European Commission

AVIATION SAFETY

Challenges and ways forward for a safe future

Research & Innovation Projects for Policy

Research and Innovation

AVIATION SAFETY – Challenges and ways forward for a safe future

European Commission
Directorate-General for Research and Innovation
Directorate H — Transport
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EXECUTIVE SUMMARY

The European Union invests significant funds in research across a wide range of interests via extensive programmes such as the current Horizon 2020 (H2020) programme. As part of its monitoring activity, the EU is investigating certain research areas to determine whether the funding is being well spent and benefiting European citizens. A series of studies is underway which analyses research projects and their impact on European policy. These studies are called projects for policy (P4P) [1].

One such study, the subject of this report, concerns aviation safety. Its objective is to analyse 160 aviation-safety research projects to determine how they are contributing to safer flights for European citizens, whether via better aviation policies, safer designs and operational practices, improved safety standards and regulations, or enhanced safety management in the industry.

Aviation is generally seen as being the leader for safety in the four transport modes (air, rail, sea and road), and safety research helps maintain this position of confidence with passengers and businesses alike. The results of the analysis of the projects show that safety research and innovation are indeed addressing today's key risks, as well as the systemic issues that underpin effective safety governance across the industry, and the emerging safety issues posed by drones.

Nevertheless, the review of the projects has identified 12 areas where more needs to be done [2]. Some of these relate to long-standing threats to operational safety, such as loss of control in-flight, and fire on board aircraft, whereas others are relatively new issues such as ground-handling safety, and mid-air collision involving a commercial aircraft without an operating transponder. Systemic issues — which run deeper but can affect the safety of the entire system — are generally well-addressed, except, for example, the fragmented way in which we take care of the human factors in aviation-safety research, and the future safety governance systems that must ensure safe integration of drones and personal air vehicles into the aviation system. Emerging issues such as the impact of new business models (e.g. 'low cost') on safety, new technologies and cybersecurity, all merit research attention.

European citizens and businesses alike would be better served by an upgraded aviation-safety research system that ensures a sharper focus on key issues, as well as more-focused research streams and flagship programmes to resolve long-standing key risks. Ten policy recommendations are proposed, including a cultural shift across the industry towards safety-sharing and a 'no competition on safety' approach, smarter use of data, more strategic use of human factors, a risk-informed research strategy and a programmatic approach for tackling key operational risks. For emerging risks, the advised research is on proportionate (yet still safe) safety governance and management approaches for new business entrants related to drone delivery services and sky taxis, as well as breaking down the silo mentality between safety and security domains. Emerging technologies, from digitalisation to advanced manufacturing to artificial intelligence, should be explored for (positive) safety opportunities. Finally, European research communities, together with their industrial partners, need to become more joined-up in their approach to aviation-safety research, so that Europe can speak with a unified voice on critical safety matters, allowing its research to have a truly global reach.

1 The legal basis for this activity is the transport part of the Horizon 2020 work programme 2016-2017 — *Decision C(2016)4614 of 25 July 2016*, topic Other Action no. 3 on 'External expertise for monitoring'.

2 Some of the areas are now addressed in the last calls of Horizon2020.

TEN POLICY RECOMMENDATIONS

SYSTEMIC

- Towards a risk-based research strategy
- Sharing safety data and safety intelligence
- Safety culture across the aviation community
- Harnessing human factors

OPERATIONAL

- Reducing the operational risk portfolio
- Improving post-accident survivability

EMERGING

- Proportionate safety-management arrangements for new aviation players
- Collaborative safety and security
- New technologies and safety solutions
- Europe as a global aviation safety research player

CURRENT AVIATION-SAFETY CHALLENGES

Aviation is a major positive economic force for Europe, creating business opportunities, connecting people and creating jobs. It allows easy and relatively low-cost movement, which in turn enhances multiculturalism and social democracy, cornerstones of European culture. People from all walks of life, whether for business or personal reasons, wish to travel. This 'right to travel' has become second nature to an increasing number of Europeans, and is underpinned by an extremely high safety record.

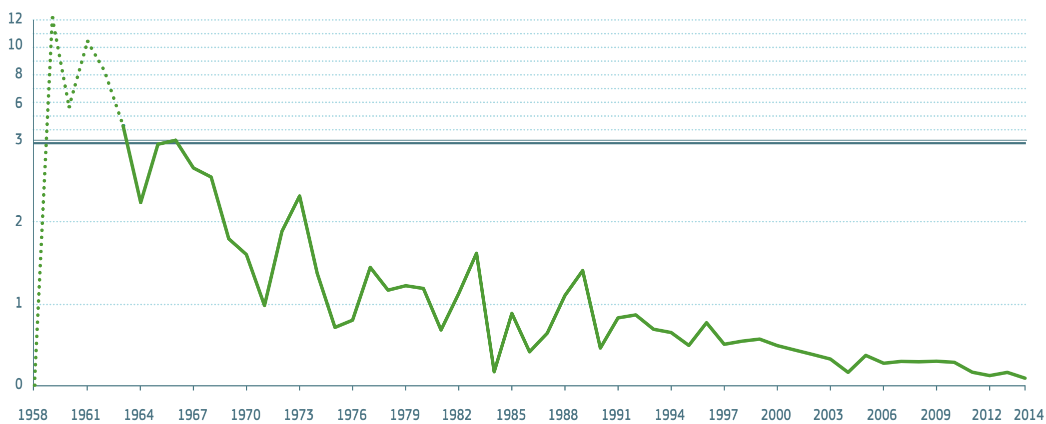
Figure 1 below shows how commercial aircraft accident rates have fallen steadily from 1958 onwards, including in the last two decades, where there has been a doubling of the amount of commercial air traffic. Much of this improvement has been due to successful technological breakthroughs, enhanced safety governance, and a strong focus on pilot training and crew resource management.

Given such a safety record, it is tempting to wonder whether aviation safety is so robust today that we could focus research efforts and resources elsewhere. Are there serious and credible threats that could damage aviation's hard-won safety reputation? Do the new business models that benefit passengers in cheap flights have any safety penalty? Do the almost continual increase in traffic levels, the new entrants to airspace (e.g. drones and even air taxis), as well as potential climate-change impacts on weather patterns mean that we must continue aviation-safety research efforts or should we even re-double them?

These are valid questions, and as part of the Horizon 2020 research programme and a series of studies called *projects for policy*, 160 aviation-safety research projects from ongoing and recent research programmes, including Horizon 2020, the Seventh Framework Programme for Research and Technological Development (FP7), the Single European air traffic management (ATM) Research (SESAR joint undertaking) and Clean Sky joint undertaking, have been analysed by an expert team to provide answers on whether the research is benefiting society, and whether improvements should be made in terms of future aviation-safety research directions.

To begin answering these questions, this chapter reviews the existing and upcoming challenges for European aviation safety. This is followed by an overview of the current portfolio of aviation-safety research projects (Chapter 2) to see the types of threats they are addressing, and to gain an appreciation of their benefit for society. Chapter 3 then summarises a more formal review of the projects, and identifies 12 potential gaps where research needs further or fresh focus (the full analysis is in Annex II). Chapter 3 also includes a summary of where research projects have led to new regulations or impacted European aviation policy, or are likely to do so in the near future (the complete table is given in Annex III). Chapter 4 concludes the study by presenting a set of 10 recommendations for the direction of future aviation-safety research, to ensure that passengers and businesses continue to enjoy a high safety level in European aviation for the coming decades.

FIGURE 1 Commercial aviation accident rates 1958-2015, yearly fatal accident rate per million flights (source: Airbus) [3]



3 http://asndata.aviation-safety.net/industry-reports/Airbus-Commercial-Aviation-Accidents-1958-2014.pdf

THE 'BIG FIVE' AVIATION-SAFETY CHALLENGES

There are numerous current and foreseeable challenges to safety in aviation, which is a dynamic and ever-growing industry, but for the sake of clarity five challenges have been identified as the major ones, introduced below.

1. NEW BUSINESS MODELS

Increasing **competitiveness** is a challenge for safety in any industry. New technologies will have an impact on operations as well as on existing certification methods and standards. The commercial pressure is real, as evidenced by certain recent bankruptcies of long-standing European airlines. New business models such as that of low-cost airlines mean fewer people in the organisation, but does that mean less safety? So far, fears that *low cost = low safety* have not been realised, but it still remains 'one to watch'[4].

Yet even existing national airline carriers are evolving their business models in order to stay in business, continually improving their services and reducing their costs, and the whole industry is engaged in continuous improvement to provide better services to both passengers and the airlines — better connectivity, flexibility, timeliness, etc. Such business evolution leads to increased **complexity** of aviation operations, which is the other side of the coin of providing better services. A system with 'many moving parts' is always a challenge, because it means there are more things that could go wrong at the interfaces and in the interactions between components of an industry which is a very large 'system of systems'.

The passenger does not see the complexity and interconnectivity of operations and organisations working smoothly behind the scenes for every single flight, from check-in to disembarkation. Strong and ever-watchful safety-management systems keep passengers safe even when there are rare but inevitable mechanical failures, or challenges posed by bad weather. The aviation system is not merely safe, it is resilient. But the increasing trend towards better (more adaptive and hence more complex), cheaper (fewer resources, including those for safety) and faster (high-tempo operations) is a risk. As far as increased cost reduction is concerned, there is a 'line in the sand' beyond which we should not proceed. The problem is, no one knows exactly where that line is. The best way to detect whether we are becoming unsafe is strong safety governance, which means that safety must also continuously evolve, rather than diminish.

2. AUTOMATION

Technology is evolving at an unprecedented pace. Driverless cars are fast approaching, so what about single-pilot or even pilotless passenger-carrying planes? Even before we reach that point, the amount of automation in the cockpit and for the air traffic controller is steadily increasing. This is fine when everything is running smoothly, but when the **automation** finds itself unable to cope, it will hand control back to the human, who has been 'out of the loop'. The last big change in the level of automation in aviation was back in the late 1980s, with a shift to today's 'glass cockpits'. Whilst this has resulted overall in significantly improved safety, the introduction of this new technology led to an initial spate of 20 or so 'automation-assisted accidents'. This would be unacceptable today, and so, ironically, the trend towards increasing automation requires a renewed safety focus on the teaming between people and automation.

4 https://www.easa.europa.eu/system/files/dfu/Practical%20Guide%20New%20Business%20Models%20Hazards%20Mgt.pdf

Looking a little further into the future, the next generation of automation will be artificial intelligence. This domain, no longer the province of science fiction, could well be the next 'game-changer' for aviation.

3. DRONES

Unmanned vehicles such as drones are the game-changer that aviation is currently trying to get to grips with, as they bring not only new vehicles (from aeroplane-sized, to swarms of far smaller drones) into our skies, but new aviation partners such as Amazon and Google. The arrival of drones should be good for business, daily life and the economy, but the introduction of these new aerial systems and new players into an existing tightly-regulated and controlled system is a major challenge. Europe, similarly to other continents, is playing catch-up in order to safely introduce drones into the airspace system. Meanwhile, yet another game-changer, the arrival of personal aerial vehicles (PAV), is already on the horizon, with new business giants such as Uber considering how to evolve their business model into the skies with Uber-style air taxis, in addition to diverse European companies developing and testing PAVs, such as Airbus and Volocopter.

4. CYBERSECURITY

Cybersecurity is another recent 'emergent' risk factor that can affect aviation safety. Whilst technically it is security rather than safety, the travelling public and businesses will not be so interested in the nuances of such a distinction. Cybersecurity addresses a significant threat to safe and efficient air travel, especially where air traffic services and pilotless planes are concerned. Because safety has always focused on accidental harm, whereas cybersecurity is about intentional harm, we will need new approaches for this threat.

5. ADVERSE WEATHER

Weather remains one of the major challenges to aviation safety, from icing effects both on the ground and at altitude, to thunderstorms and lightning strikes, to fog and snow at airports, to major events such as volcanic ash clouds that can affect large swathes of European airspace. The ability to predict and avoid or mitigate such weather effects, and the capacity of pilots to safely navigate around or through adverse weather patterns, remains a key focus in aviation safety. Added to this are the potential future risks of increased adverse weather patterns posed by **climate change**.

AN AVIATION-SAFETY FRAMEWORK

There are clearly a number of challenges competing for research resources, including existing risks as well as new ones already on our doorstep or else looming on the horizon. How can all these risks be managed in an optimal way, so that we avoid the situation of merely reacting to the latest threat, or focusing only on short-term risks whilst ignoring larger threats that are 'in the pipeline'? In order to determine which challenges deserve attention, and to serve as a basis for allocating research effort, a framework is needed. Such a framework offers a way to consider all threats to aviation safety, whether 'concrete' threats such as accident risks from weather, or more conceptual risks such as financial pressure on aviation organisations, or future and potentially little-understood risks.

Aviation is a large industry, a true system of systems, and must be managed as such. The creation of the European Aviation Safety Agency (EASA) has been a key step in helping Europe to manage current and future risks collectively. The strength of Europe is in its diversity and its willingness to collaborate. The challenge, therefore, is to collaborate for safety while remaining competitive both within and outside Europe. This requires an enduring safety mindset — also known as a **safety culture** — in the companies that make up European aviation, built on the understanding that an accident for any one company affects the whole industry, as well as the European reputation for safe air travel, and hence our global competitiveness. EASA [5] has developed a useful framework for aviation safety called the European plan for aviation safety (EPAS) comprising three overarching risk management areas.

> **Systemic issues** — safety management, human and cultural issues.
> **Operational issues** — commercial, helicopter and general-aviation operational risks such as handling flight-upset events, runway events and coping with adverse weather.
> **Emerging issues** — e.g. drones, new business models and cybersecurity.

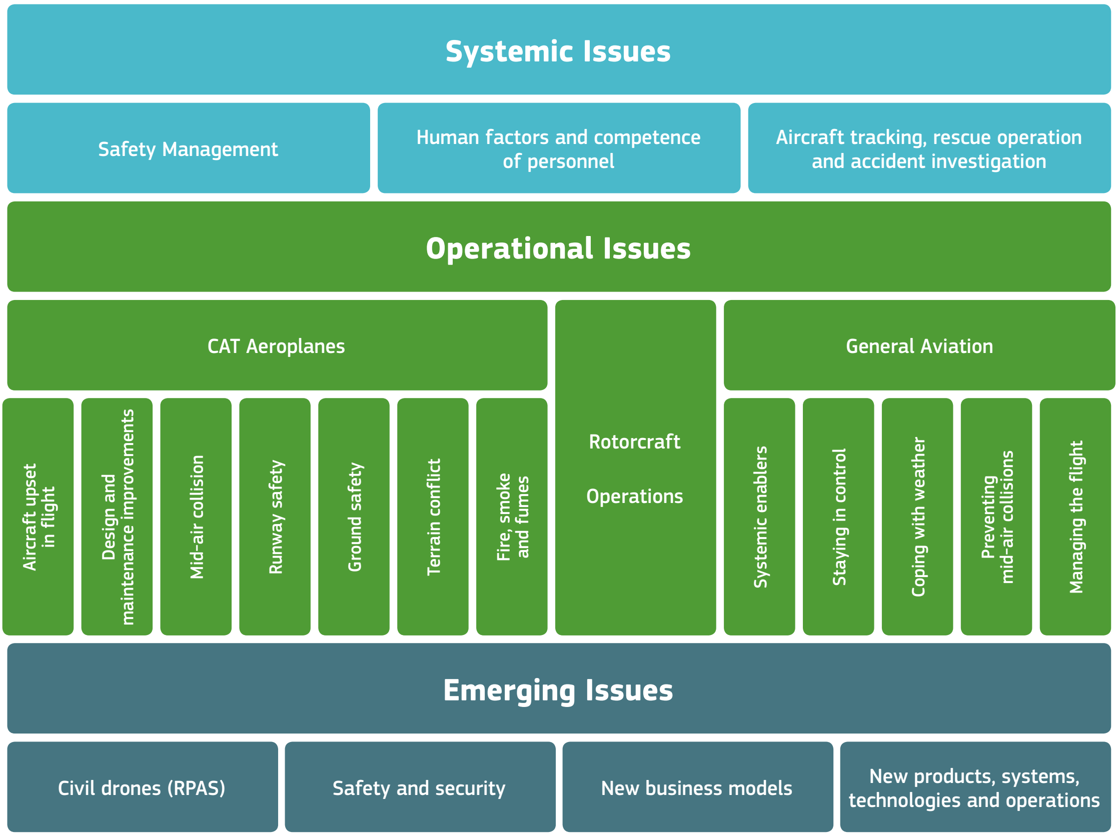
The current EPAS framework is shown in Figure 2 beside, which indicates the risks and challenges in more detail, and serves as a 'landscape' upon which to map aviation safety research projects.

The EPAS (2017-2021) goes into considerable detail on what needs to be done, both in terms of new standards and rule-making, as well as indicating areas where new research is needed. However, much of the latter is relatively short-term in its focus. A longer-term view was proposed in 2000, known as FlightPath 2050. The Advisory Council for Aeronautics Research in Europe (ACARE) developed a detailed safety research & innovation agenda to realise the 2050 safety goals [6], with five main avenues of safety research.

ACARE Future Vision of Safety

5 https://www.easa.europa.eu/system/files/dfu/EPAS_2017-2021.pdf
6 http://www.acare4europe.org/sria/flightpath-2050-goals/ensuring-safety-and-security

FIGURE 2 The EPAS safety framework (source: EASA)



- **Safe governance** — more collaborative approaches to safety management (SYSTEMIC).
- **Human-system optimisation** — including managing advanced automation (SYSTEMIC/OPERATIONAL/EMERGENT).
- **Safety intelligence** — including use of 'big data' to help us 'see around the corner' (SYSTEMIC/OPERATIONAL).
- **Safe and secure operations** — handling operational threats but also bringing safety and security closer together (OPERATIONAL).
- **Resilient design, manufacturing and certification** — ensuring 'designed-in' safety (OPERATIONAL).

These two approaches from EASA and ACARE are complementary and non-conflicting, mainly differing in how far they are looking ahead. The most practical framework for the purposes of this study is the EPAS, which will be referred to throughout the remainder of the document, supplemented where necessary by elements of the ACARE framework.

Additionally, the review team considered the results from the **Optics** project [7], which had just finalised its 4-year review of European aviation safety research, and which helped to inform the ACARE vision on safety-research needs. Although the objectives of Optics are different from those of P4P, focusing on the degree to which recent safety research is satisfying the ACARE safety goals for 2050, the insights are complementary. The Optics analyses of projects and programmes, including the international perspective on aviation-safety research, provided useful additional context for the P4P exercise. The Optics results also served as a useful benchmark during the P4P identification of safety-research gaps, and its insights were taken into consideration during the formulation of policy recommendations.

7 Observation Platform for Technological and Institutional Consolidation of research in Safety http://www.optics-project.eu/optics1/

PORTFOLIO OF SAFETY-RELATED EU-FUNDED R & I PROJECTS

PROGRAMME AREAS AND CENTRES OF EXPERTISE

Aviation-safety research has been ongoing for many years, since the early EC framework programmes. However, such research, e.g. from the early 2000s, is not always relevant to today's aviation environment and its current and upcoming safety risks. It was therefore decided to focus the review on collaborative aeronautics research under FP7 and its successor Horizon 2020, including Clean Sky (itself focused on 'greening' and competitiveness) and SESAR (air-traffic management).

The projects of most interest are those whose main aim is to improve safety. However, sometimes other projects may lead to safety insights and improvements even if this was not their main goal and such projects therefore remain of interest. A third category of projects concerns technological developments where a safety case has been carried out to show that the new concept or technology does not adversely affect safety. This third category was generally not of interest in this current review, unless it could show, for example, that the introduction of drones or personal aerial vehicles into civil airspace would be safe.

A recent review by the project Optics showed that the amount of EU funding for aviation-safety research from 2008 until 2020 is more than **EUR 300 million**, which includes 115 projects where safety was the direct goal, as well as those where improving safety was an implicit target or side-benefit. As shown in Figure 3 below, safety-based research has been mainly funded through FP7, but more recently its successor Horizon 2020 has included a sharper focus on key safety issues and risks. Technology-driven safety R & I projects have occurred within the Clean Sky and Clean Sky 2 programmes, while air-traffic-network safety improvements, which have also included some of the main methodological advances in safety management and other systemic issues, have been occurring in SESAR-related research. Note that this spending figure is an underestimate, as financial data were not available on 22 safety-related projects within the SESAR and the Clean Sky 2 programmes. Also, it does not include nationally and regionally funded research, nor safety research carried out by airframe manufacturers, for example.

FIGURE 3 EU contribution to aviation safety research 2008-2021 (source: EU-funded project OPTICS)

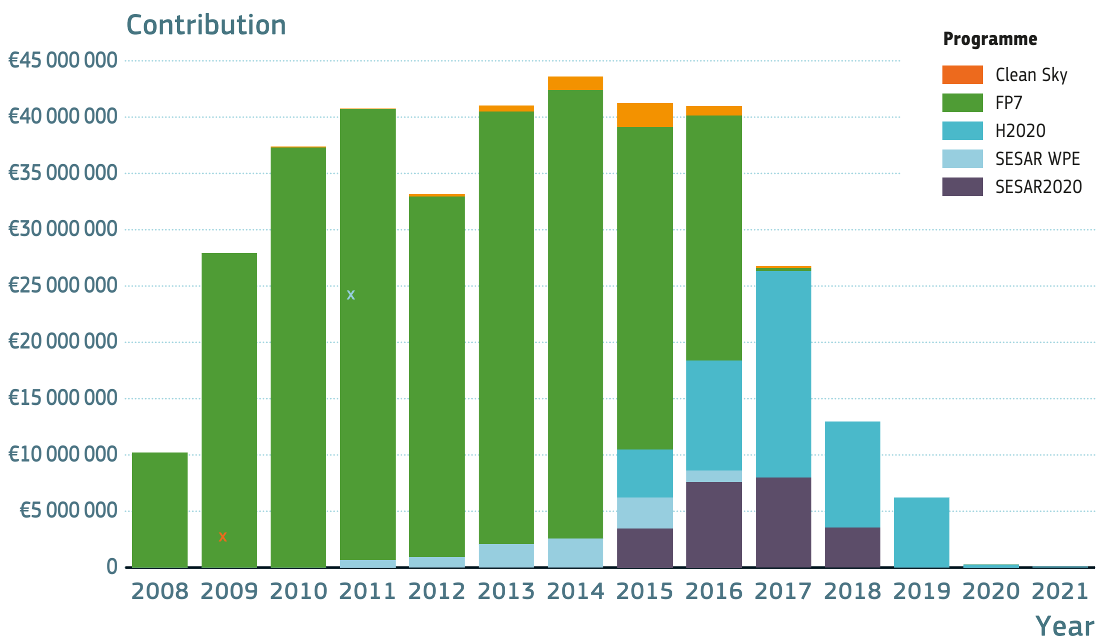


Figure 3 indicates that the overall spending on safety R & I is decreasing. This is because most EU aeronautics R & I funding has shifted from bottom-up research, directly managed by the Directorate-General for Research and Innovation and the Innovation and Networks Executive Agency (INEA) (in the graph indicated as FP7/H2020), towards Clean Sky/2 top-down research, which is more focused on the environment and competitiveness. The degree to which this reduction of safety R & I could impact on safety, given increasing traffic levels, complexity and competition, as well as the introduction of new aircraft systems (drones and personal vehicles) and new business models and players, is returned to in Chapters 3 & 4.

There are many research centres across Europe carrying out safety research, as shown in Figure 4 below (the size of the circles is an indication of the number of FP7 aviation safety projects the research centre was involved in). This map reflects on the one hand a healthily broad base of research centres and parties involved in all aspects of aviation-safety research, and on the other hand clear 'hubs' of concentrated research. It also indicates that European funding is helping to maintain Europe's aviation-safety research capability.

Another view of the spending on safety research (Figure 5) shows the previously mentioned ACARE breakdown of safety research into nine 'enablers' for safety. The top and bottom two bars are mainly systemic safety research, with the middle five bars being primarily operational. Emergent projects are not discriminated in this figure, with such projects embedded into the other two categories (however, overall, there are less emergent projects than for the other two categories). The figure shows that most of the research funding is targeting future ways of resolving operational risks and threats.

FIGURE 4 Map of aviation safety centres of expertise (source: EU-funded project OPTICS)

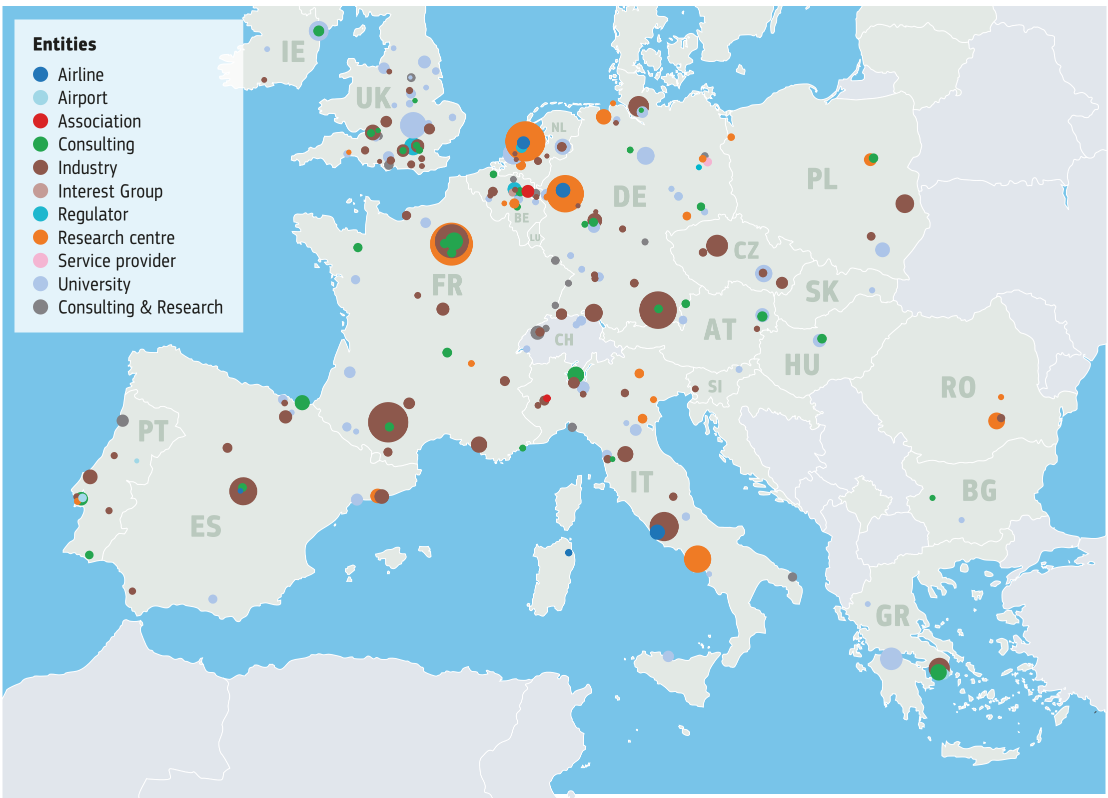
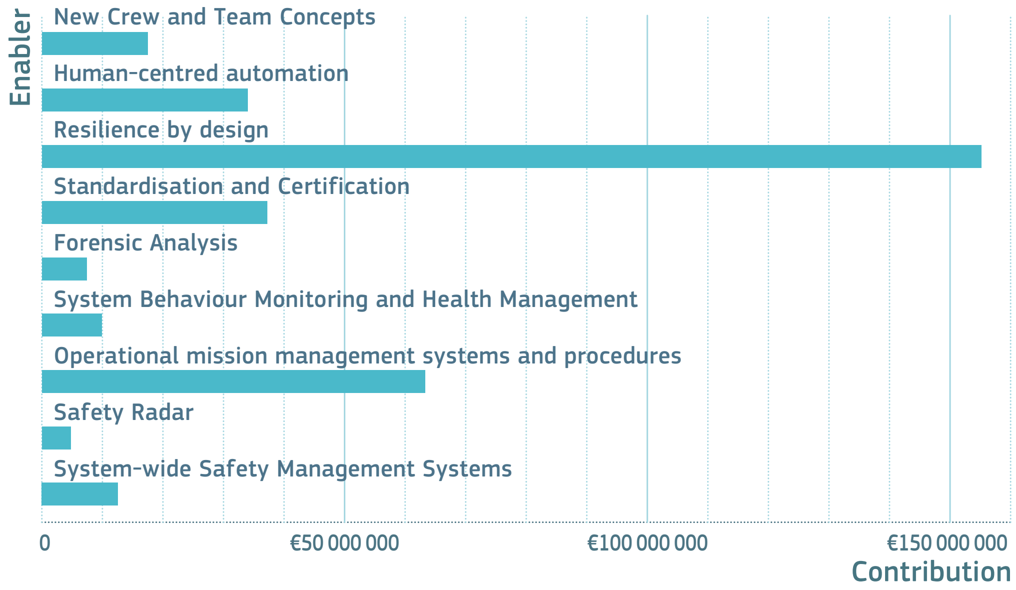


FIGURE 5 Projects and funding according to ACARE safety enablers (source: EU-funded project OPTICS)



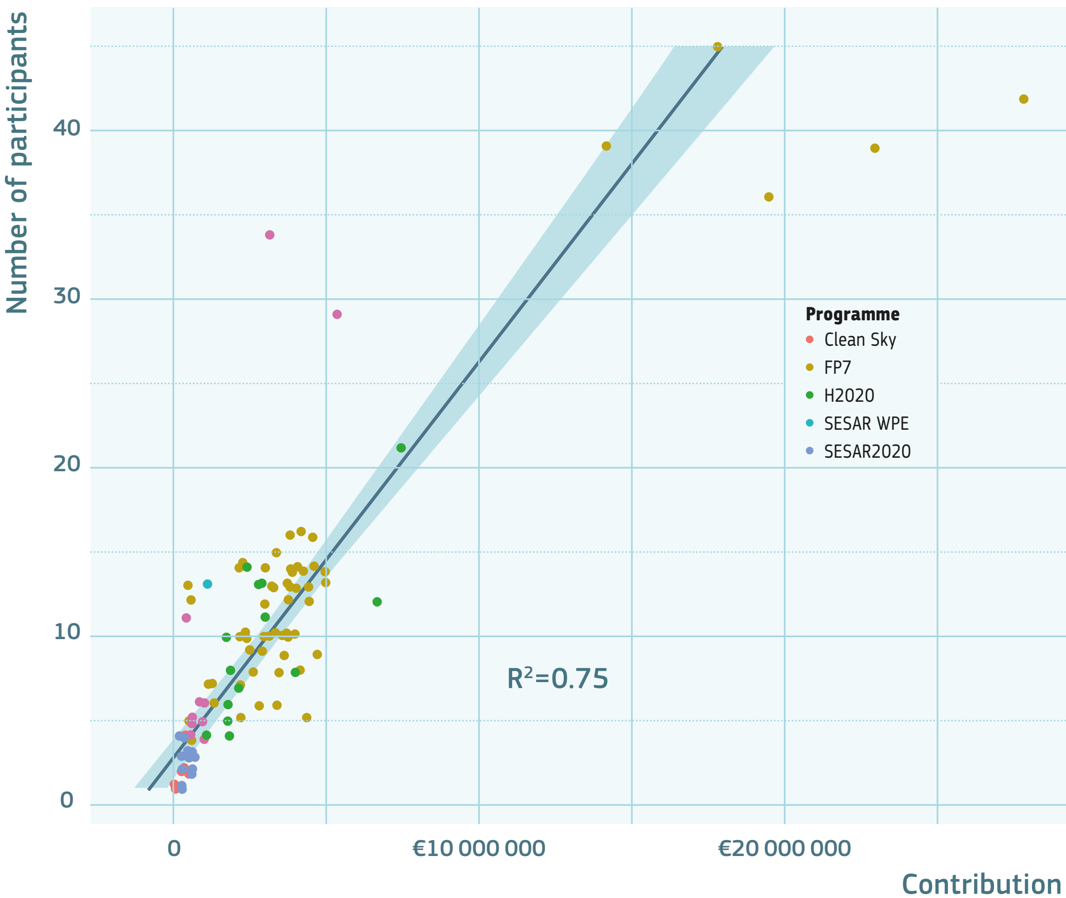
SAFETY RESEARCH BUSINESS MODELS

The financial size of a project and the number of partners in the project consortium are also important indicators of the state of safety research in aviation. Figure 5 shows that most safety projects are reasonably small and focused in terms of research funding and number of participating partner organisations.

Safety research funded by the EU appears to be carried out according to four models.

1. The first is a **'single-shot'** approach, where research is funded to tackle a specific issue, such as icing on the wings of an aircraft. Such a project is typically funded for around EUR 1-5 million in the first instance.
2. Sometimes a solution may derive from a single project, but more often it may take two or even three consecutive projects, creating a **'research thread'** in order to develop the research to sufficient maturity that it can be picked up by industry, where the solution can be implemented to resolve the threat. This is in fact how the icing hazard is being resolved.
3. A more recent approach in the past decade has been where the safety research is **'embedded'** within a much larger programme, one where industry is a major stakeholder and partner in the research (such as SESAR, SESAR 2020 and Clean Sky 1 and 2 Joint Undertakingss). This approach can lead to a more focused research stream and faster deployment into aviation operations. Although the safety projects within these programmes may be no larger than, or they may even be smaller than, the more independent FP7 and H2020-style projects, they have the advan-

FIGURE 6 Financial contribution of project vs number of partners in consortium (source: EU-funded project OPTICS)



tage of being embedded in large programmes where industry is a key stakeholder. This means that the chances of their results and innovations being deployed into actual aviation operations are perceived to be higher (e.g. certain SESAR safety improvements linked to runway incursion prevention will be deployed in 2019). In contrast, the smaller 'independent' projects and research threads are often more focused on key issues and emerging areas, and tend to be more innovative. They are able to look deeper into an issue, and more creative solutions can derive from them. In addition, in certain cases, smaller 'independent' projects can be required by the public authorities to avoid any potential conflict of interest.

4. An interesting recent fourth approach has been the **'flagship'** safety research programme, such as Flysafe and more recently Future Sky Safety, whose funding levels sit between the typical project and the large programme. Such medium-size programmes allow for innovative research but also involve industry, and so are more likely to achieve faster transition of their results into aviation operations.

CONTEMPORARY AVIATION SAFETY RESEARCH TOPICS

Using the EPAS framework as described in Chapter 1, safety research topics have been grouped into the three main categories as below, in order to give an overview of contemporary research in these different research categories.

SYSTEMIC

Organisational

On the **safety management** side, since many aviation organisations today already have mature safety-management systems, most of the research has focused on how to improve safety management, both in terms of learning from past events, and also being able to 'see around the corner' to the next one. Aviation is a complex and highly technical industry, and since it is generally very safe, there are not so many accidents to learn from, so there is recent attention on the analysis of weak signals that might turn out to be a future accident, as well as ensuring that information on hazards is tailored and channelled to those at the 'sharp end' (those affected by those hazards), whether pilots, air traffic controllers, airport personnel, etc.

Given that there is fierce competition in aviation, as well as new business models and a general cost-reduction drive, some of the research targets the 'blunt end' (those furthest from the hazards), aiming to support senior executives in ensuring that they remain competitive but do not cut back too much at the expense of safety. There is also research ensuring that safety lessons learnt in operations are fed back to those designing future systems, so that next time such vulnerabilities can be designed out. Therefore, much of the safety management research is ensuring that all actors in aviation have the right information at their fingertips to stay on top of safety, whether pilots, controllers, designers, engineers, managers or chief executive officers (CEOs). A number of recent and new projects concern the technical safety of unmanned aircraft or new business models, and some projects raise the question of how to ensure a robust safety culture in these new aviation segments.

Human Factors [8]

Much of the **human factors** research has focused on how automation can better support (rather than replace) the pilot in the future, particularly with respect to detecting and reacting to abnormal events that can threaten an aircraft's safety, whether due to technical problems aboard the aircraft, or weather conditions. Some of the worst accidents in recent years have been weather-related, leading to 'flight-upset' events where the pilots are placed in very demanding situations, physically as well as mentally. A number of projects have sought to find out where pilots' limits lie, and how to extend them via automation support. World-leading advanced simulation facilities have also been developed so that pilots can experience extreme flight conditions while still safely on the ground. Almost all research in this area has focused on pilots and cockpit design for commercial aeroplanes, with two projects focusing on rotorcraft, and a handful of projects relating to air traffic controllers via the SESAR programme. Other people in the aviation system have so far been left out, e.g. ground handlers at airports, though again this may be about to change via SESAR and Future Sky Safety.

Cultural [9]

Very little research was found on **cultural** factors, despite the fact that this is obviously an increasingly important issue as the trend towards globalisation con-

8 Some of these aspects are open for new research through the Horizon 2020 call topic MG-2-1-2018 'Human Factors in transport safety': http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/mg-2-1-2018.html

9 Some of these aspects are open for new research through the Horizon 2020 call topic MG-2-1-2018 'Human Factors in transport safety': http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/mg-2-1-2018.html

tinues, and job mobility in Europe is a key mission of the European Commission. One project within the Future Sky Safety flagship project seeks to extend the good work on safety culture achieved over the past decade in air traffic management to airlines and airports and is already showing some success.

OPERATIONAL

Weather

There is significant research effort on adverse-weather hazards, especially high-altitude icing, but also wake vortex, wind shear and volcanic ash, and one project on low-visibility conditions. Much of the research on icing is aimed at improving our understanding and modelling of icing events, so that better materials and procedures can be developed to anticipate and handle ice formation when it occurs. Other research tends to focus on how to detect and anticipate problems in real time (i.e. in-flight), so that appropriate measures can be taken. For volcanic ash and similar wide-scale atmospheric disturbances, the research is focusing on achieving better communication and coordination, so as to have less traffic disruption and better decision-making as to whether it is safe to fly or not.

In order to fully exploit existing and future capabilities with regard to weather, there remains a need to inform the pilot of up-to-date weather detail, presented in a form consistent with human factors principles. Previous and ongoing research activities, together with recent advances in technology with regard to electronic flight bags and high bandwidth connectivity, are seen as enablers to this end.

Aircraft

A cluster of research projects focused on the health of aircraft systems, so that when things go wrong, the aircraft system can recover (in-flight), including 'smart' aircraft, real-time structural-health monitoring, more resilient and fire/icing-resistant composite materials and self-healing composites, debris-impact shielding and engine protection. All these projects will help to make future aircraft more resilient to external hazards and internal failures, ensuring that, should such rare events occur, the aircraft can make it safely back to an airport. Aspects such as advanced inspection (e.g. for cracks in the fuselage) are also being researched.

FIGURE 7 Research coverage related to EASA key accident risk categories (source: EU-funded project OPTICS)

Top risk areas	Total number of projects	Low coverage	Medium coverage	High coverage
AIRCRAFT UPSET IN FLIGHT	16	7	6	3
AIRCRAFT SYSTEM FAILURE	32	21	9	2
GROUND COLLISION & HANDLING	2	1	1	
TERRAIN CONFLICT (CFIT)	4	1	2	1
RUNWAY INCURSIONS	4	1	2	1
ABNORMAL RUNWAY CONTACT & EXCURSION	1		1	
AIRBONE CONFLICT	19	9	7	3
FIRE	3	1	2	

Many of these operationally focused research projects should also help reduce aircraft vulnerability to the top European aviation safety risks, including loss of control in-flight (flight upset and aircraft system failure), runway excursions and fire, as for example shown in Figure 7 before. Although this figure shows that the key risks, such as flight upset are well-targeted by research, the 'coverage' aspect in the figure highlights the fact that much of this research is tackling only a part of these key risk categories, and/or is not at a high level of maturity.

One new project [10] focuses on the post-accident situation, in this case ditching of aircraft and helicopters in the sea. It is notable that almost all research focuses on prevention rather than post-accident survivability. Most research reviewed also focuses on civil air transport (passenger and cargo), but there is also safety research on rotorcraft and general aviation [11].

EMERGING

New risks

For the new and future risks, drones are top of the priority list because they may have dramatic effects on our daily lives and the airspace, and also because the technology itself and its potential uses are growing at a seemingly exponential rate. Following an early project, a relatively recent one [12] is now looking at the likely impact of a broader class of drones — including drones on sale to the public, and those that may be used by customer-service delivery outlets — on the airspace and their interaction with other airspace users. A large-scale demonstration project has recently been funded to see how 'live' drone traffic may be managed in practice. Related significant risks, associated with the longer term, include those such as pilotless planes and personal aerial vehicles.

One project has been looking at the impact of new business models (e.g. low-cost airlines) on safety, and this has already impacted on guidance produced by EASA on this topic. Two FP7 projects focused on personal vehicles, to begin to consider their relevant safety considerations [13].

New solutions

Two projects explored how to better use data (e.g. flight-data monitoring data) to help detect new threats, predict 'hotspots', and to generally 'see around the corner' to the next potential accident. The most recent one has a firm focus on trying to harness the power of big-data analysis, in the context of airport, air traffic and airline operations, to see how such analysis can generate safety intelligence which will enable us to anticipate and resolve or mitigate developing threats before they become operational hazards.

One project is focusing on future electric and hybrid aircrafts, with emphasis on safety and human factor considerations, to ensure that such novel configurations will remain at least as safe as the conventional ones. This is important, since the introduction of new types of vehicles can sometimes herald a spate of accidents, as happened with the introduction of 'glass cockpits' decades earlier.

Passengers today are concerned at least as much by security as by safety. Yet these two disciplines are traditionally completely isolated. One of the first projects to explore how to bring safety and security closer together is now underway.

In summary, the portfolio of aviation safety research and innovation projects is diverse, and addresses much of the safety landscape proposed by EASA, when viewed at a high level. The next chapter analyses the research projects in more detail, contrasting them with the challenges facing aviation safety, to identify gaps and areas where policy change may be warranted.

10 SARAH – Increased Safety and robust certification for ditching of aircrafts and helicopters (724139) http://sarah-project.eu/

11 General aviation (GA) refers to all civil aviation operations other than scheduled air services, from gliders to business jets.

12 PODIUM (783230) http://www.cordis.europa.eu/project/rcn/213198_en.html

13 SESAR 2020 is expected to address urban air transportation within the enabling framework of U-space.

RESULTS AND EVIDENCE

This chapter has three aims:

1. To determine whether there are gaps in the safety research being funded, calling either for new research or a fresh focus, given the existing and upcoming challenges facing aviation.
2. To determine whether existing research is informing safety policy in the form of safety standards and regulations, since these are an important part of the governance system keeping air travel safe.
3. To consider whether there are any deeper issues concerning the way aviation safety R & I is carried out in Europe that would benefit from strategic or structural change in the way research is conceived, funded, executed and exploited, to the benefit of European travellers and airspace users.

Each of these aims is dealt with below, leading to the 10 policy recommendations in Chapter 4.

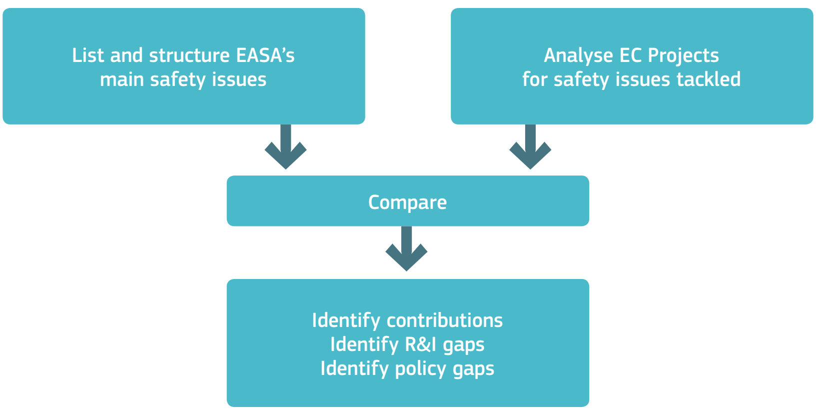
SAFETY R & I SOLUTIONS FOR POLICY CHALLENGES ASSESSMENT APPROACH

To analyse the impact of R & I projects on current safety policy, a baseline had to be established. Acknowledging EASA as the primary stakeholder for European aviation safety, the **European Plan for Aviation Safety (EPAS)** was chosen as the reference document to state EASA's understanding of safety relevant threats and issues. The current EPAS document reflects the strategic priorities to be pursued from 2017 until 2020, resulting from discussions with other stakeholders.

As already shown in chapter 1 (see Figure 3), EASA's framework is structured via **three main policy areas.**

- **Systemic issues** — affect all or at least most parts of the aviation system, including overall safety management and governance as well as human factors and post-accident support.
- **Operational issues** — affect day-to-day operations for airlines, airports and air traffic organisations (e.g. runway safety, loss of control and flight upsets, weather hazards).
- **Emerging issues** — new issues, including drones, new business models and security threats, but also new potential avenues for increasing safety, such as big data.

FIGURE 8 P4P safety R & I project analysis process



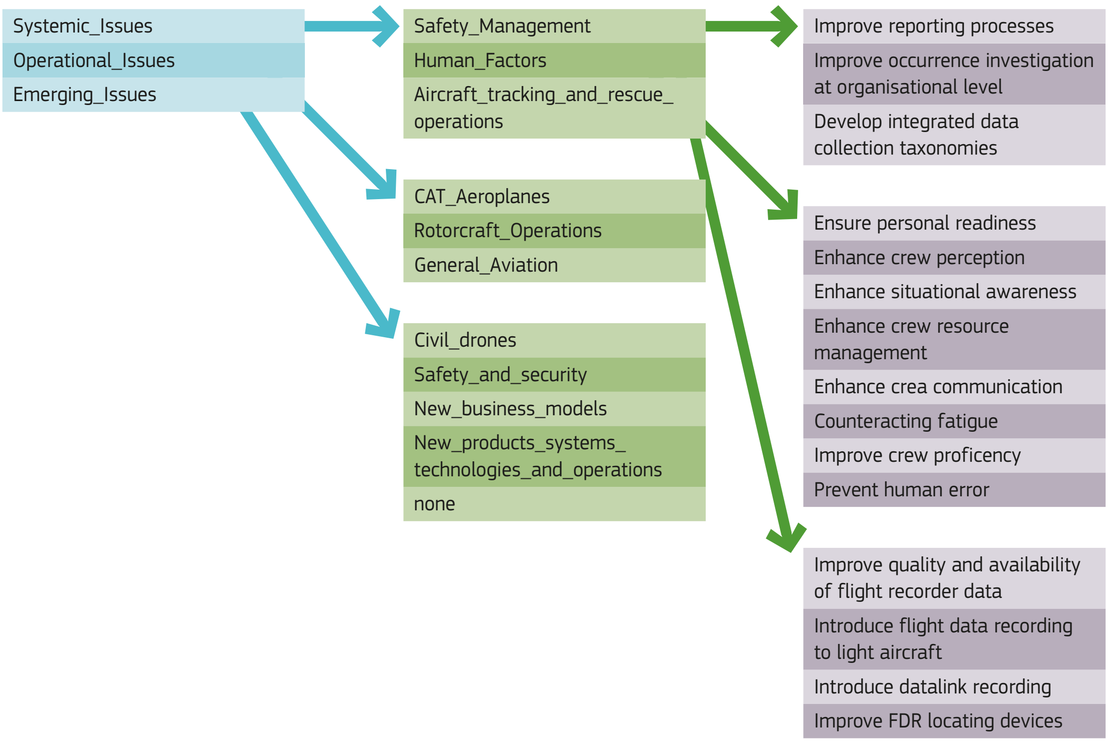
These are broken down into several 'action areas' on a second or even third level. For each area 'actions and types of tasks' are defined using the following labels: RMT (rule-making), SPT (safety promotion), FOT (focused oversight) or RES (research actions). While such activities were not set up to direct R & I efforts at an EC level, but rather to initiate and coordinate follow-up actions on authority level, the overall 'action area' layout provides a helpful and comprehensive structure to categorise recent R & I projects.

In order to determine safety research implications for EU policy, the following steps were undertaken (see Figure 9).

4. EU projects from FP7, H2020, SESAR, SESAR 2020, Clean Sky and Clean Sky 2 were scanned for safety content: 160 projects were selected for initial review by the project team.
5. Of these projects, 53 were selected for a deeper review by the project team, based on them having a clearer and stronger focus on safety.
6. The hierarchical policy structure of the EPAS document was extracted (see Figure 8) and core topics identified.
7. The 53 R & I projects were linked to respective policy action areas defined in the EPAS document.
8. The resulting relations were analysed for:
   - action areas with R & I contributions,
   - action areas with *no* R & I contributions,
   - R & I projects which could not be linked to action areas.

To aid the analysis process a Microsoft-Excel-based tool was developed, which allowed each project considered to be attributed to its respective EASA 'action area' based on key phrases reflecting the EASA policy hierarchy (see Figure 9 and Annex I). To better illustrate the action area content for the systemic issues, an additional level of key phrases was derived from the given activities defined by EASA, as well as other background knowledge for each low-level activity area. This helped the team members better understand the inherent ideas behind the EASA action areas. Up to three policy-relevant action areas were selected for each project, and any project could contribute to more than one action area.

FIGURE 9 Further breakdown of EASA activity areas for the analysis



RESULTS AT A GLANCE

In the following table the assignment of R & I projects to EASA's EPAS activity areas are shown. Projects (top-bottom) in **green show clear mapping**, projects in **yellow raised some (minor) issues** and projects in **red have clear policy issues** when compared with EPAS. Further, activity areas (left-right) in green are well supported by R & I projects, while areas in yellow have limited support or, in the case of red markings have one or no contributions. Note that the colours indicate the respective number of projects, but not necessarily their impact on safety.

TABLE 1 Assignment of projects against EPAS activity areas

	Sys – Safety management	Sys – Human Factors	Sys – Aircraft tracking and rescue ops.	Op – CAT – Aircraft upset in-flight	Op – CAT – Runway safety	Op – CAT – Mid-air collisions	Op – CAT – Design and maintenance provements	Op – CAT – Ground safety	Op – CAT – Terrain conflict	Op – CAT – Fire smoke and fumes	Op – Rotorcraft_Operations	Op – GA – Systemic Enablers	Op – GA – Staying in control	Op – GA – Coping with weather	Op – GA – Prevent mid-air collisions	Op – GA – Managing the flight	Em – Civil_drones	Em – Safety_and_security	Em – New_business_models	Em – New_prod., syst., tech. & ops
Across		x		x																
ACTIonRCraft											x									x
AISHA II							x													
Alicia		x									x									
A-PiMod		x		x																
Aristotel		x									x									x
ASCOS	x						x													
Bemosa		x																		x
Bladeout							x													x
CORUS																	x		x	
Defender							x													
Delicat				x										x						
Eunadics														x						
EVITA							x													x
Extice														x						
Flysafe		x		x					x											
Future Sky Safety (P4)	x																			
Future Sky Safety (P5)	x	x																		
Future Sky Safety (P6)		x																		
Future Sky Safety (P3)					x															
Future Sky Safety (P7)										x										x
HAIC														x						
Hisvesta									x		x									
HUMAN		x																		
Hypmoces																				x
Hypstair		x																		x
IASS							x													

	Sys – Safety management	Sys – Human Factors	Sys – Aircraft tracking and rescue ops.	Op – CAT – Aircraft upset in-flight	Op – CAT – Runway safety	Op – CAT – Mid-air collisions	Op – CAT – Design and maintenance provements	Op – CAT – Ground safety	Op – CAT – Terrain conflict	Op – CAT – Fire smoke and fumes	Op – Rotorcraft_Operations	Op – GA – Systemic Enablers	Op – GA – Staying in control	Op – GA – Coping with weather	Op – GA – Prevent mid-air collisions	Op – GA – Managing the flight	Em – Civil_drones	Em – Safety_and_security	Em – New_business_models	Em – New_prod., syst., tech. & ops
JEDI ACE														x						
LAYSA							x													
Man4gen		x																		
MISSA							x													
Monifly																	x			
Mycopter		x															x			
ODICIS		x																		
PJ02 EARTH					x															
Podium		x															x			
PPlane		x															x		x	x
Prospero	x	x																		
Reconfigure		x		x																x
Redish							x													x
SAFAR													x							
Safe-clouds	x																			
Safuel																				x
Sapient																	x	x		
SARAH											x									
SMAES							x													x
Stress		x																		
SUPRA		x																		
Svetlana	x																			
TaCo		x																		
UFO					x															
ULTRA	x																x			
Wezard														x						

R & I ACHIEVEMENTS TOWARDS POLICY RECOMMENDATIONS

The detailed analysis of the projects is given in Annex II. For the **systemic** area, safety management appeared well addressed (7 projects), except for the upcoming area of drones and remotely piloted aerial systems (RPAS). Human factors was well addressed (18 projects), though some of this research appeared fragmented, and not strongly focused on operational risks. The one area where there appeared to be a research gap was in aircraft tracking and rescue operations.

For the **operational** area, 35 projects addressed key operational risks, predominantly for commercial aircraft, with some projects focusing on rotorcraft operations. Some gaps were identified concerning general aviation. Certain gaps were also identified for key operational-risk areas, including mid-air collision involving an aircraft without a functioning transponder and ground-handling safety. Additionally, terrain conflict and fire aboard aircraft appeared under-represented by research. Lastly in this area, although a number of projects did address flight upset, the project team judged that the research was unlikely to be sufficient to significantly reduce this key risk.

For the **emerging** area, a total of 22 projects were identified, with coverage of the four sub-areas as follows: drones & RPAS (7), safety and security (1), new business models (2) and new products and technologies (12).

This analysis revealed a healthy spread of research across *systemic* (25), *operational* (35) and *emerging* (22) risk areas, with most focus on operational risks. Nevertheless, the following 12 research gaps were identified.

SYSTEMIC

1. SAFETY MANAGEMENT FOR RPAS, DRONES AND PERSONAL AIR VEHICLES

Whilst there is research on the safety of all these emergent aircraft systems, and a safety-regulation framework is developing [14], research into how to set up a comprehensive safety-management framework for them and their diverse business models is missing. The large-scale introduction of drones is imminent in Europe. This area would benefit from a focused research thread and/or embedded-research approach which must also pave the way forward for the future technologies and business models already on the horizon, such as sky taxis and personal air vehicles [15].

2. FOCUSED HUMAN FACTORS RESEARCH

Linked to specific operational issues (e.g. flight upset), the human factors research sometimes has the appearance of a shotgun approach, whereas a more focused programmatic approach, able to bring the various research strands together, is needed to resolve key risk areas, e.g. via human factors-driven automation support and advanced simulator training for flight upset conditions. This area would benefit from a flagship project.

3. GENERAL AVIATION SAFETY

Although there is a new GA safety roadmap, it may be that better safety governance of GA is required to create a 'level playing field' of safety across GA, including business jets and helicopter operations, so that GA flying risk is comparable with that of commercial aviation traffic.

4. FLIGHT TRACKING AND RESCUE OPERATIONS

Although regulations are coming into force on global tracking of aircraft following the disappearance of flight MH370, there is little research in this area. More generally, research is needed to increase the survivability of air accidents, whether aircraft or rotorcraft [16]. This area deserves a research thread or a flagship project.

OPERATIONAL

5. FLIGHT UPSET

Whether due to technical failure or adverse

14 https://www.easa.europa.eu/easa-and-you/civil-drones-rpas

15 Expected to be addressed in SESAR 2020 within the enabling framework of U-space.

16 A recent workshop on rotorcraft safety suggested that there was significant scope to improve survivability from helicopter accidents: http://www.optics-project.eu/optics1/wp-content/uploads/2017/06/OPTICS_report_4th_workshop.pdf

weather conditions, is currently the biggest risk area in Europe, and although there is research, as with item 2, it may need a more programmatic approach to significantly reduce the risk (e.g. focusing on safe handling in all weather conditions), most probably via a flagship research project.

6. MID-AIR COLLISION e.g. against aircraft without a functioning transponder

This appears to be a blind spot in research. Although there is a traffic collision avoidance system (TCAS), this does not work with an aircraft without an operational transponder. This is a top five risk in the European air traffic network, and deserves more research attention, probably via an embedded approach and/or a focused research project. Additionally, this research avenue needs to address the issue of pilots not following TCAS advice (TCAS resolution advisories).

7. GROUND-HANDLING SAFETY RISKS

This appears to be another blind spot, as incidents on the ground during ground handling can lead to events later on in-flight, as well as carrying their own risk to staff. This area needs to be addressed, probably by a new research thread or embedded research.

8. TERRAIN CONFLICT

Controlled flight into terrain (CFIT) remains a significant operational risk. This area requires more research, either alone or else in conjunction with items 2 and 4 above (therefore flagship or embedded research approach).

9. FIRE ON-BOARD AIRCRAFT

There is surprisingly little European research on fire onboard aircraft (although the European Aviation Safety Agency participates in US Federal Aviation Administration (FAA)-led research [17]) given that such fires are intensely hazardous, whether the aircraft affected is in the air or on the ground. More research is needed in this area, paying particular attention to battery issues, as cargo and energy storage device.

EMERGING

10. NEW BUSINESS ENVIRONMENTS

The systemic impact of low-cost business models on aviation safety needs to be better understood (see recent EASA guidance [18]) so that safeguards can be put in place. Additionally, new business environments and cost pressures, as well as new entrants and faster development timescales, are likely to put pressure on regulatory systems and certification processes, with a potential shifting of more certification responsibilities to suppliers. Such aspects should be tackled via a new research thread to ensure that cost pressures are not eroding aviation safety.

11. NEW TECHNOLOGIES

These can range from pilots taking their computer tablets into cockpits to have the most up-to-date weather information, to 3D printing and advanced composite materials in manufacturing, to artificial intelligence and its potential future roles in aviation. Such advances need to be evaluated for safety benefits (and not only safety threats) as is happening today via big-data algorithms applied to aviation safety. This area is probably best served by exploratory projects and subsequent research threads for the most promising research avenues.

12. CYBERSECURITY

Surprisingly little research was found on this area for aviation safety, though possibly it is occurring elsewhere under security research [19]. Nevertheless, air traffic networks, airports and airlines are obvious targets for cyberattacks, not to mention future aerial systems such as drones and personal vehicles. This area deserves an initial exploratory project, probably leading to its own research thread.

The policy implications surrounding these identified gaps in research are outlined in Chapter 4.

17 https://www.fire.tc.faa.gov/Cabin

18 https://www.easa.europa.eu/system/files/dfu/Practical%20Guide%20New%20Business%20Models%20Hazards%20Mgt.pdf

19 EU security research is available for all relevant sectors (including aviation) in Horizon 2020 societal challenge 'Secure societies — protecting freedom and security of Europe and its citizens'. It includes calls for prevention, detection, response and mitigation of combined physical and cyber threats to critical infrastructure in Europe (e.g. call topic SU-INFRA01-2018-2019-2020). The new coordination support action Optics2 is set to assess all research projects relevant to aviation security and safety (http://www.optics-project.eu/). Cybersecurity infrastructure deployment opportunities are available in the Connecting Europe Facility programme (e.g. call CEF-TC-2017-2).

IMPACT OF EU-FUNDED RESEARCH ON SAFETY STANDARDS AND REGULATIONS

Since aviation safety is underpinned by regulations, an indication of the value of safety research is given by the impact of research on safety standards and regulations. The following table highlights examples of safety research projects that have impacted — or are in the process of impacting — the development of safety standards and regulations (a fuller version is given in Annex III). Of the 53 projects analysed in more depth, 27 had impacts on policy or safety regulations, which highlights the value of the research and its impact on operational safety. Furthermore, the project Optics, which reviewed almost 250 aviation-safety research projects and programmes, suggested that on average some 40 % of aviation safety R & I projects have an impact on standards and regulations, whether directly or indirectly helping to inform them. This is a critical part of the safety-research 'business model', and appears to be working well.

TABLE 2 Examples of safety research impact on regulations [20]

Research project	Impacts on policy, society and/or industry
Across	This project has helped to inform the ongoing loss-of-control avoidance and recovery training (Locart) initiative for EASA and ICAO.
Extice	High policy impact expected on the joint development of new regulations for extreme icing conditions. > EASA, the US FAA and Transport Canada (TC) intend to jointly develop and issue updated regulations for certification of super-cooled large droplets (SLD). A comprehensive proposal for new regulations known as 'Appendix O' for extreme icing conditions.
Future sky safety (P5)	This ongoing project has already had impact, via a pan-European safety culture survey of European pilots, on recent EASA guidance on hazard identification with new business models. *EASA practical guide: Management of hazards related to new business models of commercial air transport operators.*
HAIC	High policy impact > International cooperation with public authorities (EASA, FAA, European Organisation for Civil Aviation Equipment (Eurocae), (US) National Aeronautics and Space Administration (NASA) etc.). > Initiation of a set of joint regulations. > FAA report: assessment of mixed phase and glaciated icing environment as defined in Appendices D and P; assessment of CS-25 in Appendix B. > Calibration method as basis for (US) Society of Automotive Engineers (SAE) aerospace recommended practice (ARP) 5905. ** CS-25 — Certification specification on large aeroplanes by EASA.*
IASS	The results of this project will have direct benefits on lowering power consumption whilst increasing the efficiency and the safety of new aircraft designs.
Man4gen	This project has influenced the EASA notice for proposed amendment (NPA) 2017-06 *Loss of control or loss of flight path during go-around or other flight phases* for training of flight crew for adverse flight situations and flight upsets.

20 A more comprehensive table can be found in Annex III.

Research project	Impacts on policy, society and/or industry
MISSA	Guidance material on inclusion of safety in design targeted to the industry-standards bodies has been developed. Also, the outcome of projects strengthen industries' socioeconomic position in the matters of competition. > Guidelines of aircraft systems certification & airworthiness (ARP4754 & 4761). > Software considerations in airborne equipment certification (RTCA DO-178C). * *Radio Technical Commission for Aeronautics (RTCA).*
Reconfigure	In the project scope, EASA has recently released two NPAs (NPA 2017-13 on training, NPA 2017-06 *Loss of control or loss of flight path during go-around or other flight phases*).
SMAES	The project addresses analysing of areas requested for large transport aircraft for EASA (CS 25.801 — 7.1.3.3 Aircraft safety, 7.1.4.1 *Aircraft development cost*).
SUPRA	This project on advanced simulators for flight-upset training is believed to have influenced the EASA NPA 2017-06 *Loss of control or loss of flight path during go-around or other flight phases*.
Svetlana	The project focused on a common EU-Russia approach for flight-data analysis and aimed to promote new analysis processes and standards.
UFO	High priority impact, resulting in EASA safety information bulletin 2017-10 (*Safety information on wake vortex*)
Wezard	High impact on research policy. Aim and result was to identify research gaps and derive policy recommendations. The project provided a R & D roadmap identifying research gaps and recommending research priorities for future programming to design multi-year research programmes and to inform public authorities such as ICAO, EASA and FAA on future developments.

THE CASE FOR TRANSFORMATION OF AVIATION SAFETY RESEARCH POLICY

Sometimes a review such as this one leads to the need for more research in key areas, perhaps some of which is of a more strategic nature. At other times (as is the case here) the analysis suggests a need for a more fundamental change in the way research is organised in order to transform the research approach into a more effective **research-for-society delivery system**. Before discussing the individual policy recommendations themselves in Chapter 4, the 'case for transformation' needs to be made, and is based on the following five observations on aviation-safety research in Europe.

1. NICE TO HAVE, OR NEED TO HAVE?

Clearly from the review, there is high-quality safety research ongoing, and much of it is well directed in terms of tackling valid safety concerns. However, as also noted in the Optics review of aviation safety **research, research is often not picked up by industry and good ideas are left unimplemented**. It is as if the research output is seen by industry as being 'nice to have', rather than 'need to have', or else it is seen as too costly, or not sufficiently adapted or tailored to industry needs, and/or is not mandated by the regulator.

2. FRAGMENTED OR JOINED-UP?

In other areas the research appears fragmented, and is not integrated into a common roadmap that will have a major impact on safety. Such a piecemeal approach to safety allows vulnerabilities to persist in the aviation system's defences. There are areas where we appear to get it right, such as icing research, which has sufficient 'critical mass' to lead to substantial improvements, as well as a **strategic advisory group** to keep it on the right track. Other areas, such as weather research more generally, and human factors, appear **more fragmented, leading sometimes to repetitive research** which does not impact the real system (and thus is not being adopted by the industry).

3. COMPETITIVE OR COLLABORATIVE?

A third observation relates to the competitive nature of aviation, which may be good for the customer in many ways, though not necessarily when it comes to safety. A decade ago, the idea was that if each aviation organisation looked after its own safety, then the overall system would be fine. This thinking is outdated, for two reasons. First, **aviation is a collection of tightly connected organisations which must collaborate on certain fronts, while competing on others**. If one organisation has an accident, the shock wave affects others. If an airline notes a safety threat but does not tell others (and if all airlines operate this way) then the outcome is an unsafe system, and ultimately an unprofitable one when an accident occurs. The second reason is that new, more powerful safety methods are emerging, such as **big data**, which can help safety, but only if sufficient data are shared. This open sharing of data is not yet happening, at least in Europe [21], although some airline groups are beginning to move towards a policy of 'non-competition where safety is concerned'.

4. REACTIVE OR PROACTIVE?

A fourth observation is that safety in any industry tends to be 'on the back foot', meaning it is reactive rather than proactive, not looking forward to the next challenge and what is 'around the corner'. Currently, **safety research is playing 'catch-up'** with drones, but already there are other challenges coming soon, such as personal aerial vehicles (PAVs), as well as future business models for drones, sky taxis and PAVs. Safety in aviation has a hard-won reputation, one it has built up over decades, and its safety-management system (SMS) is strong. But while today there are several hundred commercial airlines in the world, in the near future it is estimated that there will be tens of thousands of drone-operating companies. How scalable will today's airline SMS be to such companies, and how will we train and license tomorrow's sky-taxi and private PAV pilots, and certify drone taxis?

5. ENGAGED, OR WATCHING FROM THE SIDELINES?

The fifth observation relates to complacency. Aviation is very safe, especially when compared to road safety, for example. The question naturally arises of whether we really need to change anything? And even if we do need research, is European-funded research the answer? These are valid questions, with equally compelling answers. Aviation is an industry under significant cost pressure. In recent months two long-standing European airlines have filed for bankruptcy, and it is well known that safety can come under pressure in organisations as resources become scarcer and everyone has to work 'faster, better, cheaper' (the well-known and now-discarded mantra of NASA prior to the Columbia space shuttle disaster in 2003). Added to this are the major challenges facing the industry in the next decade, some of which (drones) are already arriving and challenging safety (e.g. drone infringements in the vicinity of airports). There is no room for complacency. European-funded research should be an obvious business solution, since it saves organisations from having to pay for the research themselves. Additionally, access to and involvement in such research programmes has recently been made easier, with less administrative burden, particularly for airlines. As before, this requires a collaborative rather than competitive approach to safety research by industry. If there were more serious engagement by industry in safety research, and **more industry stewardship in safety-research roadmaps** and major programmes, the quality and impact of such research would markedly increase.

Together with the research gaps identified by the analysis, these considerations lead to the policy recommendations outlined in the next chapter.

21 Although the EASA-led Data4Safety programme may change this https://www.easa.europa.eu/newsroom-and-events/news/data4safety-partnership-data-driven-aviation-safety-analysis-europe

POLICY RECOMMENDATIONS

TEN POLICY RECOMMENDATIONS

The review of the challenges facing aviation safety, the associated research avenues, apparent gaps, and observations on the current European safety-research 'business model', lead to the identification of 10 new policy considerations which together could transform aviation safety research. These policies aim to deliver better protection for passengers, business organisations and their staff, and the entire aviation community, from future accidents. The 10 policy recommendations are outlined below.

SYSTEMIC

1. TOWARDS A RISK-BASED RESEARCH STRATEGY

The analysis in Chapter 3 highlighted certain gaps in safety research, including flight upset, mid-air collision, terrain conflict, fire aboard aircraft, ground-handling accidents and areas concerning rotorcraft and GA safety. What the public might assume is that a healthy proportion of safety research is based on an estimation of the risks, and the anticipated safety 'return on investment' (i.e. potential for reduction of accidents and lives lost). This implies a risk-based research strategy, able to prioritise research based at least partly on a 'risk observatory', which continually monitors and aggregates aviation safety risks based on European data and quantifiable accident models that account for weather, technical failures, human performance, etc. This risk-informed approach would not apply to all safety research, since for both systemic and emerging areas the return on investment is hard to quantify. But it would mean that there would be an explanation for any identified gaps, so that the decision-making about what research is funded, and what is not funded, remains transparent and justifiable

2. SHARING SAFETY DATA AND SAFETY INTELLIGENCE

Safety management in aviation is seen by many industries as 'best in class'. If data are not shared and collectively analysed using both existing and new methods in order to yield and disseminate actionable safety intelligence, safety management will fall behind, and its ability to anticipate risks and fine-tune its operations for safety and efficiency will be limited. The aviation community needs to agree to share its data and the resulting safety intelligence, and not compete where safety is concerned, because one accident affects the wider community. This will lead to smarter use of data, and generate the economies of scale needed for big-data and other data-mining approaches which will allow us to 'see around the corner,' as well as fine-tuning local operations as many airlines are now already trying to do through flight-data-monitoring (FDM) analysis.

3. SAFETY CULTURE ACROSS THE AVIATION COMMUNITY

SMSs only work if there is a strong safety culture to bring them to life, especially in a highly competitive business environment. Otherwise safety standards will slowly erode. Safety culture needs to be more than a phrase or a mantra, it needs to be led from the top, energised throughout organisations, and periodically evaluated as a check against the potential to 'drift into danger'. A strong indication of safety commitment at the top is greater cross-organisational collaboration for safety, putting aside competition where safety is concerned. This would also help safeguard against the potential negative impacts on safety of new business models and new business entrants, as well as cost pressures across the industry, including those affecting regulatory authorities.

4. HARNESSING HUMAN FACTORS

The Optics review noted that human factors was used more strategically in the US than in European aviation-safety research. A narrow focus on a single human factors element such as training or cockpit design rarely resolves an issue because human beings are part of the system. Hence a more integrated human factors approach is required. Aviation remains highly human centric. This core discipline needs to be harnessed and integrated into embedded research programmes: firstly as an equal partner and secondly being applied to resolve key operational risks such as flight upsets. It should also be used proactively to explore emerging risks and practicable solutions in areas that will be harder to regulate, including drones, sky taxis and personal vehicles.

OPERATIONAL

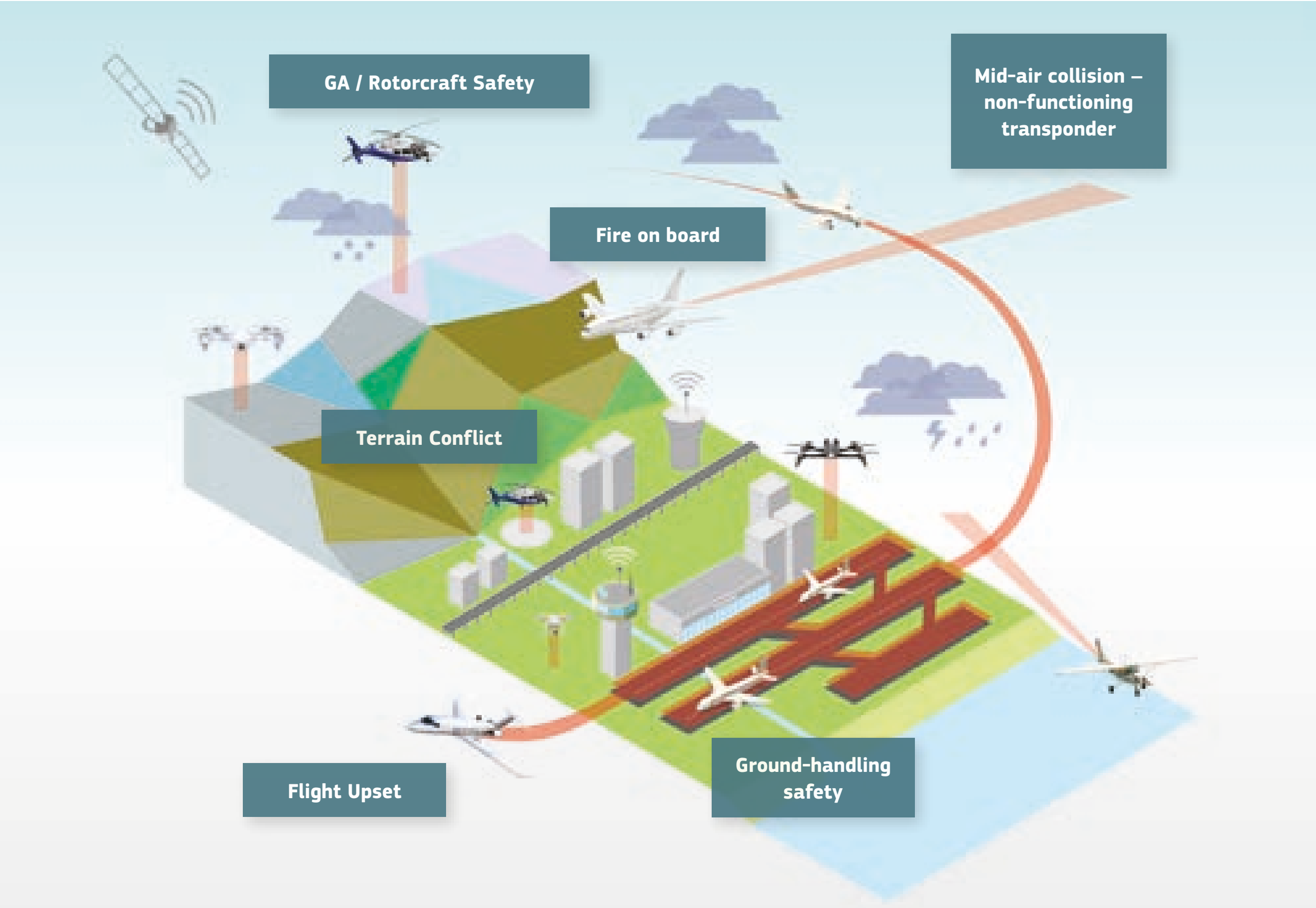
5. REDUCING THE OPERATIONAL RISK PORTFOLIO

The key risk in European air travel today is flight upset, wherein an engine or aircraft system failure, or a severe weather situation or wake-vortex encounter leads to loss of control of the aircraft, and the pilots are unable to cope with the situation. There are other operational risks as noted in the previous chapter and highlighted in Figure 10. A strategic and focused research drive towards reducing the risk of the current portfolio needs to be pursued, using an appropriate mixture of flagship, research thread and embedded research strategies, and based on risk priority and potential safety gain. This drive must include efforts to raise the level of GA and rotorcraft safety to that achieved for commercial scheduled flights. The aim should be to significantly reduce these risks by 2025.

6. IMPROVING POST-ACCIDENT SURVIVABILITY

The areas of flight tracking, rescue and survivability deserve their own research thread. This policy area concerns both scheduled and GA flights, including helicopter operations where there may be relatively

FIGURE 10 Key operational risk area priorities for research (source: DeepBlue based on the EU-funded project ALICIA)



'quick wins' in terms of saving lives following a crash, through enhanced on-board safety protection features. While there are certain accident categories (e.g. mid-air collision) with a low probability of survival, there are many others where research attention to rapid rescue and post-crash survivability could save the lives of crew and passengers.

EMERGING

7. PROPORTIONATE SAFETY-MANAGEMENT ARRANGEMENTS FOR NEW AVIATION PLAYERS

As noted earlier, aviation's exemplary SMS is unlikely to be agile enough for new entrants and players on the aviation scene, especially drones, Uber-style companies and personal vehicles. Although a track of safety research for drones is now underway, this is largely looking at their risks in relation to the current system, whereas full-scale operations, once started, are likely to evolve rapidly. The scale and rate of evolution could overwhelm and outstrip the current SMSs, and accidents (most likely collisions or third-party injuries or even fatalities) are a significant risk during early introduction. It is imperative to develop a scaled-down yet effective and fit-for-purpose safety-management and certification approach for such new aerial vehicles and business models. This approach needs to include human factors e.g. for remote piloting and safe drone control, pilot licensing and on-board displays in sky taxis (crewed and uncrewed) as well as PAVs. There is also a historic opportunity to 'leapfrog' conventional aviation's data-sharing reluctance by issuing requirements on new players in terms of sharing safety-performance data at the outset. It might also be wise to set up a central data-analysis function (an 'overwatch') to analyse and stay ahead of the rapid evolution of these new aerial systems and monitor their impact on the safety of the conventional commercial air-transport system.

8. COLLABORATIVE SAFETY AND SECURITY

Travelling passengers and business users today are as concerned with security as they are with safety, but might be surprised to learn that these two domains work almost completely independently of each other. Today's security threats, including cybersecurity, blur the traditional divide between the two approaches. The research reviewed in this P4P exercise barely scratches the surface of what could occur in terms of safety and security collaboration. At the same time, there is a trend in aviation organisations such that many former directors of safety now also find security in their portfolio. The two domains are unlikely to merge completely because they each have a distinct focus, skillset and tools, not to mention culture. Yet there are bound to be potentially valuable synergies, and the two domains could undoubtedly learn from each other's methods and practices. What is therefore needed is a research roadmap to explore how to bring safety and security closer together in useful ways, to optimise collaboration, greater efficiency from pooling of resources and leverage between the two domains, and reduce the real risk to passengers, aviation staff and business users.

9. NEW TECHNOLOGIES AND SAFETY SOLUTIONS

New technologies, from digitalisation, to 3D manufacturing, to artificial intelligence, can be seen either as disruptive technologies whose risk contribution needs to be assessed and managed, or potential avenues towards new safety solutions. Research looking for 'positive safety' needs to embrace these advances and determine what can be distilled from them to generate added safety in aviation. Aviation as an industry is known to be of very high quality, but also to be conservative, with innovations slow to appear in the cockpit or on the ground. Research on new technological advances will help aviation safety become more agile. This includes the need to look for solutions outside aviation's borders, and into other industry sectors.

10. EUROPE AS A GLOBAL AVIATION SAFETY RESEARCH PLAYER

There is clearly tremendous potential in the EU for world-leading aviation-safety research, but often such research is fragmented and compartmentalised. For example, there could be far better coordination between European-Commission funded aviation-safety research and national aviation safety-research programmes and projects. In the US, the FAA has access and control over a large portion of the aviation budget. However if the various EC-funded and European national and regional research budgets are added up they get closer to those in the US. Currently the EU does not always speak with one voice due to this fragmented and competitive state of safety research. This makes it harder to respond when a sudden safety issue emerges, such as lithium-ion batteries, and difficult to deploy fast-track research to provide prompt answers and safety assurances for passengers and other users of European airspace. The EU needs to 'join-up' the various components of its research capability to create virtual centres of excellence and expertise. This can be supported in three ways.

1. The first is the setting up of key strategic advisory groups (e.g. as already done for icing, but potentially also for drones, weather, flight upset, etc.), to help focus the research and ensure the right research is done, is adapted to the realities of aviation operations, and is subsequently implemented by industry.

2. The second is to run flagship projects in key areas, and outreach to the international community (i.e. outside the EU borders) so that the research can have a global impact.

3. The third is via an annual aviation safety research conference that brings European researchers and industry closer together, since such familiarity and networking are necessary in order to foster better alliances, and to lead to a more 'joined-up' European research capability.

These 10 policy areas come together as shown in the Figure 11, delivering a comprehensive aviation safety research framework for European air transport, one that will maximise the benefits to European citizens and all users of European airspace.

FIGURE 11 An aviation safety research framework for safe European air transport

CONCLUSIONS

Aviation is generally seen as being the leader for safety in the four transport modes (air, rail, sea and road), and safety research helps maintain this position of confidence with passengers and businesses alike. Yet despite commercial aviation's outstanding safety record, the existing system still contains inherent and difficult-to-eliminate operational risks, such as flight upset and subsequent crash of an aircraft. It is also embracing new business models which can put pressure on safety, and addressing the arrival of new air vehicle types such as drones.

Safety research and innovation is tackling the key risks, as well as the systemic issues that underpin effective safety governance across the entire industry, and the emerging issues such as drone safety. The amount of safety research is significant, involving collaboration between diverse European centres of expertise, with the lion's share of research focusing on overcoming key risks of today and keeping the future aviation system resilient against future risks.

Nevertheless, the review of the projects has identified 12 areas where more needs to be done. Some of these relate to long-standing threats such as loss of control in-flight, and fire on-board aircraft, whereas others are relatively new such as drone-safety governance, ground-handling safety, cybersecurity on safety, mid-air collision, and rotorcraft and general aviation safety.

Systemic issues — which run deeper but can affect the safety of the entire system — are generally well addressed, but there is room for improvement via research on how to spread safety culture across the aviation community to the extent that safety data and information are willingly shared and analysed, which will lead to better safety intelligence and a risk-based research agenda. Similarly, the way in which we take care of human factors in aviation safety research needs to improve, and research is required on the future safety governance systems which will ensure safe integration of drones, sky taxis and personal air vehicles into the aviation system.

European citizens and businesses alike would be better served by an upgraded aviation safety research process, one that ensures sharper focus on key issues, as well as research streams and flagship projects to resolve long-standing key risks, and to better prepare us for the future. The 10 policy recommendations should deliver better 'return on investment' in terms of safety for European airspace users, generating safety solutions that fit industry needs, and paving the way towards more suitable safety solutions for new business entrants offering novel services, including citizens who in the future will take to the skies themselves via Personal Air Vehicles.

This is a timely opportunity for an upgrade to the way aviation safety research is funded and overseen. This will lead to more effective research, whether focusing to significantly reduce or mitigation of key risks, dealing with systemic issues or emerging risks and safety opportunities. This new approach will be achieved via better focus as well as industrial participation and stewardship, as well as a less compartmentalised and more 'joined-up' European research community, including the enhanced collaboration between DG Research and Innovation and the European Aviation Safety Agency (EASA). This approach will maintain aviation safety's position as the leader in the field of safety both now, and for the foreseeable future, whilst making Europe a global player in aviation-safety research.

ANNEXES

ANNEX 1 BREAKDOWN OF KEY PHRASES USED IN THE ASSESSMENT

TABLE: KEY PHRASES FOR SYSTEMIC ISSUES

EASA focus issue	EASA key phrase level 1	EASA key phrase level 2	EASA key phrase level 3 (only for L2: CAT_Aeroplanes and general aviation)
Focus Issues			
Systemic_Issues	**Systemic_Issues**		
	Safety_Management	**Safety_Management**	
		- improve reporting processes - improve occurrence investigation at organisational level - develop integrated data collection taxonomies	
	Human_Factors	**Human_Factors**	
		- ensure personal readiness - enhance crew perception - enhance situational awareness - enhance crew resource management - enhance crew communication - counteracting fatigue - improve crew proficiency - prevent human error - none	
	Aircraft_tracking_and_rescue_operations	**Aircraft_tracking_and_rescue_operations**	
		- improve quality and availability of flight recorder data - introduce flight data recording to light aircraft - introduce datalink recording - improve FDR locating devices - none	

LEGEND:

Items directly derived from EASA policy structure

Complementing Items

TABLE: KEY PHRASES FOR OPERATIONAL ISSUES

EASA focus issue	EASA key phrase level 1	EASA key phrase level 2	EASA key phrase level 3 (only for L2: CAT_Aeroplanes and general aviation)
Operational_Issues	**Operational_Issues**		
	CAT_Aeroplanes	**CAT_Aeroplanes**	
		Aircraft_upset_in_flight	**Aircraft_upset_in_flight**
			- prevent loss of control
		Runway_safety	**Runway_safety**
			- prevent runway overruns & deviations - prevent tail, wing & nacelle strikes
		Mid_air_collisions	**Mid_air_collisions**
			- introduce collision avoidance equipment to light aircraft - develop necessary organisational and technical requirements on airspace design - enhance and harmonise provision of aeronautical information
		Design_and_maintenance_improvements	**Design_and_maintenance_improvements**
			- enhance design-time aeroplane-level safety assessment - enhance crashworthiness - enhance MRO procedures - enhance inspection methods - mitigate effects of bird strike - mitigate effects engine disintegration
		Ground_safety	**Ground_safety**
			- prevent collisions with other aircraft, vehicles & personal - prevent incidents related to ground handling (loading, refuelling, etc.) - prevent aircraft contamination on ground

LEGEND:

Items directly derived from EASA policy structure

Complementing Items

TABLE: KEY PHRASES FOR OPERATIONAL ISSUES

EASA focus issue	EASA key phrase level 1	EASA key phrase level 2	EASA key phrase level 3 (only for L2: CAT_Aeroplanes and general aviation)
		Terrain_conflict	**Terrain_conflict**
			- prevent CFIT
		Fire_smoke_and_fumes	**Fire_smoke_and_fumes**
			- prevent in-flight fire - provide adequate cabin air quality
	Rotorcraft_Operations	**Rotorcraft_Operations**	
		- Improve survivability of rotorcraft occupants (crash, ditching, etc.) - Enhance pilot vision - Prevent CFIT - Prevent accidents related to helicopter operations (hoisting, etc.) - Prevent accidents related to engine, gear, rotor components - Prevent human-factors-related accidents	
	General_Aviation	**General_Aviation**	
		Systemic_enablers	**Systemic_enablers**
			- develop safety improving technology
		Staying_in_control	**Staying_in_control**
			- prevent loss of control accidents
		Coping_with_weather	**Coping_with_weather**
			- better provide weather information to the cockpit - prevent inadvertent entry into IMC
		Preventing_mid_air_collisions	**Preventing_mid_air_collisions**
			- prevent collisions with other aircraft - prevent airspace infringement
		Managing_the_flight	**Managing_the_flight**
			- improve fuel management - improve terrain and obstacle awareness

LEGEND:

Items directly derived from EASA policy structure

Complementing Items

TABLE: KEY PHRASES FOR EMERGING ISSUES

EASA focus issue	EASA key phrase level 1	EASA key phrase level 2	EASA key phrase level 3 (only for L2: CAT_Aeroplanes and general aviation)
Emerging_Issues	**Emerging_issues**		
	Civil_drones	**Civil_drones**	
		- develop operational procedures - prevent collisions with other aircraft - consolidate certification requirements	
	Safety_and_security	**Safety_and_security**	
		- prevent passenger interference with aircraft on-board systems - prevent unauthorised interference with ATM systems	
	New_business_models		
	New_products_systems_technologies_and_operations	**New_products_systems_technologies_and_operations**	
		- develop training procedures for Powered lift (tilt rotor) aircraft - develop operational procedures for Powered lift (tilt rotor) aircraft	

LEGEND:

Items directly derived from EASA policy structure

Complementing Items

ANNEX 2 SAFETY RESEARCH INFORMING STANDARDS & REGULATIONS

IMPACTS

Research project	Safety focus issue	Impacts on policy	Impacts on society and/or industry	Remarks
Across	Systemic	This project may have had impact on the ongoing **Locart initiative for EASA and ICAO.**		Of interest to EASA, few Project meetings with EASA experts.
AISHA II	Emerging/ operational		Innovative solutions and lighter parts of aircraft for improving competitiveness of European aeronautics.	A success for the funding policy of the EC within the FP7.
ASCOS	Systemic	Considering that adapting rules and the applicable certification processes usually are long-lasting and 'grandfather rules' may apply, the measurable results may be achieved from 2020 onwards. The results of the project may be achieved after entering into force of the reviewed aviation safety basic regulation.	ASCOS continuous safety monitoring tool is made available through the Eccairs Portal of the EC-JRC.	Systemic issues monitored by EASA, contributing to EASAs identified tasks.
Capito	Emerging		**Performance standards for traffic alert & collision avoidance systems (RTCA SC-147 and Eurocae WG75)** ** RTCA — Radio Technical Commission for Aeronautics* ** Eurocae — European Organisation for Civil Aviation Equipment, a standardisation body of worldwide recognised industry standards for aviation*	Not analysed in P4P.
Delicat	Operational	Medium policy impact at the moment, technology not mature enough it is in the state of supplemental type certificate, more test campaigns necessary (beyond light events) in order to give recommendations for certification.		Operational issues monitored by EASA.
EVITA	Emerging/ operational		The new technique was devised as a means to support inspection activities linked to design, manufacturing and assembly of such structures.	Emerging issue followed by EASA.
Extice	Operational	High policy impact expected as they explicitly provide joint development of new regulations for extreme icing conditions. > FAA, TC and EASA **intend to jointly develop and issue updated regulations for certification of SLD**. A comprehensive proposal for new regulations known as 'Appendix O' for extreme icing conditions. ** TC — Transport Canada*		Emerging issues monitored by EASA.

Research project	Safety focus issue	Impacts on policy	Impacts on society and/or industry	Remarks
Flybag2	Emerging/ systemic	Security regulations on mandatory use of blast mitigation devices on-board aircraft.	**Standards on containment of explosive damage.**	Not analysed in P4P.
Future sky safety (P5)	Systemic	Project has already had impact from one of its safety culture surveys on recent EASA guidance on hazard identification with new business models. > Recent EASA practical guide from 15.9.2017 **Management of hazards related to new business models of commercial air transport operators.** > Future potential standard on Safety Culture (ICAO/EASA).		
HAIC	Operational	High policy impact > International cooperation with public authorities (EASA, FAA, Eurocae, NASA etc.). > **Initiation of a set of joint regulations:** • FAA Report — assessment of mixed phase and glaciated icing environment as defined in Appendix D and P; assessment of CS-25 in Appendix B. • Calibration method as basis for SAE ARP 5905. ** CS-25 — Certification Specification on Large Aeroplanes by EASA* ** SAE — US-based Society of Automotive Engineers* ** ARP — Aerospace Recommended Practice*		Emergency issues monitored by EASA, linked to a Safety Recommendation by EASA. High priority.
IASS	Emerging/ operational		The results of project will have direct benefits on lowering power consumption whilst increasing the efficiency and the safety of new aircraft designs.	Emerging issue monitored by EASA.
LAYSA	Emerging/ operational		Strong strategic impact expected with clear socioeconomic benefits within the next five to 10 years by contributing to enhance European aeronautic industry competitiveness, enhance European employment, meet social needs for more environmental friendly, safer and efficient manufacturing/air transport.	
Man4gen	Operational/ systemic	This project is believed to have influenced the **EASA NPA 2017-06 Loss of control or loss of flight path during go-around or other flight phases** for training of flight crew for adverse flight situations and flight upsets.		Human Factor issues followed by EASA.

Research project	Safety focus issue	Impacts on policy	Impacts on society and/or industry	Remarks
MISSA	Systemic		The guidance material targeted to the industry standards bodies has been developed. Also, outcome of project strengthens industries socioeconomic position in the matters of competition. > **Guidelines of aircraft systems certification & airworthiness** (ARP4754 & 4761). > **Software considerations in airborne equipment certification** (RTCA DO-178C).	
Prospero	Systemic	This can be a basis for development of an integrated ATS safety performance management concept that can fulfil the safety goals of Single European Sky for the reference period 3 (commencing in 2020).		Emerging issue followed by EASA, contributing to EASA's identified tasks.
Reconfigure	Operational/ systemic	In the project scope, EASA has recently released two **NPAs (NPA 2017-13 on training, NPA 2017-06 Loss of control or loss of flight path during go-around or other flight phases).**	RECONFIGURE achieved the principal aims of the project, and significant progress has been made on FDD and FTC for large civil aircraft. The importance and relevance of the investigations performed within the project is achieved on the basis of the industrial representativeness of the benchmark, i.e. the aircraft model and fault problematic. Moreover, the final goal of the project was to validate the more promising designs in the actual Airbus' flight control systems V&V setup, which ensures industry-wide acceptance of the results. ** FDD — Fault Detection and Diagnosis* ** FTC - Fault Tolerant Control*	Operational human factor issues monitored by EASA.
SAFE-CLOUDS	Systemic	First EC-funded R & I attempt at big-data analysis for safety in aviation. New standards/regulations on safety data.		
SARAH	Operational	This project on helicopter ditching has not had impact yet, as it is ongoing. However, it **supports development of performance-based regulation.**		Contribution through collaboration.
Safuel	Emerging/ operational	The results of this research project have been analysed by a group of experts of EASA in order to **define an acceptable means of compliance (AMC) with the requirement.**		Linked to Safety recommendation of EASA. Followed by EASA.
Scales	Emerging/ systemic		**Security and resilience standards (ISO/ TC 292)** ** ISO — International Organisation for Standardisation* **Design and operation of resilient systems and critical infrastructure.**	Not analysed in P4P.

Research project	Safety focus issue	Impacts on policy	Impacts on society and/or industry	Remarks
SMAES	Emerging/ operational	The project addresses analysing of areas requested for large transport aircraft for EASA (CS 25.801 — 7.1.3.3 Aircraft Safety, 7.1.4.1 *Aircraft development cost*).		Operational issues monitored by EASA.
SUPRA	Systemic	This project may have influenced the **EASA NPA 2017-06 Loss of control or loss of flight path during go-around or other flight phases.** ** NPA — notice for proposed amendment*		Operational issues monitored by EASA.
Sveltana	Systemic		The project focused on a common EU-Russia approach for flight data analysis and aims to promote new analysis processes.	Contribution to tasks of EASA + Advisory Board.
UFO	Operational	High priority impact, resulted with EASA Safety recommendation. **EASA Safety information bulletin 2017-10 (Safety information on wake vortex).**		Operational issues monitored by EASA, linked to Safety recommendation. Results presented.
ULTRA	Emerging/ systemic	No clear impact yet. A new framework will need to be developed, which is 'lighter' than conventional Safety Management System, yet still underpins safety culture. Safety data sharing could be a focus for new UTM systems, making data monitoring and sharing a licence condition. The results of the project may be achieved after entering into force of the reviewed aviation safety basic regulation. ** UTM — unmanned aircraft system traffic management*		Contributing to the identified tasks of EASA.
Wezard	Operational	High impact on research policy. Aim andresult was to identify research gaps and derive policy recommendations. The project provided an R & D roadmap identifying research gaps and recommending research priorities for future programming to design multi-year research programmes and to inform public authorities as ICAO, EASA and FAA on future developments.		Emerging issue. Linked to safety recommendation. Member of Advisory Board. High priority.

ANNEX 3 OVERVIEW OF PROJECTS AFFECTING STANDARDS AND REGULATIONS

Research project	Long title
Across	Advanced cockpit for reduction of stress and workload
AISHA II	Aircraft integrated structural health assessment II
Alicia	All condition operations and innovative cockpit infrastructure
ASCOS	Aviation safety and certification of new operations and systems
Capito	Enhanced air and ground safety nets
Delicat	Demonstration of lidar based clear air turbulence detection
EVITA	Non-destructive evaluation, inspection and testing of primary aeronautical composite structures using phase contrast x-ray imaging
Extice	EXTreme ICing Environment
Flybag2	Advanced technologies for bomb-proof cargo containers and blast containment units for the retrofitting of passenger aeroplanes
Future sky safety (P5)	Future Sky Safety
HAIC	High altitude ice crystals
IASS	Improving the aircraft safety by self-healing structure and protecting nanofillers
LAYSA	Multifunctional layers for safer aircraft composites structures
Man4gen	Manual operation for 4th generation airliners
MISSA	More integrated systems safety assessment
Prospero	Proactive safety performance for operations
Reconfigure	Reconfiguration of control in-Flight for Integral Global Upset recovery
Safe-clouds	Data-driven research addressing aviation safety intelligence
SARAH	Increased safety and robust certification for ditching of aircrafts and helicopters
Safuel	The safer fuel system
Scales	Emerging/systemic
SMAES	Smart aircraft in emergency situations
SUPRA	Simulation of upset recovery in aviation
Sveltana	Safety (and maintenance) improvement through automated flight data analysis
UFO	Ultrafast wind sensors for wake-vortex hazards mitigation
ULTRA	Unmanned aerial systems in European airspace
Wezard	Weather hazards for aeronautics

ABBREVIATIONS

ACARE	Advisory Council for Aviation Research in Europe
ALICIA	Air Condition Operations and Innovative Cockpit Infrastructure
AMC	Acceptable Means of Compliance
ATS	Air Transport System
CAG	Collaborative Analysis Group
CAT	Commercial Air Transport operations
CFIT	Controlled Flight into Terrain
EASA	European Aviation Safety Agency
EC	European Commission
EPAS	European Plan for Aviation Safety
EU	European Union
FAA	Federal Aviation Administration (US)
FDD	Fault Detection and Diagnosis
FDM	Flight Data Monitoring
FTC	Fault Tolerant Control
FP7	Seventh Framework Programme for Research and Technological Development
GA	General Aviation (all civil aviation operations other than scheduled air services, from gliders to business jets)
H2020	Horizon 2020 Framework Programme
ICAO	International Civil Aviation Organisation
IMC	Instrument Meteorological Conditions
INEA	Innovation and Networks Executive Agency
LOCART	Loss of Control Avoidance and Recovery Training
MRO	Aircraft Maintenance (Maintenance, Repair, Overhaul)
MS	Member State(s)
MTOM	Maximum Take-Off Mass
NAA	National Aviation Authority
NoA	Network of Analysts
P4P	Projects for Policy
PAV	Personal Aviation Vehicle
R & I	Research and Innovation
RPAS	Remotely-piloted Aerial Systems
RTCA	Radio Technical Commission for Aeronautics
SESAR	Single European Sky ATM Research
SLD	Super-cooled Large Droplets
SMS	Safety Management System
TC	Transport Canada
TCAS	Traffic Collision Avoidance System

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The subject of this report concerns aviation safety. Its objective is to analyse 160 aviation-safety research projects to determine how they are contributing to safer flights for European citizens, whether via better aviation policies, safer designs and operational practices, improved safety standards and regulations, or enhanced safety management in the industry.

Aviation is generally seen as being the leader for safety in the four transport modes (air, rail, sea and road), and safety research helps maintain this position of confidence with passengers and businesses alike. The results of the analysis of the projects show that safety research and innovation are indeed addressing today's key risks, as well as the systemic issues that underpin effective safety governance across the industry, and the emerging safety issues posed by drones.

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