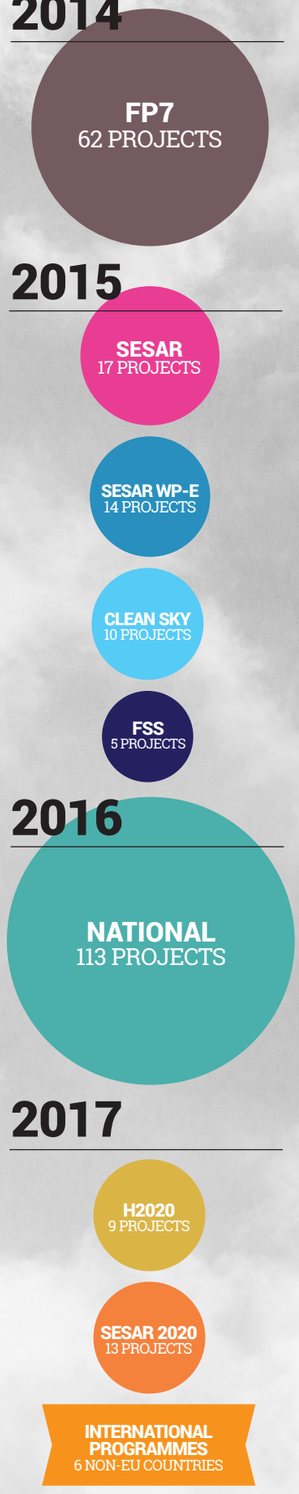
Maturity is next, and tells us how close, on average, research is to commercial uptake – whether it is still at the concept stage, or at the prototype stage, or is conducting live trials and is close to realising its operational potential. Through this indicator, OPTICS tries to understand how research projects actually make it into operational deployment.

Ease of Adoption relates firstly to the **economics** of the research – will it be too costly to ever implement? Whilst OPTICS has found some projects that fall into this category, most do not. This means that the researchers are not overly 'dreaming' when it comes to safety research.

Ease of Adoption also concerns the **legal aspects** of the research, usually relating to certification requirements should the research mature to readiness. In some cases, the good ideas found in some projects are unlikely to ever make it into practice because the discussions with the regulators did not occur early enough. This is an issue which EASA is concerned about, and the topic was discussed several times during the OPTICS workshops.

The third **Ease of Adoption** aspect relates to industry's appetite for what the research is aiming to deliver, and is often called the **organisational 'pull'.** Great research will not make it into practice if industry does not know about it or remains unconvinced or is looking at other options. This is a concern to OPTICS, and the 3rd OPTICS workshop was dedicated to understanding how to obtain better industry engagement with the research delivery process.





The state of the art was integrated with projects from different research programmes: SESAR, SESAR WPE, Clean Sky (C-SKY), Future Sky Safety (FSS), as well as FP7 projects with an implicit, rather than direct, safety goal.

The third year was dedicated to the national research projects in Europe, funded by national or regional funds. SESAR2020 and H2020 Projects were integrated in the fourth year, together with a comparison with some international programmes (USA, Canada, Brazil, Russia, Japan and China).

At the end of the project, after four years of research and assessment of more than 200 projects, OPTICS is able to provide a reasonably complete overview of the status of the European aviation safety research, and how well we are performing against the SRIA goals. OPTICS has also looked outside Europe, performed a comparison with international programmes and answered the questions: are they looking at similar issues, or not? Are they tackling any of the issues in a different way?

ENABLER 1
System-wide Safety Management Systems

Managing safety is a strength of aviation. Most sectors across aviation use a Safety Management System or equivalent, i.e. formal ways of managing safety through analysis of safety and operational data. This helps learning from the past to protect the future, as well as using safety cases to determine if new systems or system changes are safe enough, and if not, to determine what needs to be done.

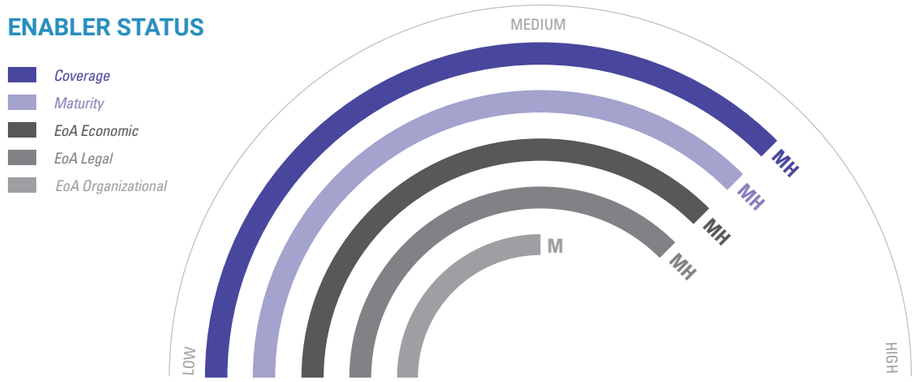
Most of the Capabilities of this Enabler are addressed with a good level of coverage. Aspects that are well addressed by European research concern the implementation of operational risk management systems and the development of tools, metrics and methodologies to assess and proactively manage current and emergent risks. Although complete coverage is not yet achieved, there seem to be no major obstacles in order to implement this innovation using existing data.

The actual adoption of a system-wide SMS that fits the total aviation system - including operations from e.g. small aircraft and RPAS - is still far from happening. Few projects consider the aviation system as a whole, and cross-boundary hazards, as well as risk issues dependent on the interactions between stakeholders, are often unaddressed. Addressing the transport system as a whole, including multi-modal safety concerns, is even further from reality.

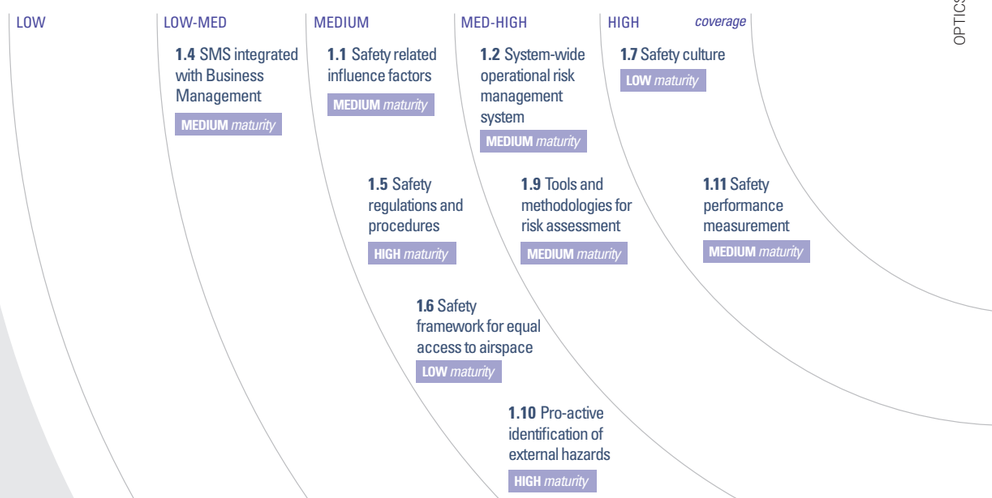
The lack of data sharing across organisations and sectors of the industry is a serious bottleneck preventing progress. Even when it comes to the research field, constraints are encountered due to confidentiality of data, legal issues, union considerations, etc. As emerged during the 2nd OPTICS Workshop, the only way to reach an overall SMS is to persuade the industry to get on with sharing operational data (not only incident data), and use new data science approaches to 'see around the corner'.

The Enabler full coverage can only be reached by tackling the trans-modal aspects, for example through a multi-modal approach to safety or implementing effective and efficient trans-modal safety regulations and procedures. The former is probably a 2035 issue, and thus is not seen as urgent, while for the latter there is work ongoing via the approach of performance-based regulation (although there are not yet specific research projects on this area). A future potential game-changer, comparable to today's remotely piloted aircraft systems, could be the arrival of personal vehicles, which would pose novel safety issues (e.g. non-professional pilots). Research exploring the safety aspects of future operational concepts involving personal vehicles should start soon.

ENABLER STATUS



ADDRESSED CAPABILITIES

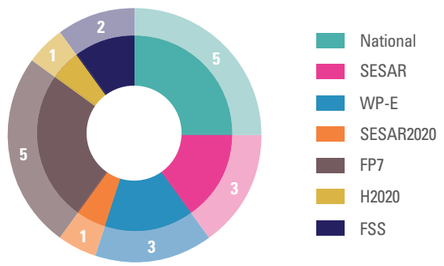


UNADDRESSED CAPABILITIES

1.3 Multi-modal transport safety governance.

1.8 Common safety risk management policy across all sectors of transport.

COVERAGE COMPOSITION



RESEARCH ROADMAP
What's next?

Enable the use of Safety Performance Indicators covering the total aviation system by addressing bottlenecks related to data ownership, data use and data protection, and regulatory acceptance.

Transfer findings on tools, metrics and methodologies for the assessment and pro-active management of current and emergent risks to key aviation players, including regulators, in order to allow the adoption of proactive risk-based performance management systems across the entire aviation system.

Start looking at the long term challenges, such as the development of integrated safety competence and safety management policies across multiple transport modes, as well as the seamless introduction of personal air vehicles.

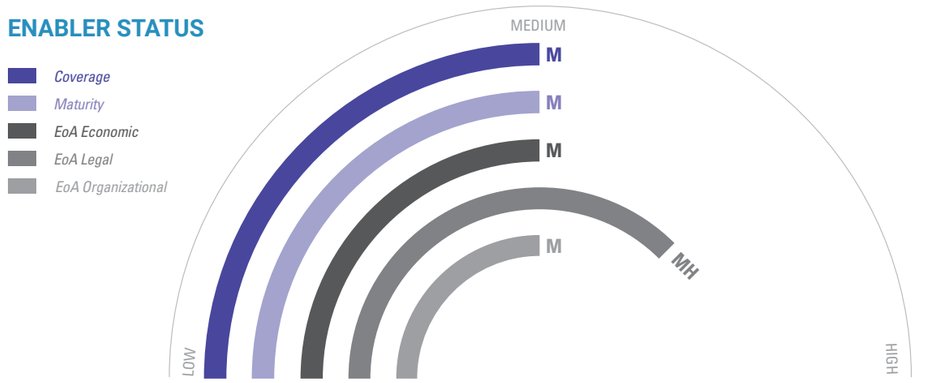
ENABLER 2
Safety radar

All three Capabilities under this Enabler are covered by research. However, the research does not yet provide a means to establish a real time safety radar function. This area could benefit from data acquisition across the aviation system, while up to now only certain segments seem to have been considered, e.g. in the ATM domain. A significant improvement in the coverage was provided by the analysis of nationally funded projects, which extended the scope of research and addressed additional stakeholders of the aviation system.

The projects address a variety of environmental and external hazards, including extreme weather events, high-altitude icing, and wake-turbulence. The focus is on understanding the characteristic of these hazards and making aircraft resilient to the threats. There is less research on the pro-active identification of these hazards. More focused research is needed to bring the technology readiness level (TRL) closer to an operational safety radar, or at least a prototype. Such a system could be developed in ATM, for example, initially in certain locations but ultimately for the entire European network.

When it comes to behavioural analysis, a large set of aviation stakeholders are addressed, even though additional research for flight crew is needed to achieve the SRIA targets. Similarly, the analysis of passenger behaviour should be extended to situations other than emergency evacuation under fire conditions.

ENABLER STATUS

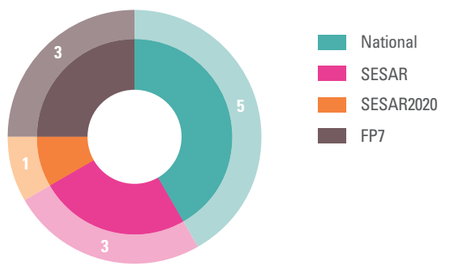


ADDRESSED CAPABILITIES

UNADDRESSED CAPABILITIES

All capabilities are covered.

COVERAGE COMPOSITION



RESEARCH ROADMAP
What's next?

There is still a lack of investigation on the dependencies between certain passengers' behaviours and safety critical situations.

Issues in data sharing are a bottleneck to achieving the real-time safety radar target.

A better access to data will benefit all three Capabilities under this Enabler.

ENABLER 3
Operational mission management systems and procedures

This is a key Enabler since it concerns safe flight operations. As the 'sharp end' of safety, it is not surprising that this area is relatively well-served by research.

A notable amount of research is being performed on on-board sensors to ensure hazard avoidance in-flight and on the ground. New safety concepts to allow airspace and runway optimisation, and to maximise the use of these resources across the airspace network, are also well addressed.

Projects from all the funding schemes can be found under this Enabler, and research on the identification, warning and avoidance of meteorological and other external hazards (e.g. traffic proximity, wild life, FOD), is quite advanced. Thus, considering the limited economic and legal constraints for the introduction of such products, a project aimed at bringing together the outcomes of the previous works should be encouraged. This would go a long way to achieving the 2050 goal of being able to operate in more difficult weather conditions. To what extent the models and technologies developed enable the provision of meteorological information on a strategic, pre-tactical and tactical basis, should also be assessed.

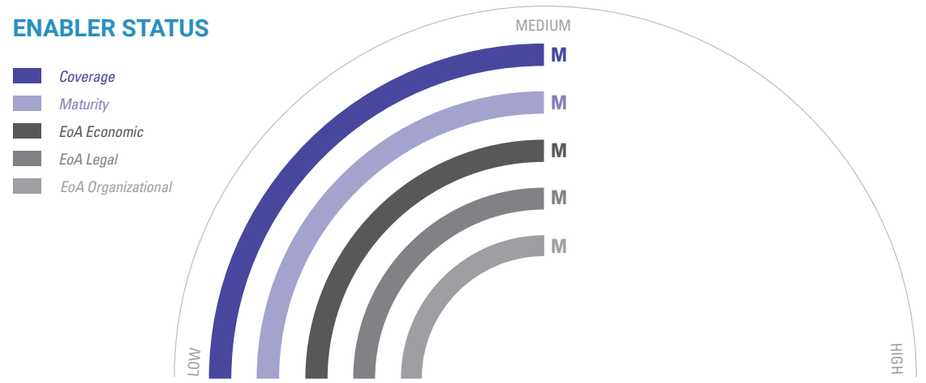
Hazard avoidance on the ground remains quite an unexplored area, as well as commercial space operations and integrated search and rescue capabilities. Research on the positive identification of all flying vehicles is also lacking at the moment.

Finally, the integration of RPAS and drones into civil airspace needs urgent research, and this research now appears to be starting in earnest. This is timely since at the present there seems to be no stable detailed concept of operations on the table, although the introduction of drones is already happening.

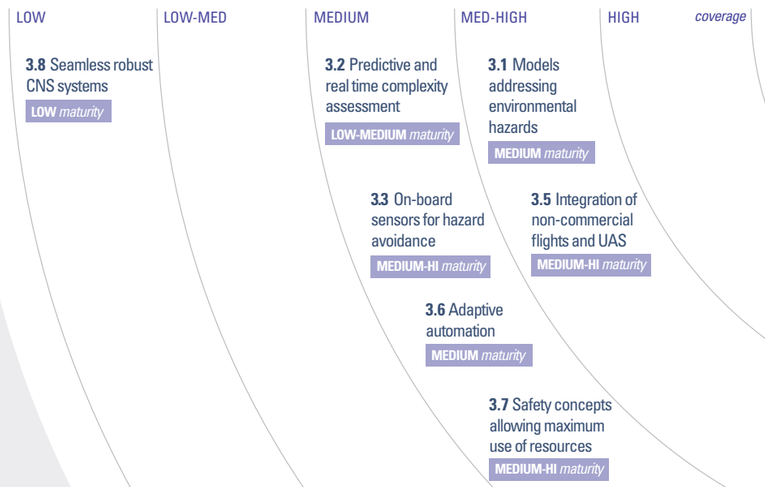
This is seen as a game-changer we were not prepared for by research, since most past research focused on large-scale RPAS of the military variety, rather than the smaller 'domestic' drones or use of drones by global players such as Amazon and Google. Research in this field should go together with the development of 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?).

ENABLER STATUS



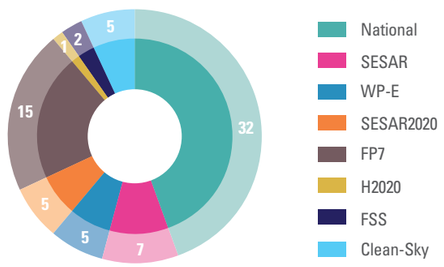
ADDRESSED CAPABILITIES



UNADDRESSED CAPABILITIES

- **3.4** Safe merging of 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** Unique and positive identification, tracking and monitoring of all flight objects.
- **3.11** Globally networked organisational structures to support safety crisis.

COVERAGE COMPOSITION



RESEARCH ROADMAP
What's next?

Hazard avoidance on the ground is still quite unexplored, and little attention is given to hazard to civil aviation, such as bird detection.

Aircraft operators are under-represented, so there is a need to balance mission planning from a pilot´s perspective and the impact on network operations (one new project, EUNADICS, will begin to address the mission planning impact on network operations for volcanic ash). The impact of Human Factors on the successful/safe introduction of UAS in the civil airspace seems to be absent.

Independent positioning of all flying vehicles should be recorded at all times.

ENABLER 4
System behaviour monitoring and health management

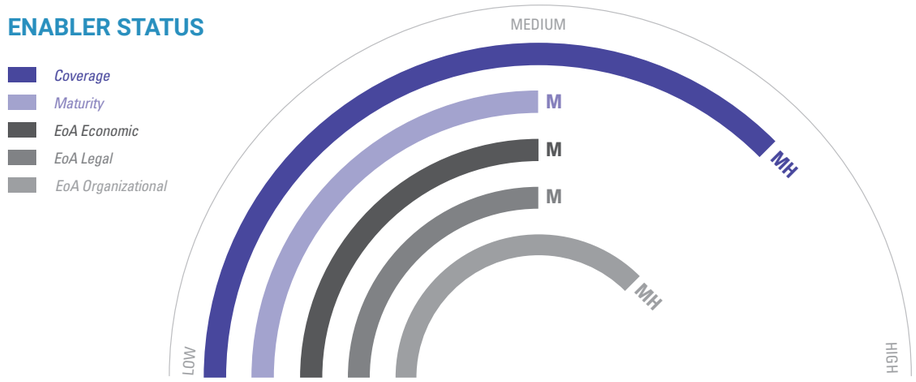
One of the 2050 safety goals concerns tracking of aircraft throughout a mission, addressed only in one national project dedicated to the investigation of technologies enabling global surveillance and vehicle monitoring. A safe and efficient concept of operation is needed as well.

The lack of European projects on this topic confirmed ACARE's Working Group 4 (Safety and Security) opinion that aircraft tracking and search and rescue is under-represented by research. Research on the tracking and monitoring of all flights is lacking as well (although there is a global tracking initiative in place at the moment, under the auspices of ICAO, following the loss of MH370).

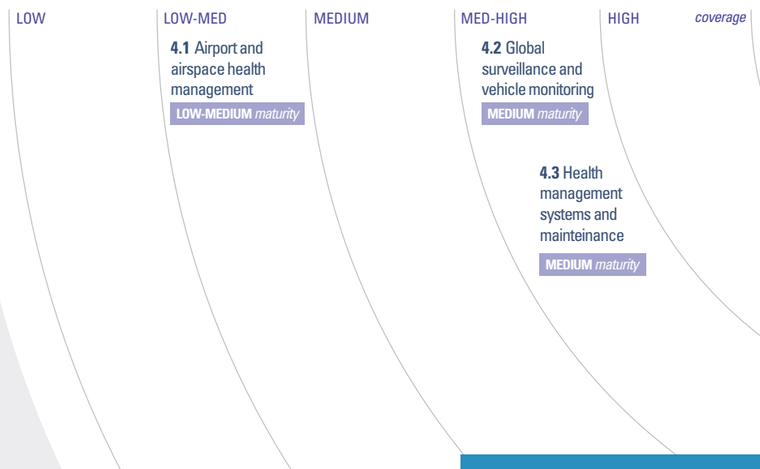
Most of the effort under this Enabler is devoted to improving health monitoring capabilities and maintenance processes. This research area is particularly well addressed by national research, which covers a wide range of systems and tools to improve health monitoring and system response to failures. Despite the amount of work, research on self-healing technology is still at a low level of maturity, and additional effort is required to see real progress in the field and accomplish the 2050 goal of enabling automated self-correcting capabilities for all critical systems.

Another gap to be filled is the need to guarantee reliability and security for health management systems, which are vulnerable to risks due to technological limits or malevolent attacks. Health management and self-healing for air vehicle operations in flight and traffic management are also a relatively empty research area. There is a need to overcome current limits in fast and efficient implementation of aircraft system health management, and for the ability to face slowly or rapidly evolving critical situations during flight.

ENABLER STATUS



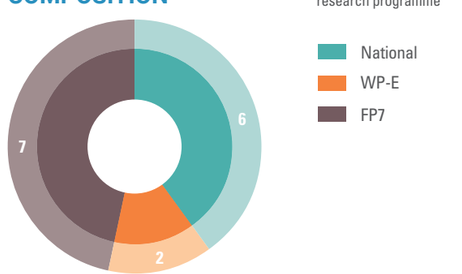
ADDRESSED CAPABILITIES



UNADDRESSED CAPABILITIES

All capabilities are covered.

COVERAGE COMPOSITION



RESEARCH ROADMAP
What's next?

Need for additional research on the tracking and locating of air vehicles in case of serious accidents.

Novel manufacturing techniques can be used to improve damage tolerance of materials.

Research on continuous health monitoring of airports and airspace is still at low TRL, and the identified approaches for system performance monitoring are barely applicable to complex systems.

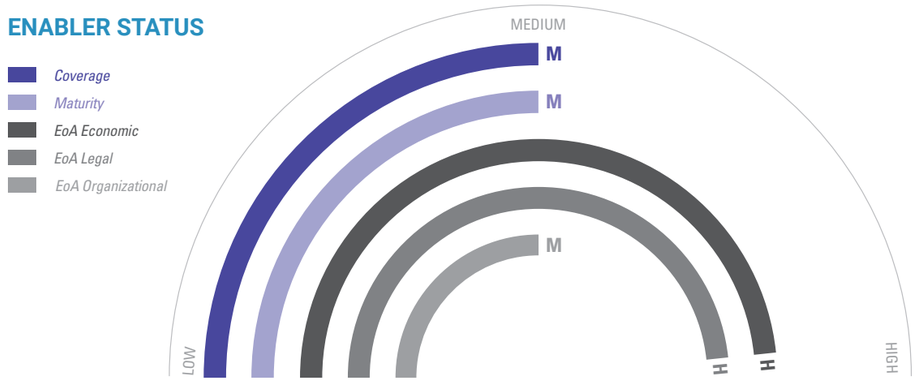
ENABLER 5
Forensic analysis

Incident and accident investigation is a cornerstone of safety in the entire aviation system. Recent initiatives have helped to ensure better reporting through just culture and safety culture initiatives, as well as regulations in the area.

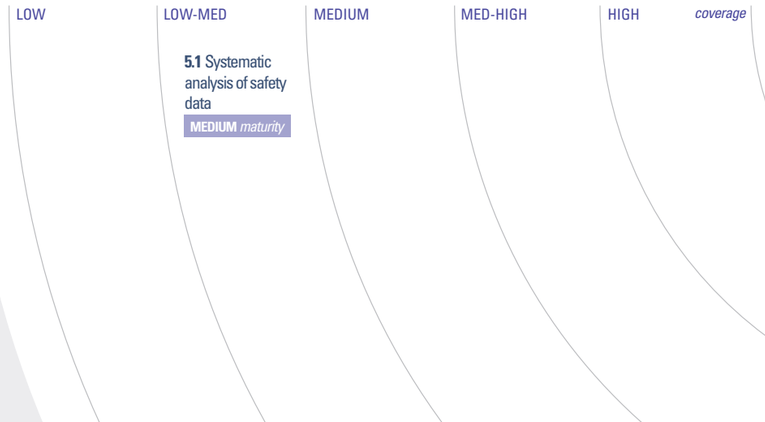
There is a challenge in obtaining reliable incident data across the air transport system (including general aviation) and making sure the retrieved information is used by all stakeholders. As pointed out during the 3rd OPTICS Workshop, the only sensible way forward is to improve cooperation between the different aviation segments, e.g. via Collaborative Analysis Groups involving all the key stakeholders and data owners.

None of the assessed research addresses new sensor technology to capture key safety data. Furthermore, the development of leading indicators of safety (e.g. based on safety culture and processes) is still missing. Lastly, as yet there is no research dedicated to the identification of emergent vulnerabilities, i.e. looking forward to predict the next event. Whether the focus should be on forensic analysis alone, or whether all forms of safety intelligence should be considered by harnessing new technologies such as big data to try to learn before the event and not only afterwards, needs further discussion and research.

ENABLER STATUS



ADDRESSED CAPABILITIES

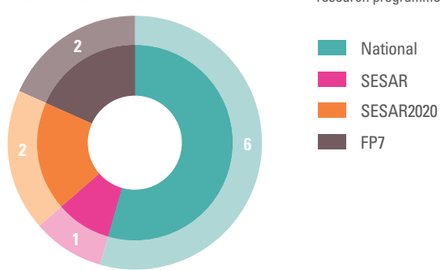


UNADDRESSED CAPABILITIES

5.3 New sensor technology to capture key safety/security data.

5.2 *is a security-related capability.*

COVERAGE COMPOSITION



RESEARCH ROADMAP
What's next?

Increase the research effort on the identification of emergent vulnerabilities.

Need for a fully integrated means of capturing safety data of all stakeholders across the ATS (including general aviation).

Start research on new sensor technology to capture key safety data.

More research is needed on Big Data (the new H2020 SafeClouds project is addressing this area).

ENABLER 6
Standardisation and certification

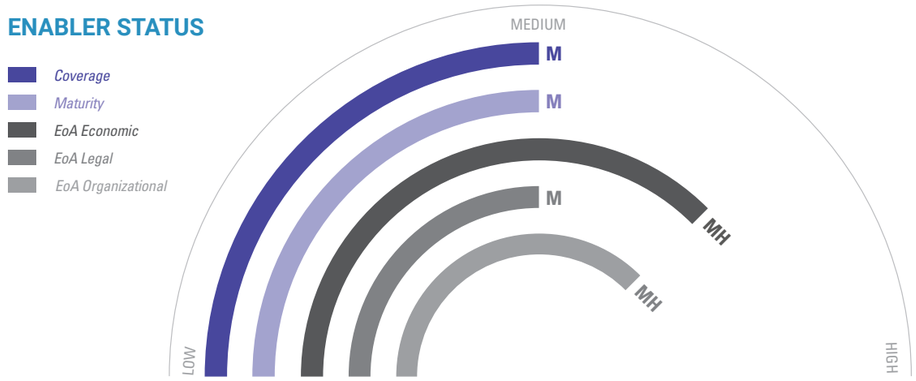
Both safety Capabilities under this Enabler are addressed, at least partly. In particular, the development of a common certification framework and the identification of new technologies and methods for the certification and approval process seem to be the most investigated areas in aviation safety R&I, with 28 projects addressing this Capability.

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

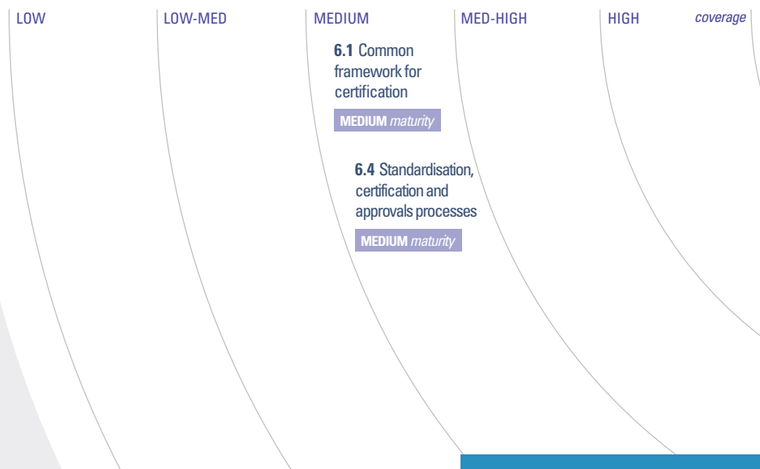
However, several segments of the total aviation system are not yet addressed (e.g. light aircraft, although helicopter ditching is now being researched). There is a lack of use of large operational data sets to feed risk models, and the impact of organisational changes is not yet properly addressed. An issue specific to research is that sometimes projects do not consider certification aspects until too late, leading to research ideas that cannot be implemented.

Enabler 6 is one of the Enablers characterised by high complementarity with other Enablers. So, research under its Capabilities is seen as a contributory factor to other Capabilities, more as an ease of adoption facilitator than a research area by itself.

ENABLER STATUS



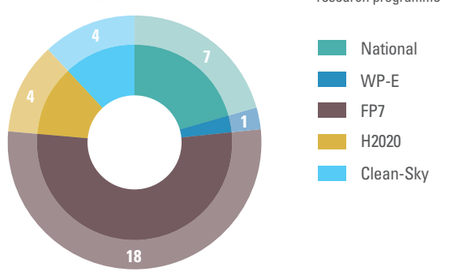
ADDRESSED CAPABILITIES



UNADDRESSED CAPABILITIES

6.2 & **6.3** *are security-related capabilities.*

COVERAGE COMPOSITION



RESEARCH ROADMAP
What's next?

Several segments of the total aviation system are still not considered (e.g. general aviation).

Lack of work on system inter-dependencies and Human Factors.

Use of large operational data sets to feed risk models is still missing, and the impact of organisational changes is not yet properly addressed.

For some areas (e.g. resilience of rotorcraft) certification is seen as too fragmented. A more holistic certification approach is needed.

ENABLER 7
Resilience by design

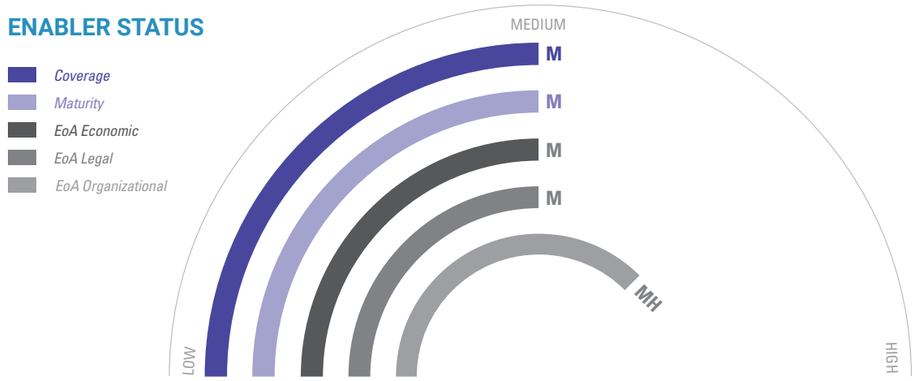
Resilience is neither a well-understood nor well-agreed concept, and yet it covers a broad range of areas and domains. This led to the need for the OPTICS team to expand the Resilience Capabilities into sub-capabilities, in order to be able to match projects to this area. To complete the view on this topic, a dedicated OPTICS Workshop on New Resilient Designs for Aviation was organised. In the SRIA update, ACARE's Working Group 4 has already determined that this Enabler needs better explanation and rationalisation.

Despite this lack of clarity over the concept, there has been a significant amount of research in this area. Ongoing research focuses on design to mitigate environmental hazards, new technologies and improved system designs, as well as new materials and manufacturing techniques to improve survivability. 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. There is an urgent need to consider the new emerging threats on board, such as personal devices (mobile phones and/or tablets), and to evaluate their impact on the aircraft.

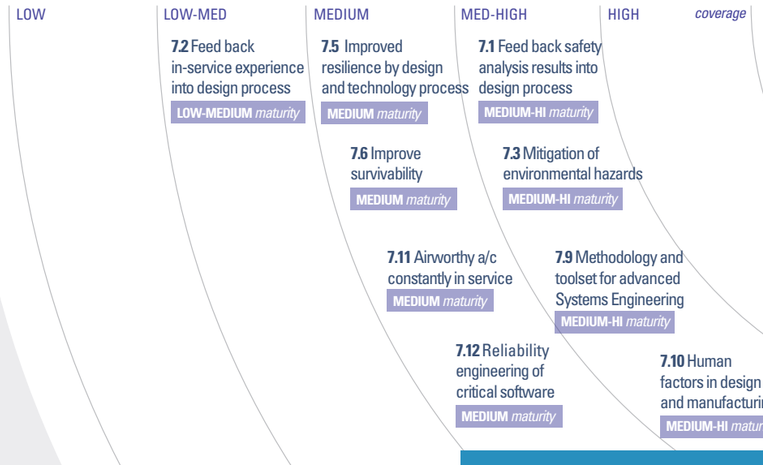
A research gap linked to human Resilience concerns the availability of a suitably qualified and adaptable workforce as the aviation industry continues to evolve. This area of Resilience has strong links with Human Factors Enablers and in particular both Human-Centred Automation and New Crew and Team Concepts. SESAR's approach for ensuring that the results of safety analyses are fed back into the design process could be extended to other parts of the air transport system.

Research on crashworthiness is also lacking, though this is clearly a Resilience area. This may require some low-TRL research to come up with new ideas. Use of new materials and structures with adaptability properties can support the systems to reduce consequences of failure and increase passenger survivability chances. Improvement of standards in the design for survivability is strongly recommended, as well as learning from other domains where survivability is a key issue.

ENABLER STATUS



ADDRESSED CAPABILITIES



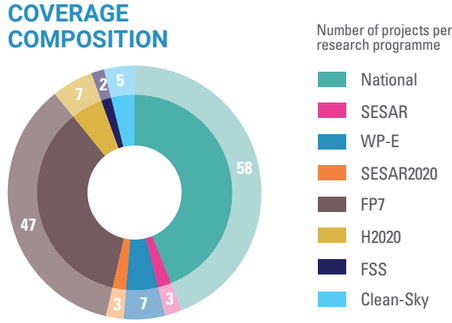
UNADDRESSED CAPABILITIES

7.7 Multi-modal forums for ATS design.

7.8 Availability of a suitably qualified and adaptable workforce and a framework which ensures the continued support to legacy and emerging technologies.

7.4 *is a security-related capability.*

COVERAGE COMPOSITION



RESEARCH ROADMAP
What's next?

Adopt a multi-disciplinary approach to research on crashworthiness and survivability, involving different disciplines and expertise. Where possible, look at solutions from other domains (e.g. nuclear and automotive).

Extend the work on environmental hazards to risks other than ice and wake vortex. Future direction can be the development of integrated predictive sensors for environmental threats.

More has to be done to form a suitably qualified and adaptable workforce as the aviation industry continues to evolve.

ENABLER 8
Human-centred automation

Human Centred Automation appears to be an area where there is 'low hanging fruit', i.e. the research is ready to be brought closer to industrialisation. However, there is a significant blockage, in that Human Factors does not typically enjoy a good position in organisational hierarchies, and there is a tendency to see Human Factors as the final step in design and development, by which time it is too late to 'get it right'.

Human Factors is seen as complementary research for technology-driven projects. From the comparison with International Research (US in particular), there is a need for HF-driven projects, with a clear focus since the very beginning on operational benefits from the human point of view.

Overall, the community is sometimes perceived as being fragmented, heading in different directions, with lack of consolidation of past results. There isn't a good view on what's achieved, and it's possible to find projects doing similar research at different levels of maturity.

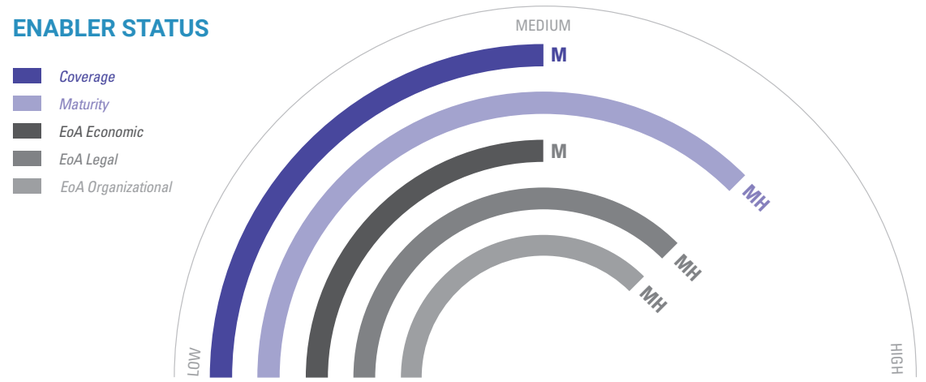
This situation could be improved by launching a consolidation project to 'harvest' the results of automation research, including projects from other transport modes. Expected outcomes of this project should include the application of results to other industry segments, like maintenance, General Aviation and RPAS pilots, and other aviation workers. Clarifying the current status of automation research will open space for more exploratory, low maturity projects, with a focus on disruptive automation.

Legal aspects of automation are still a bottleneck, as well as the impact of automation of human roles, despite the amount of work on the optimal allocation of functions between human and machine, both in normal and degraded operations. Organisational needs and their resistance could be tackled by benchmarking organisations and industry segments according to their Human Factors "know-how", then defining strategies tailored for each segment.

As pointed out at the 1st OPTICS Workshop, although automation has been around for a long time in aviation, there are still many unknowns about how to get it right, and in defining what automation entails. Caution was expressed from a regulatory perspective, when addressing adaptive automation and personalisation adapted to an individual's performance.

Preventive maintenance and system upgrades of automated systems are still unaddressed. Research on technologies to support turnaround processes could benefit from the integration of existing solutions with airport and aircraft.

ENABLER STATUS



ADDRESSED CAPABILITIES

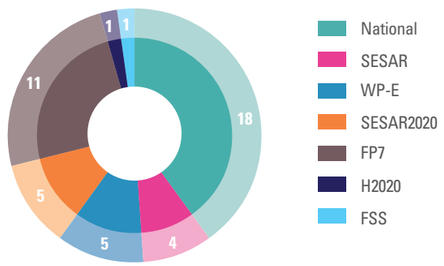
LOW	LOW-MED	MEDIUM	MED-HIGH	HIGH
8.4 Technology to support turnaround process **HIGH** *maturity*		**8.2** Human collaboration across seamless concepts **HIGH** *maturity*	**8.1** Automation support **MEDIUM** *maturity*	

coverage

UNADDRESSED CAPABILITIES

8.3 Preventive maintenance and system upgrades of automated systems.

COVERAGE COMPOSITION



RESEARCH ROADMAP
What's next?

A consolidated state-of-the-art overview on Human Centred Automation would be beneficial.

The scope of Human Factors research needs to be extended to all the industry segments, e.g. maintenance, General Aviation and RPAS pilots.

Research on disruptive concepts – not constrained by current concepts of operation - could be carried out in connection with Enablers Operational Mission Management and New Crew and Team Concepts.

ENABLER 9
New crew and team concepts

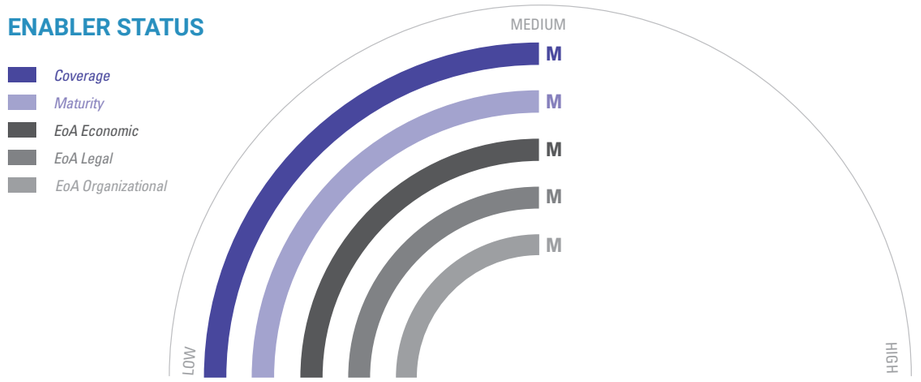
Crew Resource Management has been a mainstay of aviation for decades, and a Human Factors success story. However, the future will almost certainly hold new challenges and new crew concepts. Questions such as how air and ground staff will interact with each other and with RPAS, for example, or future pilotless aircraft or even personal vehicles, remain relatively unaddressed. There needs to be research to evaluate the potential impact of such future concepts on human performance and safety of the entire air transport system.

Most of the projects in this area focus on solutions or concepts to support pilots or air traffic controllers, while other aviation operators such as remote pilots, engineers, ground handlers or maintenance operators, are not covered by research. The typical focus is on individuals, at best on a 2-persons' team, which is a limitation in research scope. In the future, more and more jobs will become inter-connected, so team concepts need to extend to the cooperation across professional roles beyond controllers and pilots. Multiple and more diverse organisational cultures are likely to interact as well. A project on the aviation workforce of the future (not only pilots and controllers) has been recommended for Enablers Resilience by Design and Operational Mission Management, and it would be a key advancement also for this Enabler.

Although some projects proposed interesting and mature solutions, their adoption seems still far from becoming a reality. Acceptance issues can be anticipated, e.g., operators' opposition against being monitored, and opposition against different team concepts (e.g. single pilot operations). Similarly to high automation level acceptance, there is a need to tackle legal and organisational issues proactively, and at the system level (as a strategic issue, not project by project).

Additionally, none of the assessed research addresses the psycho-social needs of crew/team/organisation following a major accident, and passenger/personnel culture.

ENABLER STATUS



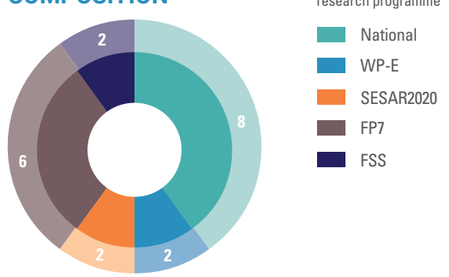
ADDRESSED CAPABILITIES

UNADDRESSED CAPABILITIES

9.4 Critical incident stress management for crew/team/organisation following major disruption or disaster.

9.5 Analysis and understanding of the dimensions of passenger and personnel culture to foster system effectiveness in relation to safety and security goals.

COVERAGE COMPOSITION



RESEARCH ROADMAP
What's next?

Team concepts need to outreach further than controllers and pilots, integrating maintenance operators, RPAS pilots and other aviation workers.

Collaboration between teams from different organisations and cultures needs to be explored. Application of project results to job design or training should be part of the research to improve the ease of adoption.

Consolidation of research on neurophysiological monitoring of operators, tackling privacy concerns and resistance from operators proactively, and at the system level, needs to occur as a strategic issue.

Analysis of the impact of increasing automation on the human role across aviation is needed, with definition of skills and competencies for the future aviation workforce.

ENABLER 10
Passenger management

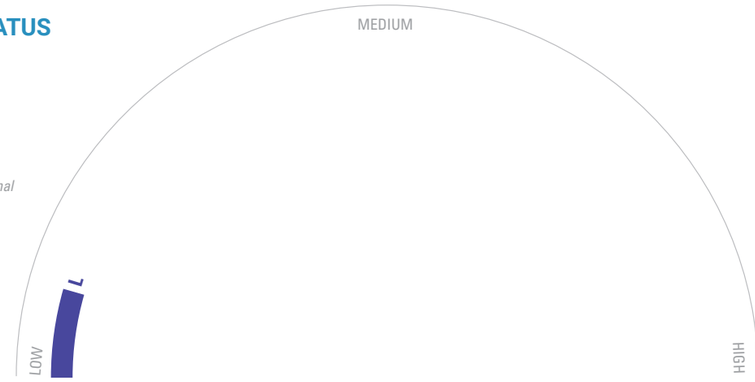
Clearly from the diagram, this appears at present to be a 'research desert'. All three safety relevant Capabilities – management of human behaviours during emergencies, post-traumatic stress and psycho-social needs after distress, and passenger culture – are practically unaddressed by European and national projects.

Research still needs to occur, at least to reach the short term goals of developing an operational framework for emergency management, training multidisciplinary teams for crisis management and post crisis trauma, and investigating the dimensions of cultural diversity in order to understand their impact and relation with safety procedures.

However, it may be noted that in the revised SRIA (July 2017), Passenger Management is no longer an Enabler, and relevant aspects have been subsumed with other Enablers (especially with respect to Security R&I needs).

ENABLER STATUS

- *Coverage*
- *Maturity*
- *EoA Economic*
- *EoA Legal*
- *EoA Organizational*



ADDRESSED CAPABILITIES

LOW | LOW-MED | MEDIUM | MED-HIGH | HIGH | *coverage*

UNADDRESSED CAPABILITIES

10.2 Management of human behaviours during emergencies.

10.4 Services addressing post-traumatic stress and psycho-social needs of passengers and public following major disruption or disaster.

10.5 Understanding of different dimensions of passenger culture to enhance system effectiveness in relation to security goals.

10.1 & **10.3** *are security-related capabilities.*

RESEARCH ROADMAP
What's next?

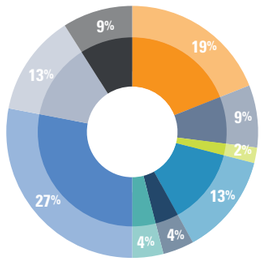
Training multidisciplinary teams for crisis management and post crisis trauma would be a benefit for aviation.

Investigating the dimensions of cultural diversity in order to understand their impact and relation with safety procedures is also necessary.

WHAT DO THE **EXPERTS SAY?**

The top research priorities emerging from the expert workshops

1ST WORKSHOP
STAKEHOLDERS SEGMENTATION



Human Factors in Aviation Safety

Parallel to the project assessments, OPTICS held in 2014 its 1st Expert Workshop *Human Factors in Aviation Safety*, attended by 77 experts from 17 countries. The Workshop determined the major Human Factors R&I priorities and gaps in the SRIA. The **top 3 priorities** in the context of Aviation Safety emerging from the experts' debate were:

Human Centred Automation. Automation is key for the success of Flightpath 2050, and if the Human Factors associated with how people will use this automation is not properly done, the intended performance benefits won't be realised.

Human Performance Envelope. A relatively new concept in Human Factors, it is nevertheless a place-holder for the detailed research on a range of Human Factors issues that are poignant in Aviation, including fatigue, workload and situation awareness. Better understanding of such factors' interactions, and better methods in these areas are still needed to achieve Flightpath 2050.

Human Factors in Design and Manufacturing. Integration is needed and progress must be made in the identification of a new systems engineering approach, considered as a crucial factor in improving safety across the industry.

The experts highlighted complacency as one key danger for Aviation, since safety often appears to be so good, people think there is no need for research. Human Factors R&I must be seen instead as adding safety and productivity to the system, or else it risks staying on the sidelines, rather than being acknowledged as an essential player in assuring future system performance.

Hazard Management and Operational Resilience

The 2nd Workshop was dedicated to *Hazard Management and Operational Resilience*, attended by 50 experts in aviation safety. The Workshop succeeded in finding a top ten priority list for research directions for four focal areas in aviation and aviation research today: autonomous systems, use of data, self-healing and weather. The resulting **top 10 priorities** for research directions is given below. The first four represent the top priority in each of the four focal areas.

Develop a new CONOPS that accommodates the rapidity and scale of developments occurring with RPAS/UAS and their impending integration into airspace.

Develop real-time data analysis capability of human and system behaviour, and their interactions, in order to detect precursors to adverse events and initiate protective measures before safety margins are affected.

Demonstrate the safety benefits to aviation and air transportation through the application of resilience in complex socio-technical systems.

Increase the resilience of operation in adverse weather conditions by making possible shared understanding of weather hazards and cooperative building of weather awareness.

Derive a new and more agile Verification and Validation approach for RPAS/UAS, one that includes in-service validation.

Develop advanced models of shared situation awareness and collaborative and dynamic decision-making for fully integrated RPAS/UAS systems.

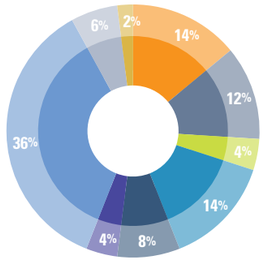
Determine the success factors in automation and its development cycle that lead to human trust in automation.

A new, fast-track system for feeding back operational data into design needs to be developed. 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'.

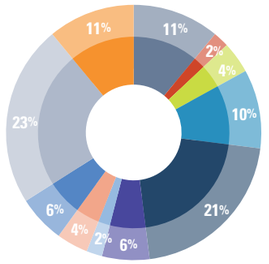
Develop affordable technologies to go beyond current flight limitations in adverse weather conditions.

Use the weather knowledge in the decision chain to optimise the interest of each aviation actor while ensuring safety and global fairness.

2ND WORKSHOP
STAKEHOLDERS SEGMENTATION



3RD WORKSHOP
STAKEHOLDERS SEGMENTATION



How to reconcile Politics and Safety?

In 2016, the 3rd Workshop was co-organised by OPTICS and EASA to talk about *how to reconcile Politics and Safety*. With 60 participants from all over Europe, representing a diverse range of aviation sectors and research communities, the event saw discussions around four key topics: how to monitor safety; how to 'see around the corner' to future safety events and game-changers; how to improve research uptake by industry; and how to ensure effective use of European aviation safety research facilities.
Overall, everyone taking part in the 3rd Workshop saw that the only sensible way forward was for more collaboration across the industry, and the need to forge effective and efficient research-industry partnerships.
Two key priorities were identified:

Improve Safety and Business Performance

Targets on leading indicators might be more beneficial for safety by inducing positive behaviour; it is easier to share information on leading indicators than incident reports.

'Hard data' (accidents and incidents) needs to be tempered by expertise, knowledge and qualitative data (e.g. safety culture surveys) to determine our true risk levels and priorities.

Talk to people doing line operations – they are the closest to what is coming. But Just Culture is imperative.

Deeper analysis of combinations of known events can help identify the weak but important signals. Consider those events we currently deem 'non-credible' and then assess them.

Think outside the box and consider social changes – e.g. use of social media and smart devices in the workplace.

Implement the good safety research and make efficient use of the European Safety Research resources.

Look for better ways to involve the airlines in research, and make industry involvement 'admin-lite'.

More mobility of researchers around the European research network, as well as between industry and academia, would lead to better collaborative relationships and a better-understood combined European research capability.

Better information about existing infrastructures is urgently needed, following the US example.

The biggest facility lacking in research is the airline. Easier access to airlines by researchers would be a significant step forward. If researchers cannot engage with the operational parties, research will remain 'academic' and lower-TRL.

New Resilient Designs for Aviation

The final OPTICS Workshop *New Resilient Designs for Aviation* was dedicated to resilience and survivability, with a focus on novel aircraft concepts, improved materials and new aircraft sensors, crashworthiness and post-crash survivability. In addition, all the other tools, products and services that ensure resilience of systems and operations, and the ability to face current and emerging environmental (safety and even security) hazards were considered. 45 attendees from all over Europe met in Capua, with Italian researchers and industry representatives dominating the participation.
The **top 10 priorities** identified are:

Barriers to hazards need to be developed **in the design stage** of the product. The adaptation and application of the "three layers of defence to hazard" approach from the nuclear power industry could lead to a step change in aviation resilience.

Need for **advanced control systems in degraded pilot/engine/aircraft situations**, together with an HMI that does not overload the pilot with information ("return home capability").

Need for **a global index summarising the "survivability" property** of aircraft systems.

Design methods and tools for operations taking into account new threats, new concepts of operations, and new actors.

Improve damage tolerance of materials using novel manufacturing techniques and new multi-functional protective materials.

Invest in the development of **predictive sensing of environmental threats** (ice and ash).

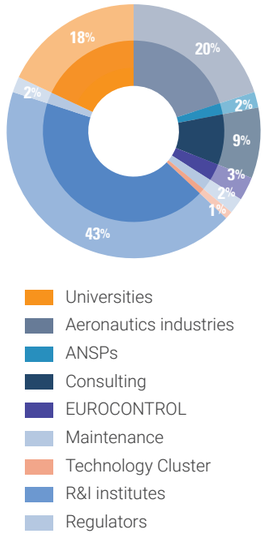
Need for a **performance-based framework** for the **assessment of resilience** (as being developed for safety).

More investigation is needed in modelling aircraft material dynamic behaviour in case of accidents.

Regulators should work on **specific standards for survivability.**

Technology transfer from nuclear and automotive domains to increase survivability rate in the aeronautics domain.

FINAL WORKSHOP
STAKEHOLDERS SEGMENTATION



LOOKING OUTSIDE EUROPE
International Benchmarking

The OPTICS assessment of 243 aviation safety research projects in Europe forms a basis for international comparison. Information on aviation safety research was collected from six countries outside Europe: the United States, Canada, Brazil, Russia, Japan and China.

The international information was analysed in order to answer questions such as: is aviation safety research from outside Europe looking at similar issues, or not? Are they tackling any of the issues in a different way, with better ideas? Mainly due to a lack of detailed information at project level, the international research is not rigorously mapped to the SRIA in detail.

A high-level look at the research topics covered internationally shows that three Enablers are extensively covered: Operational mission management (Enabler 3), Resilience by design (Enabler 7), and Human-centred automation (Enabler 8). Five other enablers are covered to a lesser extent: System-wide Safety Management System (Enabler 1), Safety radar (Enabler 2), Forensic analysis (Enabler 5), Standardisation and certification (Enabler 6), and New crew and team concepts (Enabler 9). No evidence was found - in the sources available to OPTICS - of coverage of System behaviour monitoring (Enabler 4) and Passenger management (Enabler 10). This spread of coverage roughly matches the coverage we found in European research.

Most information was collected for aviation safety research in the **United States**, mainly via the Research, Engineering, & Development Advisory Committee - REDAC. Additionally, FAA research on Human Factors was considered. Helicopter operations and General Aviation play an important role in US research, presumably due to their importance and exposure. In general, it appears that the volume of research into new propulsion concepts is significantly higher than in Europe. Both in the US and in Europe emphasis is put on meteorological issues and flight safety. While in Europe most Human Factors activities may be considered as add-on's to technology-driven projects, the Human Factors research in the US is primarily Human Factors-driven, covering a broader scope than in Europe.

In **Canada** most effort is put in research on operational mission management. In **Brazil** the SIRIUS programme aims to further develop the national ATM system. In **Russia** around one-tenth of the research budget is spent on structural health monitoring, aviation safety regulation and certification. More than half of the budget is spent on new aircraft concepts.
China covers a wide range of topics, with a focus on structural health monitoring, composites, fire modelling and simulation, and icing and lightning protection.
In **Japan** research is performed on optimized aircraft separation, improvement of surveillance performance and development of a resilient ATM system. The EU/Japan cooperation network SUNJET resulted in several projects that are assessed by OPTICS.

Assessed research outside Europe

INTERNATIONAL ASSESSMENT
Outside Europe

Aviation safety research outside Europe extensively covers Operational mission management, Resilience by design and Human-centred automation.

In Europe Human Factors activities are accompanying actions to technology-driven projects.
In the US Human Factors research is primarily Human Factors-driven.

ARE WE DOING **THE RESEARCH RIGHT?**

Besides the right direction of research, OPTICS was interested to understand whether safety research contributes to the socio-economic well-being of EU citizens.

Do the direct and indirect benefits justify the investments made in aviation safety research, and do they allow the European market to maintain global leadership in aviation? Following the Enabler-Capability information breakdown, OPTICS developed a framework for Socio-Economic Impact Assessment (SEIA) which, using projects and initiatives as "units of analysis", assessed the broad societal impact of research to provide answers to five questions:

#1 Does European safety research contribute to the well-being of society?

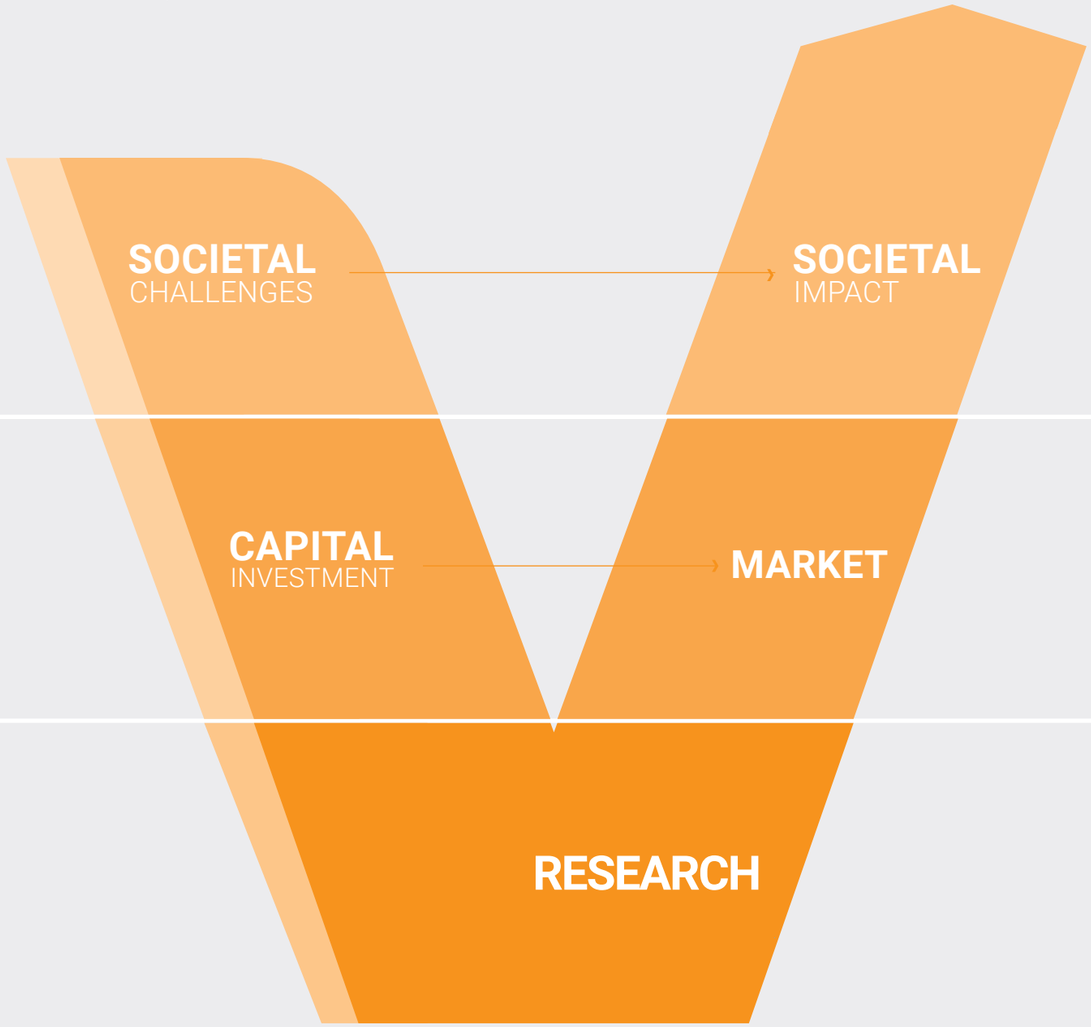
#2 Is European safety research giving Europe a competitive edge in the global market?

#3 Is European aviation safety research actually addressing European top safety risks?

#4 Are we well-equipped to do world-leading safety research?

#5 What is the societal 'return on investment' of aviation safety research?

OPTICS Socio-Economic Impact Assessment Framework



Areas of analysis and Indicators

Societal benefits

Exploring benefits to society in areas comprising passenger comfort, environmental sustainability and safety improvements.

Public Awareness | Expert Perception | Political Awareness | Environmental Impact | Seamlessness | Intermodality | Research coverage of European Top Safety Risks Areas

Economic impact

Exploring benefits to market comprising innovations, ground-breaking new solutions, public policy and employment.

Employment | Business Opportunities | Cutting Edge Solutions | Innovation Spillover | EU Safety Standards | EU Safety Regulations | Global Penetration

Research capacity

Exploring the resources and capabilities required to mantain top-level education and excellence in research facilities and skills.

Research Investment | Dispersion of Investment | Reactivity vs Proactivity | Managed Lifecycle | Knowledge Preservation and Generation | Facilities Availability and Accessibility | Facilities Preservation and Generation | Research Excellence | International Recognition

The SEIA analysis was applied to a representative sub-set of ongoing research projects.
The selected sample covered the large range of SRIA Enablers and gathered projects with different levels of maturity and sources of funding. The SEIA used data collected via internet and through surveys and interviews to project coordinators and generated valuable results. This report presents a selection of those results, in the following areas:

Societal Benefits, through the investigation of research coverage of European Top Risk Areas;

Economic Impact, through the analysis of European Safety Standards and Regulations;

Research Capacity, via the analysis of investments.

The application gives an initial understanding about the societal and economic benefits deriving from research, as well as recommendations for future full-scale applications of similar approach.

RESEARCH COVERAGE OF EUROPEAN TOP SAFETY RISK AREAS

Is aviation safety research actually addressing top safety risks?

Statistics over the past decade show that European operators maintain a rate of fatal accidents that is amongst the lowest in the world, remaining below 2 accidents per ten million departures since 2006 ***(Commercial Air Transport - EASA Annual Safety Review 2017).***

It is reasonable to think that aviation safety research has played a role in the continuous improvement of safe operations within the air transport industry. But this contribution is hard to quantify, with little explicit evidence showing direct causal relationships.

OPTICS assessed all the European Projects of the OPTICS Repository in order to find out whether and to what extent research activities contribute to the eight top risk areas for commercial air transport identified by EASA.

The expert assessment resulted in the identification of 79 relevant projects, each of which mapped onto one or more risk areas. No explicit link with the top risk areas was identified for the remaining 51 projects. These projects include research on systemic topics that can impact multiple risk areas (see OPTICS Deliverable 2.4 for further details).

The research mapping shows that the **research coverage of top risks is uneven.** The two major risk areas – *Aircraft system failure* and *Airborne conflict* – and the most fatal one – *Aircraft Upset in flight* – are observed to be addressed most by European research activities. However, most of these projects only marginally contribute to the risk areas (low and medium coverage) and this is strongly linked to the already identified maturity bottleneck. Furthermore, little research is found on *Abnormal runway contact and excursion, Fire, Ground collision and Ground handling.*

The link between the SRIA and European Top Risks was also explored. The link between research strategy and safety issues is not sufficiently clear. Building this link could be a significant step towards a more strategically organised research landscape.

In conclusion, what is needed is a better balance in research investment between tackling the 'now' issues, as in these EASA top risks, and delivering the longer term vision supplied via the Flightpath 2050 goals and the ACARE SRIA.

Sub-set of analysis
All European Safety Research Projects
62 FP7 Projects
10 Clean Sky Projects
14 SESAR WP-E Projects
17 SESAR Projects
13 SESAR2020 Projects
9 H2020 Projects
5 Future Sky Safety Projects

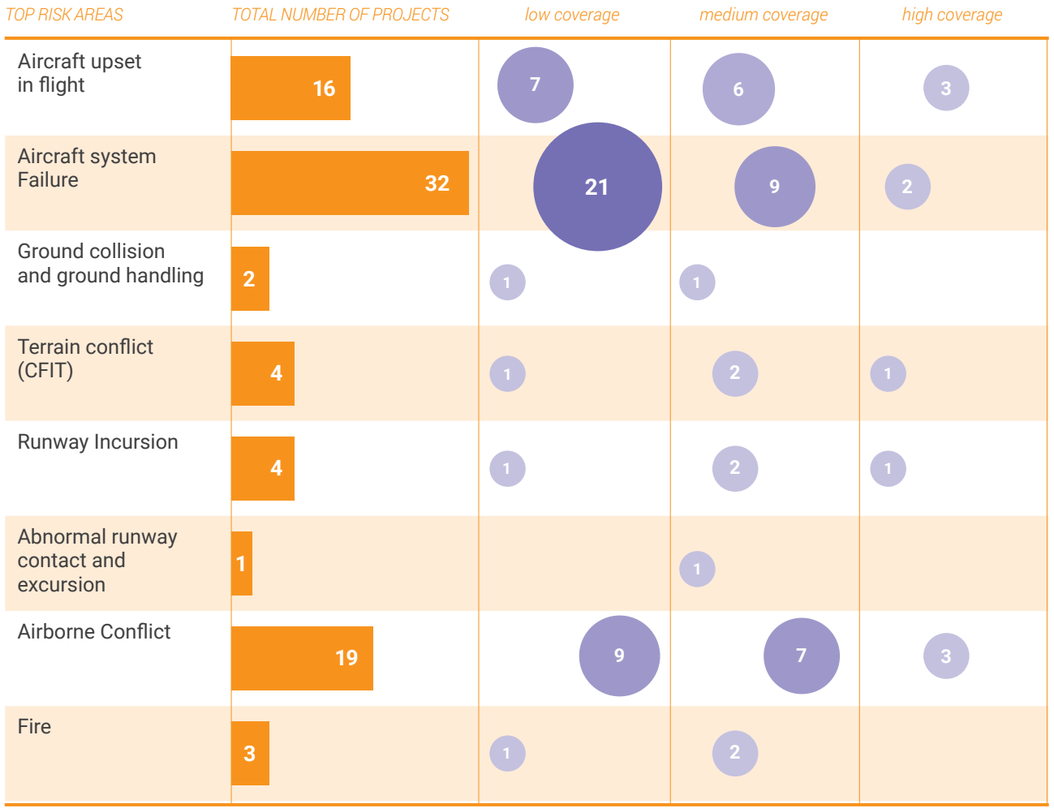
Level of coverage classification criteria:

Low coverage
Direct contribution to the risk area and low level of maturity, or indirect contribution and medium or low level of maturity.

Medium coverage
Direct contribution to the risk area and medium level of maturity, or indirect contribution and high level of maturity.

High coverage
Direct contribution to the risk area and high level of maturity of the project outcome.

RESEARCH COVERAGE OF EUROPEAN TOP RISKS



Top risks and SRIA Enablers

Enabler 1 | System-wide Safety Management System: minor contribution to risk areas mostly due to the systemic nature of the Enabler.

Enabler 2 | Safety radar: minor contribution to risk areas due to the limited number of research activities addressing the Enabler.

Enabler 3 | Operational mission management systems and procedures: relevant contribution to risk areas targeting most of them.

Enabler 4 | System behaviour monitoring and health management: strongest focus on risk areas with a narrow focus on *Aircraft system failure.*

Enabler 5 | Forensic analysis: little contribution to risk areas.

Enabler 6 | Standardisation and certification: considerable contribution with strong focus on *Aircraft system failure.*

Enabler 7 | Resilience by design: significant contribution, mostly low and medium, with a strong focus on *Aircraft system failure.*

Enabler 8 | Human-centred automation: uneven coverage of risk areas with a small focus on *Aircraft upset in flight* and a near-total lack of direct contribution.

Enabler 9 | New Crew and Team Concepts: strongest focus on risk areas with a narrow focus on *Aircraft upset in flight.*

EU SAFETY STANDARDS AND REGULATIONS

Is safety research impacting new standards and regulations?

The future of air transport relies on increased investment in the safety technologies of tomorrow, as the market demands shorter cycles for the integration of new technologies, and international competitors enter the market with an aggressive approach on prices.

In this regard, one of the expected benefits of European aviation safety research investment is the potential influence on the standardisation and regulatory process.

OPTICS investigated whether European research contributes to the development or improvement of existing or new Industry Safety Standards. Expectations were that on average 2 standards may be derived from the outcomes, including technical as well as procedural standards, standards of global and local applicability, and of various levels of development. When asked, all of the project coordinators indicated they believed that the contributions ensure the legal ease of adoption of the project results.

To gain insight into the impact of projects on EU Safety Regulations, the project coordinators were asked whether they expected the results of their project to contribute to the development, revision and/or improvement of any Safety Regulations. A positive answer was given by 40% of coordinators, with an expected contribution to EU regulations, global regulations, or both (see examples in box).

There is still room for improvement when it comes to the cooperation with research in the area of regulation and certification. It is important to better comprehend the whole landscape of safety activities but also to improve the regulation development process. Projects do not always consider the mandatory changes in regulation their results may imply, because they focus on the development part and not so much on the implementation of their outcomes. There is a need for appropriate involvement of the regulator in the research to ensure the early identification of potential legal obstacles.

To conclude, safety research results are adopted more easily if they are linked to the improvement of EU safety standards and safety regulations. However, this requires the reduction of legal barriers through evolution of the legal regulatory framework, more cooperation between the research community and the regulator from an early start onwards, and coordination between the research community and policy makers, during the project as well as after project completion.

Sub-set of analysis

12 FP7 Projects
1 Clean Sky Project
3 SESAR WP-E Projects
1 SESAR Project
3 Future Sky Safety Projects
1 H2020 Project

Safety standards

- Guidelines for aircraft systems certification and airworthiness
- Performance standards for traffic alert & collision avoidance systems
- Software considerations in airborne equipment certification
- Security and Resilience Standards
- Standards on containment of explosive damage
- Standard on Flight crew licensing
- Standard on Safety culture
- Standard on Safety Data

Safety regulations

- Flight crew licensing
- Requirements for training in decision making
- Design and operation of resilient systems and critical infrastructure
- More stringent requirements on safety culture aspects
- New regulations on safety data
- New regulations on traffic alert & collision avoidance systems
- Security regulations on mandatory use of blast mitigation devices on board

RESEARCH INVESTMENT

Is there a business model of aviation safety research in Europe?

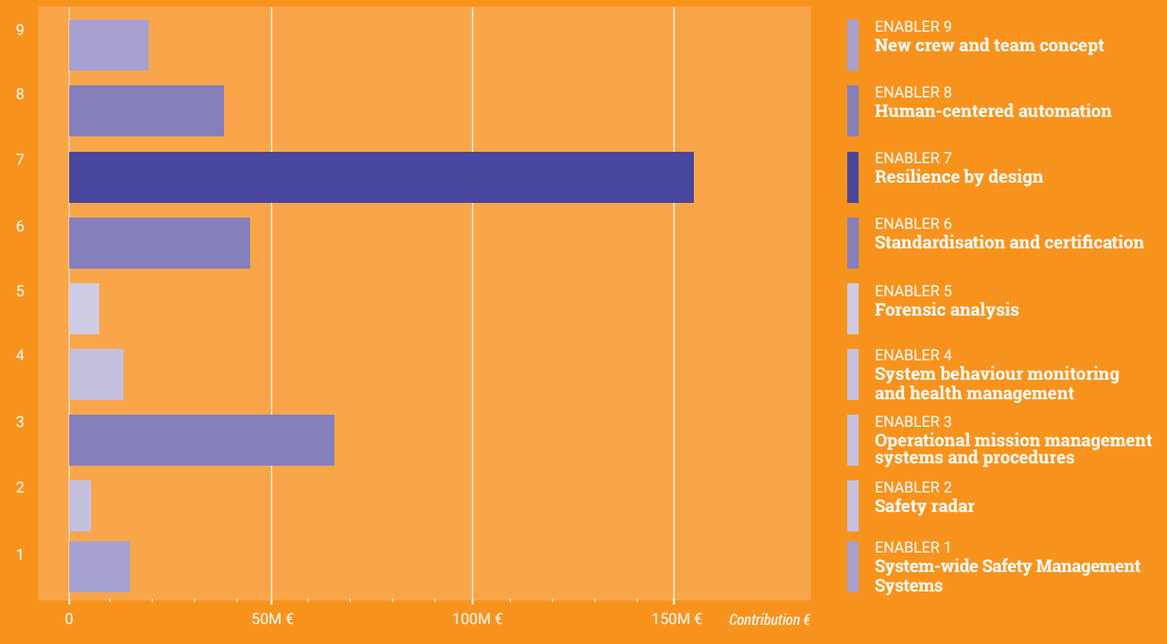
The analysis of resources distribution across Europe, complemented with the broad overview on the state-of-the-art of European research, helps understanding how European money is invested in aviation safety research.

The distribution of funding among the SRIA's safety-related Enablers and Capabilities was explored. The analysis comprises the majority of the projects assessed for the state-of-the-art and is based on the financial data available on the web or accessible through internal sources (investment period: 2008-2021).

The analysis shows that the greater part of the European Contributions among the SRIA Enablers goes to enabler 7 'Resilience by design', followed by Enabler 3 'Operational mission management systems and procedures' and Enabler 6 'Standardisation and certification'. Zooming in to the analysis at Capability level, Capability 7.5 'Improved resilience through new technologies or system designs' is by far the most funded topic with about 85M€ received. Significant resources are also allocated to Capability 6.1 'Common framework for certification' (about 33M€), which turns out to be more a contributory factor to other Capabilities, thus an **ease of adoption** facilitator, rather than a research area by itself. Capabilities 7.3 'Mitigation of environmental hazards' and 8.1 'Automation supports human in both normal and degraded operations' are other well-funded topics, counting around 32M€ each.

Sub-set of analysis
All projects for which financial data is available
62 FP7 Projects
10 Clean Sky Projects
15 SESAR WPE Projects
13 SESAR2020 Projects
9 H2020 Projects
5 Future Sky Safety Projects

DISTRIBUTION OF EUROPEAN CONTRIBUTIONS BY ENABLER *(Period: 2008-2021)*



Although Enablers 7 'Resilience by design' and 6 'Standardisation and certification' are significant areas of investment, a progressive decrease in funds allotted to these research areas is observed from 2010 up until today. No noteworthy variation is recorded for Enabler 3 'Operational mission management systems and procedures'. An increasing trend is however observed in the funds for research activities on Enablers 1 'System-wide SMS', 8 'Human-centred automation' and 9 'New Crew and Team Concepts'. Overall, a gradual contraction of investment in aviation safety research started in 2015.

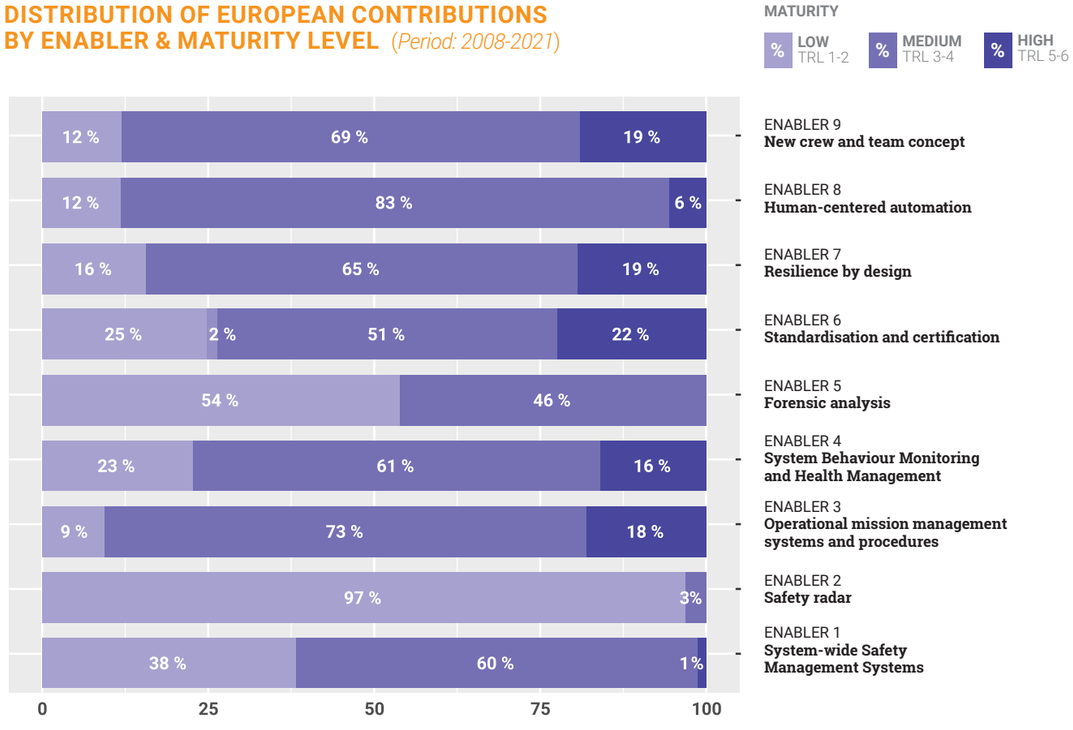
When looking at the three metrics of the Safety Research Assessment (Coverage, Maturity, Ease of Adoption), the analysis shows that the majority of investments went to projects addressing a significant (medium coverage) or a small part (low coverage) of the scope of SRIA Capabilities.

The lack of research activities addressing their full scope (high coverage) may be related to the level of definition of the Capabilities in the SRIA. Satisfying results emerge when looking at the maturity metric, as a strong concentration of funds went on projects that eventually delivered medium maturity outcomes (TRL: 3-4).

The delivery of high maturity (TRL: 5-6) project outcomes seems to be rather marginal, bringing to light a potential bottleneck inhibiting the effective transition into operations of research outcomes. Furthermore, legal constraints and costs of adoption appear to be the most critical barriers towards industry uptake, hindering all the projects delivering new products, tools or systems that imply certification costs.

To conclude, it can be argued that **coverage and maturity are mostly at the medium level**, with few indications of an ongoing transition to high maturity focused research. The progressive advancement from low to high maturity (with eventual industrial take-up) does not appear to be the most applicable business model to Aviation Safety Research. Thus, **a different business model may be needed**, clarifying the role of research and stimulating a greater involvement of the industry.

DISTRIBUTION OF EUROPEAN CONTRIBUTIONS BY ENABLER & MATURITY LEVEL *(Period: 2008-2021)*



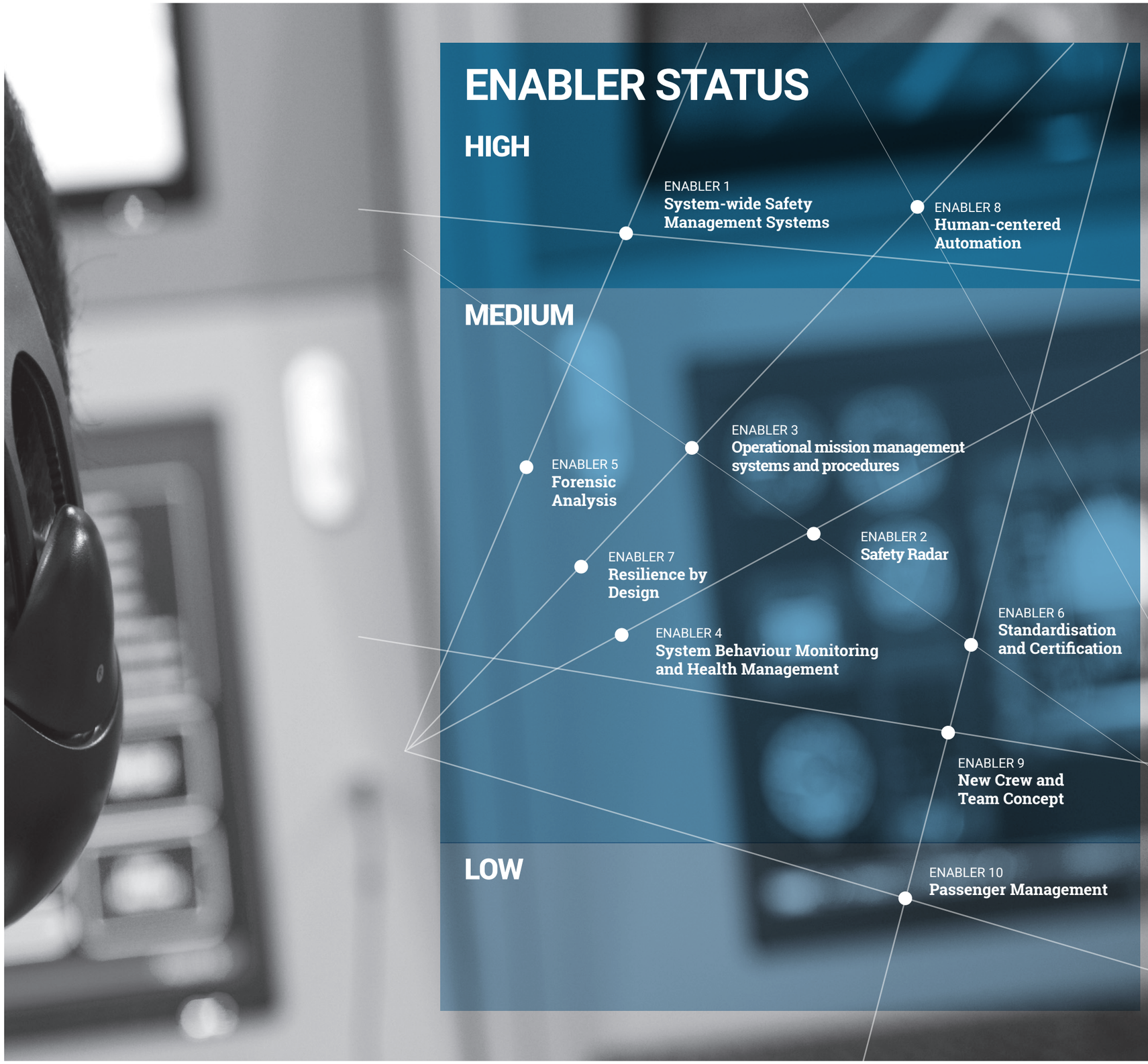
CONCLUSIONS
AND STRATEGIC RECOMMENDATIONS

OPTICS has had quite a journey, exploring and charting the aviation safety research and innovation landscape over the past four years. It began with EC Framework 7 projects, then considered institutional programmes such as Clean Sky and SESAR, and moved on to national projects and ongoing Horizon 2020 projects, and finally considered the international (outside Europe) dimension. In all, over two hundred research projects and programmes have been reviewed.

The map OPTICS began with was the ACARE SRIA roadmap of Enablers and Capabilities, the research required to deliver us to a safer 2050. The first major challenge was developing a robust yet efficient methodology with which to consider a very heterogeneous set of projects. The SRIA Enablers helped, for example sorting out projects focusing on very concrete areas such as materials design, from those focused on human aspects or safety management. But the real advance came when the main criteria for assessment were defined: coverage of the Enabler, maturity, and ease of adoption in terms of cost, legal aspects, and industrial desirability. This methodology, developed in the first year of OPTICS, along with its internal and external checks and balances to prevent bias, stayed the course and meant that all subsequent assessments led to an increasingly rich picture of the state of safety research in Europe.

The overall picture is positive. Much of the research assessed over the past four years is on the right track towards the goals of Flightpath 2050, satisfying the Enablers and their constituent Capabilities. Given that it is currently 2017, and that the roadmap is for 2050, this is a distinctly positive result. Of course, some Enablers are better served than others. Two that are doing particularly well, for example, are System-wide safety management, and Human-centred automation, whereas Passenger management has the least coverage, and other Enablers fall somewhere in between. As an overall observation, however, the OPTICS assessment process has to an extent 'validated' the ACARE SRIA roadmap, and has helped in the development of the updated SRIA released in July 2017.

Yet doing the right research does not automatically guarantee that such knowledge is translated into solid steps towards achieving the goals of Flightpath 2050. In particular, there are **two blocking points**. The first is that some of the promising research **does not seem to be picked up by industry,** or used



to inform safety policy or rule-making. The second point is that some research seems to **get 'stuck in the middle'** in terms of remaining at a medium maturity level, and thus never reaching the point at which it can help industry or inform policy or rules. To make a simple analogy, there is some good cooking going on in the safety research 'kitchen', but sometimes it never seems to come out of the oven, while at other times well-prepared meals make it out of the kitchen into the restaurant, but there is nobody sitting down to eat them. This means that **the 'business model' of aviation safety research is not as efficient and effective as it could be.** This was reinforced by the findings of the international review, where for example US aviation research seemed to be more clearly focused and harnessed by industry. Europe needs to consider how to tighten up its act, so that good safety research is not ignored, and research results progress to TRL6 whereupon industry can properly decide if and how to use them.

As well as the formal assessments of projects, the four workshops – on Human Factors, data-sharing, UAS and autonomy, collaborative safety management, and resilience and survivability – were extremely productive in terms of generating priority research directions for aviation safety (this is important since the SRIA Enablers are not themselves prioritised). An early concern that such workshops might be fruitless, due to experts disagreeing, was quickly disproven. Each workshop resulted in a strong consensus on the top 3 and top 10 research priorities in each of the chosen safety areas. Perhaps more importantly, the workshops showed that there is a strong safety community spirit in Europe, and that there need to be forums such as those provided by OPTICS, to allow more collaborative discussion and planning on safety enhancement. The ideas, and the passion for safety, were palpable in all of the OPTICS workshops and dissemination events. All that is needed is to bring the right people and stakeholders to a common table.

The Socio-Economic Impact Assessment (SEIA) part of OPTICS began in earnest in the second half of OPTICS, and is the first analysis of its kind. It has shown that **Europe has a significant aviation safety research capability**, and can be a world leader in this domain. It has also suggested that there needs to be a balance between large institutional programmes such as SESAR and Clean Sky, which are excellent for ensuring that research is implemented, and smaller FP7 and H2020-type projects, where most creativity and innovation happens.

Of the range of questions the SEIA posed, the most interesting one concerns **whether safety research is addressing today's key risks.** The research coverage of top risks seems to be uneven and it is questionable if sufficient resources are dedicated to the resolution of current known safety deficiencies. This question was discussed in the final dissemination event, and it became clear that this would be a way to help focus research and ensure that potentially good research is picked up, or new research launched where there are gaps or bottlenecks relating to key risk areas. This could therefore help our 'business model' become more strategic, which would in turn ensure that European aviation continues to retain its hard-won safety record.

At the final dissemination event, several presenters raised the possibility that aviation safety has reached a plateau, whereby it is hard to further increase safety. Other experts noted that with all the ongoing changes in the industry, and with new emerging risks arising, aviation will be sufficiently challenged just to remain on this plateau. Nevertheless, it was suggested that aviation should take a look outside its own borders to other industries, to see if there are safety lessons that could be translated into the aviation domain.

There are numerous recommendations arising from the OPTICS work, including those from the four workshops, as well as clear needs for new research and reduction of bottlenecks arising from the analysis of projects against Enablers. But at a high level, the recommendations on the following page stand out as being of a more strategic nature.

In conclusion, the OPTICS review has shown that Europe has a **strong aviation safety research capability,** and that there is **widespread commitment to safety** – a passion for safety – **across the industry**. There is, however, room for improvement, and there are significant challenges facing aviation in the near and medium term. It is hoped that the recommendations and the insights in this report and supporting documents, will help to ensure that Europe remains a leader both in aviation safety, and in aviation safety research.

RESEARCH ROADMAP

Strategic recommendations

There is an **urgent need for research into the integration of RPAS, drones and personal vehicles** into shared airspace.

One of the largest bottlenecks to safety advancement is data sharing. Means need to be found whereby the truly useful data can be shared and analysed without affecting the reputations and competitiveness of individual organisations.

Research needs to deliver better predictive tools and look-ahead time, whether via on-board sensors, or via satellite or ground-based systems to warn of system-degrading situations, from adverse weather to pilot fatigue.

More research needs to be carried out on the 'post-event' situation, including a 'return home' capability for aircraft, and increased crash survivability (especially rotorcraft).

Human Factors needs to be seen less as an add-on when needed due to technological change, and **more as an integral part of the aviation business,** fully integrated into design and operational processes. In particular human centred automation research results need to be harvested and translated into industrial benefits.

Aviation safety research needs to look outside its own borders for new ways to increase safety, whether to **road safety** for ideas on survivability, or to **nuclear power** to develop better 'barrier' approaches at the system concept and design stages.

Collaborative safety is the way forward for European aviation, but it needs research to develop robust governance approaches that will maintain a strong safety culture and achieve effective business outcomes, given the existing and upcoming challenges such as new business models (e.g. low cost), disruptive technologies, and major new partners (such as Amazon and Google).

The European aviation safety research capability is strong, but the research-to-industry 'business model' warrants improvement. Better ways to connect the research community to industry, and to increase industry uptake of potential safety advances, need to be found.

The European aviation safety research landscape needs to be more strategically organised, and linked to key risk areas (current and future), most probably steered by a stakeholder group representing the key components of the industry, including not only manufacturers and operators (airlines, ANSPs, airports, etc.), but also those at the sharp end (pilots, controllers, and passengers).

Whilst aviation safety may have reached a plateau, security certainly has not, and the threat levels are significant in many parts of Europe. Urgent research is needed on how safety and security can aid each other, and **it is recommended that any future OPTICS-type project should consider security research as well as safety**.

Designed and produced by Deep Blue
printed in September 2017

For further information, including the presentations from the various workshops and the detailed final report, please visit the OPTICS website: **www.optics-project.eu**

CONTACTS

Dr. Barry Kirwan
Safety Research Coordinator
barry.kirwan@eurocontrol.int
www.optics-project.eu

CONSORTIUM

EUROCONTROL (BE), Coordinator
EASA (EUR)
NLR (NL)
CIRA (IT)
Bauhaus Luftfahrt (DE)
CDTI (ES)
ONERA (FR)
Deep Blue (IT)
DLR (DE)
Rolls-Royce (UK)

OPTICS is a Coordinated Action funded by the European Union Seventh Framework Programme (FP7-AAT-2013_RTD-1) under Grant Agreement n° ACS3-GA-2013-60542 but this document does not necessarily reflect the views of the European Commission.