FUTURE SKY SAFETY

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A JOINT PROGRAMME FOR AVIATION SAFETY

TYPE OF PROGRAMME
Coordinated research and innovation action (C-RIA)

PROGRAMME COORDINATOR
NLR

www.futuresky-safety.eu

EREA

FUTURE SKY

Prague, 18th February 2017

Dear Experts,

let me cordially greet you in the occasion of the first Future Sky Safety Public Workshop, which I see as one of the most important actions during execution of the Programme. And believe me, I'm really happy that Future Sky Safety is step by step fulfilling all dedicated objectives and go close to real "safety enhancements" in our daily life.

EREA created the Future Sky Joint Research Initiative as effective instrument for coordinated and targeted contribution of European Research Establishment in Aviation to high strategic European goals defined in ACARE – Strategic Research and Innovation Agenda and long term goals defined in Flightpath 2050. SAFETY is one of the most important pillars of the Future Sky and EREA selected this theme for prior solution, because all safety aspects are every day influencing our lives. Safety first!

Future Sky Safety is the first activity of Future Sky, where we are checking viability of the concept. It is not easy to be a pilot activity and manage the complex relations of all safety stakeholders and simultaneously coordinate synergic internal projects of the EREA Research Establishments. Nevertheless, significant progress is being made and the Future Sky Board appreciates the professional effort of the Future Sky Safety team.

We have to catch rare opportunity and use Future Sky Safety team of experts as nucleus for sustainable growing joint research, focused on future safety improvements. Critical mass of knowledge and experience is crucial for ensuring a good way forward.

I wish you successful and safe future,

Josef Kaspar
EREA Vice Chairman
FUTURE SKY Coordinator

AIT (AT) – CSEM (CH) – CEIIA (PT) – CIRA (IT) – DLR (DE) – FOI (SE) – ILOT (PL) – INCAS (RO) – INTA (ES) – ITWL (PL) – NLR (NL) – ONERA (FR) – TsAGI (RU) – VKI (BE) – VZLU (CZ)

European Commission

Brussels, 21st February, 2017

Dear Expert,

Safety remains at the core of any aviation vision, and research is recognised as instrumental to further improve aviation safety.

The European Aviation industry has fully embraced Flightpath 2050 - the EU vision for Aviation and Air Transport - and its Strategic Research and Innovation Agenda, a pathway for research and innovation to achieve the challenging goals contained therein.

The European Commission, the European Aviation Safety Agency (EASA) and EUROCONTROL have contributed in their development within the Advisory Council for Aviation Research and Innovation in Europe (ACARE).

In the 2014 call of the Horizon 2020 Framework Programme for Research and Innovation (H2020), the coordinated research and innovation action Future Sky Safety has been initiated to contribute to target the highest levels of safety for the European aviation that are envisioned in Flightpath 2050.

Funded by the European Commission, the 48-month-project Future Sky Safety has been contributing to the coordination of several institutional safety research programmes across EU, and has been performing collaborative research on safety risk priority areas with the objective to finding new solutions for today's accidents, strengthening the capability to manage risk, and improving the resilience of systems, operators and aircraft.

The 1st Future Sky Safety Public Workshop is focussing upon presenting the main findings of the project and its contribution to Flightpath 2050 safety goals. It is to be held on 8th and 9th of March 2017 at the EUROCONTROL Headquarters in Brussels.

The outcome of this workshop is expected to have a significant impact on the future direction of aviation safety research in Europe and to pave the way for future cooperation by the relevant stakeholders in the field.

I would like to encourage your contribution, as an acknowledged expert, to help sharpen the focus of aviation safety research.

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PROGRAMME OVERVIEW

PROGRAMME DURATION
Jan. 2015 - Dec. 2018

The European Commission (EC) Flight Path 2050 vision aims to achieve the highest levels of safety to ensure that passengers and freight, as well as the air transport system and its infrastructure are protected. However, trends in safety performance over the last decade indicate that the ACARE Vision 2020 safety goal of an 80% reduction of the accident rate is not being achieved. A stronger focus on safety is required. **Future Sky Safety**, established under coordination of EREA, is built on European safety priorities, around four main themes with each theme consisting of a small set of Projects.

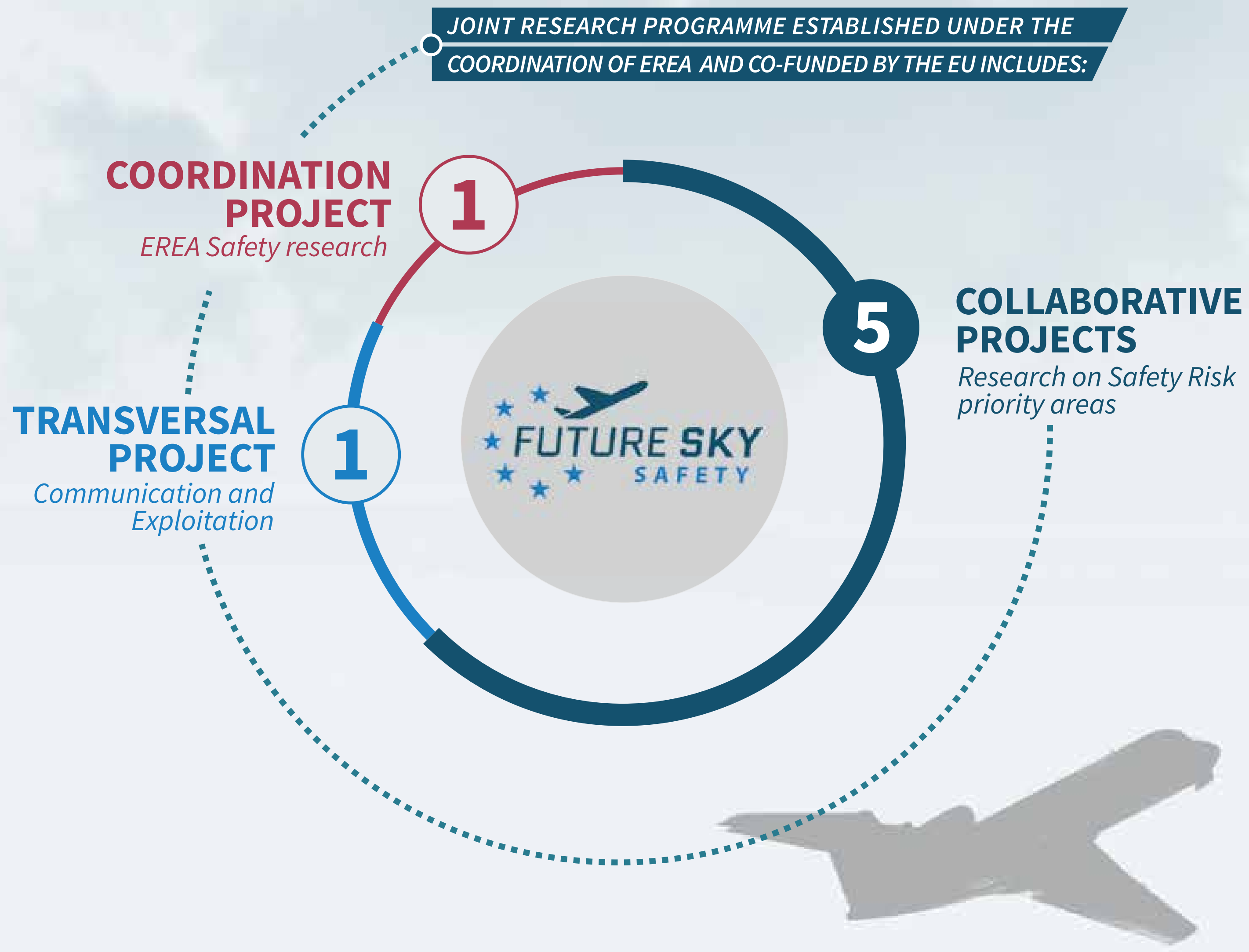
THEME 1
New solutions for today's accidents
Aims for breakthrough research with the purpose of enabling a direct, specific, significant risk reduction in the medium term.

THEME 2
Strengthening the capability to manage risk
Conducts research on processes and technologies to enable the aviation system actors to achieve near-total control over the safety risk in the air transport system.

THEME 3
Building ultra-resilient systems and operators
Conducts research on the improvement of Systems and the Human Operator with the specific aim to improve safety performance under unanticipated circumstances.

THEME 4
Building ultra-resilient vehicles
Aims at reducing the effect of external hazards on the aerial vehicle integrity, as well as improving the safety of the cabin environment.

To really connect and drive institutionally funded Safety R&D (by EREA) to safety priorities as put forward in FlightPath 2050, the EC ACARE SRIA Safety challenges, and EASA's European Aviation Safety plan (EASp) and, EREA's Safety Research Coordination activities are planned. Focus on key priorities that impact the safety level most will significantly increase the leverage effect of the institutionally funded Safety Research and Innovation actions planned and performed by EREA Institutes.



PROGRAMME OBJECTIVES

The two main objectives of Future Sky Safety are:
- **Coordination of institutional safety research programmes**
- **Collaborative safety research**

The collaborative research within Future Sky Safety will address five safety priorities. Specific objectives are:

- Perform breakthrough safety research, in accordance with the EAPPRE priorities, to enable a significant reduction of runway excursion risk in the medium term.
- Reduce the likelihood of organisational accidents in aviation via development and implementation of a Safe Performance System (SPS).
- Develop a prototype risk observatory to assess and monitor safety risks throughout the Total Aviation System and allow frequent update of the assessment of risks.
- Define and apply the Human Performance Envelope for cockpit operations and design, and determine methods to recover crew's performance to the centre of the envelope, and consequently to augment this envelope, through HMI principles, procedures or training.
- Develop solutions to mitigate the risk of fire, smoke and fumes related (fatal) accidents.

PROJECT #1

COORDINATION OF INSTITUTIONALLY FUNDED SAFETY RESEARCH

PROJECT MANAGER
DLR

TYPE OF PROJECT
Coordination project

Prior to Future Sky Safety, the safety research conducted by the association of European Research Establishments in Aeronautics (EREA) was not as coordinated among the establishments as it could be. This doesn't mean that the Research Establishments were together not conducting a sizeable volume of research in this field. On the contrary, a survey on Research Establishments activity revealed that they spend thousands of Person Months in doing safety research each year. However, based on this brief review, it seemed that the institutional programmes could be better connected and more structured around the European safety research priorities. Even if only partial coordination could be achieved, large benefits are expected by this connection. Therefore, for the first time, P1 aims at bringing the safety research of the EREA under coordination to maximize efficiency, develop a critical mass, and ensure excellent alignment with the relevant safety agendas in Europe.

The core of P1 is the coordination of institutional funded safety research of the participating Research Establishments. The coordination will lead to a significant leverage of the invested EU funding by means of a more efficient and effective use of resources.
Institutional Research Establishments programmes are often the result of bilateral coordination between governments and national institutes. However, there are multiple forces that shape these programmes, like institute ambitions, governmental responsibilities and ambitions, and European plans.

Therefore, the goal of the research coordination is to add another driving force to shape the national programmes.

Since there are significant differences between the institutional funding mechanisms of the participating countries, P1 performed an initial survey to analyse these mechanisms as baseline information for the research coordination planning. One major result was the comparison of institutional funding mechanisms, including both details and timeline. Three different kinds of funding mechanisms were identified:

1) Long-term roadmap with a detailed annual planning;
2) Availability of dedicated money through calls for proposals;
3) Annual institutional funding without an official roadmap.

In addition, P1 conducted and analysed yearly surveys of ongoing and planned institutionally funded safety research activities in order to create awareness and foster cross-linking of research work. With the identification of areas of common interest, in which results and resources may be combined, it is expected that a critical mass of researchers may be achieved on topics where this is currently not the case. This will lead to new, additional institutionally funded activities in the field of safety, thus levering the EU contribution to Future Sky Safety. The surveys showed that there is already a lot more of additional activities carried out by the institutes compared to the EU-funding requested for the Future Sky Safety Technical Projects. Thus, P1 tried to address this issue and first effects of its coordination activities are already visible in the planned research of the year 2015 to 2017, which indicate:

› A tendency for more international research consortia;
› A shift from passive sharing of information to active coordination efforts;
› The fact that the majority of projects are open to coordination or cooperation with other EREA partners.

Furthermore, P1 established an annually updated Aviation Safety Research Plan (ASRP) for the coordination of the research activities of the participating Research Establishments. This ASRP identifies important safety research topics where coordination between Research Establishments would be useful and promising. The ASRP is basically a public document available on the Future Sky Safety website; nevertheless, sensitive or confidential parts may be restricted to a limited audience. In conclusion, the ARSP, together with a thorough implementation plan, helps in filling research gaps, avoiding duplications of efforts and resources, and putting current initiatives on a common, more robust path. Thereby, a strong leverage effect will be achieved.

***Above:** first Future Sky Safety internal workshop*

FOCUS ON

The focus of P1 is to create a shared insight among the Research Establishments of the ongoing and planned safety research, in order to achieve coordination in the planning and conduct of new safety research projects and to create cooperative research projects in which multiple Research Establishments work together. This goal will be achieved by producing an annual Aviation Safety Research Plan for the participating institutions that will also be shared with the main European stakeholders. The coordination of institutionally funded safety research will be especially driven by this ASRP by identifying missing links and new institutionally funded safety research topics. The main goals of the EREA ASRP are:

› **First**, define an EREA Safety Roadmap and thus identify new institutionally funded safety research topics within the EREA partners;
› **Second**, support the Future Sky Safety Technical Projects for identifying missing links in their safety research;
› **Third,** coordinate the EREA Safety Roadmap with other relevant European Safety Research Roadmaps.

PROJECT RESULTS

One of the three cooperation activities that started in 2016 was already completed successfully, resulting in a master thesis and the preparation of publications.

Other coordination topics for 2017, which were discussed in an organized workshop with nearly 50 participants, led to the preparation of proposals for H2020 calls, the development of a specific safety roadmap and a cooperation activity on rotorcraft landing on ships, which is already approved by the programme directors of the respective EREA partners.

The coordination work for 2018 is very active: a first workshop for cooperation topics took place in Palaiseau (France) on the 1-2nd of February 2017, involving around 20 participants from EREA. The next Aviation Safety Research Plan will be published soon on the Future Sky Safety website.

To assist the Research Establishments further, P1 developed a communication platform to share publications and information and drafted a cooperation agreement template to facilitate the signature of new collaboration agreements between Research Establishments.

In 2017, a thorough analysis to evaluate the leverage effect of the coordination and cooperation of the institutionally funded safety research (both by quantitative KPIs and qualitative parameters) will follow. P1 will thereby show that starting new cooperation and coordination activities between EREA partners is both possible and highly beneficial for the aviation safety research community.

PROJECT #3

SPECIFIC SOLUTIONS FOR RUNWAY EXCURSION ACCIDENTS

PROJECT MANAGER
NLR

TYPE OF PROJECT
Collaborative project

The European Action Plan for the Prevention of Runway Excursions (EAPRRE) has identified areas where non-ATM research is needed to further reduce runway excursion risk:
› Flight mechanics of ground operations on slippery runways under crosswind conditions;
› Impact of fluid contaminants of varying depth on aircraft stopping performance;
› Advanced methods for analysis of flight data to monitor runway excursion risk factors.
A fourth work package will look into new technologies, other than the Runway Overrun Prevention System (ROPS) (e.g. gear technologies, pavement technologies, on-board guidance) to prevent excursions or the consequences of excursions.
The main goal of the project is to perform breakthrough safety research, in accordance with the EAPPRE priorities, and to enable a significant reduction of runway excursion risk in the medium term. The results of the research performed by P3 will further improve the knowledge on runway excursion prevention and risk mitigation. Therefore, it is expected that this research will contribute to an additional reduction in the number of runway excursion accidents, incident and occurrences.

A runway excursion is the event in which an aircraft veers off or overruns the runway surface during either takeoff or landing. Safety statistics show that runway excursions are the most common type of accident reported annually, in the European region and worldwide. There are at least two runway excursions each week worldwide.

Runway excursions are a persistent problem and their numbers have not decreased in more than 20 years. Runway excursions can result in loss of life and/or damage to aircraft, buildings or other items struck by the aircraft.

Excursions are estimated to cost the global industry about $900M every year. There have also been a number of fatal runway excursion accidents.
These facts bring attention to the need to identify measures to prevent runway excursions. Several studies were conducted on this topic. Most recently, a EUROCONTROL sponsored research "Study of Runway Excursions from a European Perspective" showed that the causal and contributory factors leading to a runway excursion were the same in Europe as in other regions of the world. The study findings made extensive use of lessons from more than a thousand accident and incident reports. Those lessons were used to craft the recommendations contained in the European Action Plan for the Prevention of Runway Excursions, which was published in January 2013. This action plan is a deliverable of the European Aviation Safety Plan, Edition 2011-2014. European Action Plan for the Prevention of Runway Excursions provides practical recommendations with guidance materials to reduce the number of runway excursions in Europe. The Action Plan also identified areas where research is needed to further reduce runway excursion risk. The present project focuses on a number of these identified areas. Four areas of research were selected for which additional research is needed:

› Research on the flight mechanics of runway ground operations on slippery runways under crosswind conditions;
› Research on the impact of fluid contaminants of varying depth on aircraft stopping performance;
› Research on advanced methods for analysis of flight data for runway excursion risk factors;
› Research into new technologies to prevent excursions or the consequences of excursions.

The first research topic is important as accident/incident data on runway excursions showed that the combination of a slippery runway and crosswind significantly increases the likelihood of a veer-off. Pilot guidance material provided by aircraft manufacturers for these operations is often based on simplified simulation models. The present project will identify the shortcomings of these models and will explore the areas of improvement. Since the start of the project, several results have been obtained. In the area of runway ground operations on slippery runways under crosswind conditions progress has been made in aerodynamic modelling and state of the art knowledge on ground simulation models.
Flight test have been conducted on a water-contaminated runway to analyse braking forces and hydroplaning effects.
Data to be used for safety analyse of veer-off occurrences have been identified and developments on special flight data detection algorithms has started. Finally, new technologies and solutions to prevent runway excursions have been identified and are currently explored, e.g. the automatic determination of runway state.

On the left: *waterpond construction at Twente Airport*
On the right: *aircraft in flight testing*

FOCUS ON

A wide number of factors causes runway excursions. The present project is not able to consider all of them. The project, however, does address areas that could improve the level of safety. A lot can be expected from the introduction of new technologies on aircraft and at airports, which are considered in the present project. This combination of technologies could proof to be a larger contributor in reducing the number of excursions in the future.

PROJECT RESULTS

Some interesting results have been obtained so far:

Full-scale flight tests have been conducted using a business jet aircraft on an artificially flooded runway.

Both unbraked and braked runs were conducted in order to collect data on braking friction under very flooded conditions. Such barked tests have not been conducted since the 1990. The collected data will be used for further predictive model developments that can be used to derive aircraft field performance data for pilots.

Aerodynamics of aircraft under high sideslip angles (as can occur during ground roll in heavy crosswinds) have been analysed for a regional jet using advanced computer models. The results illustrated the complexity of aircraft aerodynamics under such conditions. These results can be beneficial when deriving crosswind limits on contaminated runways, which has proven to be a major factor in runway excursions in the past.

PROJECT #4

TOTAL SYSTEM RISK ASSESSMENT

PROJECT MANAGER
NLR

TYPE OF PROJECT
Collaborative project

The goal of P4 is to develop a prototype risk observatory to assess and monitor safety risks throughout the Total Aviation System and allow frequent updates of the assessment of risks. The risk observatory will acquire, fuse and structure safety data and translate it to actionable safety information: output that helps the user to implement appropriate measures to positively influence safety. The foreseen users of the risk observatory are safety analysts, safety managers and accountable managers from aircraft operators, air navigation service providers, aircraft manufacturers, airports and authorities.

While the fatal accident rate for commercial aviation in Europe has been decreasing over the last decades, the accident rate stagnates at around 40 accidents per ten million flights: forty times higher than Europe's ambition. Aviation organisations introduced safety management systems to get a clearer picture of risks and to focus risk mitigations on the highest risks. However, to date safety management is performed on islands: it is done per organisation, taking into account an organisation's own domain.
A breakthrough is needed, and it can be provided by enabling inter-organisation and inter-domain safety management, by sharing safety data and information across organisations and across domains. P4 is developing a prototype risk observatory aiming to enable this.

The key value proposition of the risk observatory is to offer to the user safety information obtained by processing, organising or analysing safety data in a given context, to make it useful for safety management purposes.

The safety information will be used for safety risk management and safety assurance, the core pillars of a safety management system. The risk observatory improves an organisation's ability to perform hazard identification and risk assessment (safety risk management) and safety monitoring (safety assurance) by giving access to safety information from other organisations and domains. Consequently, this facilitates informed decision-making, allowing the use of the available resources for the largest possible safety improvement.
The foreseen users of the risk observatory are safety analysts, safety managers and accountable managers from aircraft operators, air navigation service providers, aircraft manufacturers, airports and authorities. For them, the risk observatory is a web-based collection of pages containing searchable and specifiable safety information. Supporting software and hardware are needed to realise such a web-based environment, and a dedicated organisation is required to run and maintain it.
In the first year, P4 followed a design-focused approach by developing an early prototype demonstrating the end-user experience.
It was designed iteratively using the requirements drafted from stakeholder consultations, literature research and consortium expertise. The prototype served to validate the requirements with the stakeholders.

The early prototype has a homepage that gives access to four main dashboards:

(1) an occurrences dashboard;
(2) a risk dashboard;
(3) a search dashboard and;
(4) a what-if analysis dashboard.

P4 used the software tool Balsamiq to implement the early prototype in the form of a mock-up of web-based dashboards. Both the occurrence dashboard and risk dashboard display safety information, using two methods to translate safety data into information. The occurrence dashboard directly visualises the safety data to improve the informative nature of the data. The risk dashboard translates safety data to a picture of risk using risk modelling.
The search dashboard allows searching for hazards, occurrences, best practices and mitigation actions stored in a database. The idea is that stakeholders share such information, to have it available to other organisations. The inclusion of this functionality is a clear wish from the stakeholders consulted. The search dashboard can be extended to include shared safety analyses and safety reports from stakeholders.

The what-if analysis dashboard allows the user to perform comparative analysis by altering safety performance indicator (SPI) rates to estimate the effect on risk. The user can select SPIs and associated risks (accident types), and assess the impact on the risk level of changing the frequency of occurrence of the SPIs. This allows improved decision-making: a user can determine which SPI frequency reduction has the largest impact on risk, identifying the biggest opportunity for risk mitigation.

In the second year of the project, risk model developments have started. The P4 partners bring to the table different kinds of risk models, ranging from models that mimic the physical characteristics of aircraft to models that model the cause-effect relationships of aviation accidents. By further refining and combining different risk models, P4 wants to strengthen the capability to translate safety data into a picture of risk. Further efforts are also undertaken to improve the way risk is visualised by utilizing modern data visualisation tools such as Tableau.

A preliminary business model is developed that outlines a Risk Observatory Organisation.
This model includes value proposition, customer segments, key activities and resources, costs and revenue streams. It also proposes several options for a governance framework and the success factors of the organisation.

FOCUS ON

There is more and more safety data available in aviation. In the future even more data will be collected that can be used for safety management purposes. Safety data itself will however not provide answers to questions like: what are my highest risks, and are my safety actions reducing them? To provide answers, safety information is needed: safety data processed, organised or analysed in a given context to make it useful for safety management purposes. P4 studies how to acquire safety information and how to present it to safety specialists and managers.

***On the right:** risk observatory prototype tool*

PROJECT RESULTS

The risk observatory provides access to safety information across organisations and domains. This can have four effects boosting safety performance:

More safety information available to individual organisations, leading to an easier comparing of safety performance (especially for smaller operators) and to a reduction of the duplication of effort.

By allowing access to common data, the risk observatory facilitates joint actions by different organisations and/or domains. This way, safety actions that go beyond the individual reach of an organisation (financially, organisationally, and politically) can be made.

A focus of resources on highest risks and/or risks with highest opportunity for mitigation is possible thanks to risk modelling. The highest possible risk reduction per euro spend can be achieved, which is preferable to ad-hoc event-driven safety management.

Tackle concerns at interfaces between organisations and domains, by offering and combining data from different organisations and different domains, in order to identify, assess and mitigate these risks.

PROJECT #5

RESOLVING THE ORGANISATIONAL ACCIDENT

PROJECT MANAGER
EUROCONTROL

TYPE OF PROJECT
Collaborative project

Safety focus has traditionally been on technical failures and human error as they occur in operations. Instead, new and promising approaches now consider the overall socio-technical system in its full operational and organisational context.

P5 addresses the effects of organisational structures, processes and culture on safety performance in aviation organisations. The aim is to reduce the likelihood of organisational accidents in aviation via development and implementation of a Safe Performance System (SPS). The key work areas for P5 are safety intelligence, safety culture, safety mindfulness and an agile response capability at organisational and inter-organisational levels. These elements are all available, but they need to be focused on the daily realities of aviation-related organisations, and then integrated into a cohesive system, one that is at the heart of operations. This will give all levels in the organisation a better "safety radar", and this should then be extendable to all parts of the aviation industry, whether ground or air, operational or support.

The next accident in commercial aviation will most likely be attributed to organisational failures, such as top management focusing on costs at the expense of safety, or workers bending the rules to get the job done, or a lack of organisational preparedness for the events leading up to the accident. Poor safety culture is likely to be seen as a root cause. Aviation is not alone in this respect, as evidenced by accidents such as Fukushima in the Nuclear Power industry, or Deepwater Horizon in the Oil and Gas industry. A range of theoretical approaches have been proposed over the last three decades, from Normal Accidents, Swiss Cheese models and High Reliability Organisation (HRO) theory, to Safety Culture Measurement, Safety Mindfulness, Resilience Engineering and "Safety 2". Yet, few of these theories are integrated into the management of safety. We continue to write about organisational accidents in an academic way rather than resolving them at an operational level. P5 aims to change that, by innovating novel approaches and focusing them on the realities of current aviation operations, which are flexible, adaptive and agile, which in turn means they are complex, constrained, inter-dependent and continually evolving.

Reliance on "static" safety analyses and procedures is no longer enough.

There needs to be a focus on work as done, rather than work as designed. We need an agile safe performance system, one in which safety emerges in the operations no matter how they evolve.

When people do what needs to be done to get the job done, whether at top, middle or operational layers in the organisation, we need to know that it will be safe. Aviation is a system of systems, so we also need an approach that can work across organisational and cultural boundaries. Since we cannot predict and prevent everything (there will always be surprises), we need an inter-organisational capability to react swiftly and work together to recover from unsafe events and conditions to avoid accidental outcomes. So, how do we resolve the roots of organisational accidents? The foundations and techniques for a successful transition to a safer organisational system are all available.

Safety Intelligence. Since many accidents can be traced back to high-level decisions made in organisations, we need to help those at the top better understand safety, and give them and middle management the data and tools to enable them to make the right decisions in the first place, thereby addressing safety "upstream".

Safety Mindfulness. We need to analyse the operational, engineering and support layers in organisations, where human social considerations play the key role in determining whether there will be safety mindfulness in operational activities and decision-making, so that safety emerges in continually evolving work practices.

Safety Culture. We need to understand how to optimise safety culture within and across different national and professional cultures at top, middle and operational/ engineering layers in organisations, and map positive safety culture factors onto common organisational processes, so as to embed it in the daily functioning of organisations.

Resilience. We need to understand how organisations can work together to recover quickly from major system crises or "surprises", which can never be fully designed out. This includes how such events are detected and communicated, and how distributed parts of the aviation system can respond to resolve them.

Safe Performance System. The step-change in safety will come only when all of the above components can be inter-related and integrated into a cohesive and collaborative Safe Performance System.

Above: *Luton Airport, London*

FOCUS ON

The Safety Culture work package has carried out something never done before. It is called the "safety culture stack". This approach focuses on a single airport and airline hub location, and surveys the key partners operating there: the ANSP, the airport, the principal airline, support organisations such as baggage handlers and de-icing companies, and the key aircraft manufacturer. It then brings them together to determine how to improve safety culture and safety of the individual organisations and the entire local system. The first "stack" meeting took place in early 2017, and has already been hailed as a success by the partners. P5 hopes to carry out one further "stack" meeting at another European location later in 2017.

PROJECT RESULTS

- Guidance on safety intelligence for CEOs and Senior Executives, based on sixteen interviews with industry leaders, showing how they lead safety in their organisations.
- Analysis of how middle managers pass safety information and messages up and down the organisation, based on interviews in a range of aviation organisations.
- Development of a generic Safety Dashboard for use in aviation organisations.
- Prototype mindfulness support tools and user requirements for operational staff (airline/air traffic).
- Safety culture surveys of >7000 pilots, plus two airframe manufacturers, an airline and an airport.
- The first ever safety culture "stack" workshop, where six organisations based at a London airport. came together to discuss their safety culture, with a view to improving safety culture and safety management.
- Analysis of pan-European aviation crisis simulations at the European Aviation Crisis Coordination Cell, and a second major crisis control centre, in order to develop guidelines for remaining agile during crisis events.
- First outline of how organisational safety might fit into an existing Safety Management Structure using the CANSO SMS Standard of Excellence and ICAO Annex 19 as a basis.

PROJECT #6

HUMAN PERFORMANCE ENVELOPE

PROJECT MANAGER
DLR

TYPE OF PROJECT
Collaborative project

P6 on the Human Performance Envelope builds on a concept previously proposed in the ATM domain. The Human Performance Envelope is to some extent a new paradigm in Human Factors. Rather than focusing on one or two individual factors (e.g. fatigue, situation awareness, etc.), it considers a range of factors and how they collectively influence performance. The objective is to define and apply the Human Performance Envelope for cockpit operations and design, to determining methods to recover crew's performance to the centre of the envelope, and, consequently, to augment this envelope through Human Machine Interface (HMI) principles, procedures or training. Through studies and simulations, the project will: find the points at which performance deteriorates; determine behavioural or physiological markers and recovery measures that could be applied in real-time; identify ways to augment the envelope in order to increase safety and improve performance.

Fourteen partners are working together and forming a multi-disciplinary team to achieve the objectives P6 aims to. The metaphor underpinning the Human Performance Envelope concept suggests that,

when studying performance degradation and recovery, we need to consider a range of interdependent factors (e.g., workload, fatigue, etc.) as a whole, instead of considering one/two single factors in isolation.

If these factors, working alone or in combination, are studied borrowing the envelope metaphor, it can be possible to determine the starting point in which significant performance degradation could affect safety. The safe region of the envelope is bordered by markers, which can be measured and signalled allowing the pilots to detect and recover, or enabling external agencies to prompt recovery, or allowing automation to kick in and take over.
The impact of P6 will primarily be through the improved design and operational practices in the cockpit. The ultimate objective is to augment the Human Performance Envelope through HMI principles, innovative HMI design, automation concepts and flight crew monitoring solutions (with impact on procedures and training).

Three factors were identified and selected to investigate the Human Performance Envelope concept within this project: workload, stress and situation awareness. These three were selected by a group of experts as the ones with the highest impact on the pilot's performance and those most likely to be investigated by using simulations. The Human Performance Envelope concept was then tested through real time simulations performed in May 2016 with an A320-200 motion simulator with six degrees-of freedom. The goal of the simulation was to confirm the independent effect of each factor on human performance and their interaction effect in a more complex environment, and to establish the boundaries (performance decrement limits) of the envelope. The scenarios and their characteristics were defined in collaboration with pilots and human factors experts.

Ten A320 first officers from a major European airline participated in the experiment and performed two scenarios. The first scenario consisted in an approach phase during which the subjects (acting as Pilot Flying) had to fly manually until landing. Eight different runs for this scenario were developed, with varying but well controlled and combined levels of workload, stress and situation awareness. The second scenario was a very complex approach scenario with a technical failure in a low fuel situation. The levels of workload, stress and situation awareness were not specifically controlled and varied throughout the scenario. The subject pilot in this scenario had the role of the Pilot Monitoring.

In these simulations, psycho-physiological, behavioural, performance-based and subjective data were collected.

Main physiological parameters were heart rate, breath rate, core body temperature, and eye movements (point of gaze, blink rate, and pupil diameter). Questionnaires were asked to subjectively asses the level of workload, stress and situation awareness. Structured interview techniques like a cognitive walk-through were applied during debriefings in order to analyse the mental representation of the pilots before, during and after a critical situation. Performance metrics were deviations from target values (like speed, glideslope and localizer) together with subjective ratings along a performance curve, and a crew competency evaluation through external professional pilots. Furthermore, behavioural markers were identified which can indicate potential performance declinations.

Above: *real time simulations with pilots*

FOCUS ON

On the basis of the results of the experiments conducted, new HMIs will be developed that help the pilots to recover when one or several factors are degraded and thus to remain inside the boundaries of the Human Performance Envelope. The new HMIs will focus on critical decision making under stress. They will be mapped on pilot representations and will be based on key aspects of decision making (understanding the situation, assessing possibilities, assessing consequences of decision, and performing decided actions).
It will be investigated, if physiological parameters can be used to recognise when the pilot is approaching the edges of the Human Performance Envelope and triggering this way the need for support by means of the new HMIs. Finally, the new HMIs will be validated in further flight simulator experiments with pilots at the end of 2017.

PROJECT RESULTS

The analysis of the large dataset produced during the simulations is still on-going. While the measurement tools for workload and stress delivered good results, the measurement of situation awareness remains more challenging. The results showed that physiological measures are sensitive to an increase in workload and/or stress. Different band of frequency from the heart rate variability appear to be good candidates for the measurement of workload, stress and their interaction.

Furthermore, it turned out that a workload increase led to an increase in the pupil diameter. Additionally, the results indicated that the combination of low degraded factors can lead to higher decrements of performance compared to the effect of a single degraded factor. One of the behavioural measures in particular showed that the edges of safe performance were sometimes touched or even exceeded, if factors were combined. Correlation of behavioural, performance and physiological data will help the consortium in identifying the combination of factors and phases in which pilots' performance was more affected, thus giving hints for the selection of proper recovery measures or mitigation means.

Overall, the Human Performance Envelope turns out to be a useful concept and can be manipulated and measured in a realistic operational context. It has been validated to an extent within this project.

PROJECT #7

MITIGATING THE RISK OF FIRE, SMOKE & FUMES

PROJECT MANAGER
ONERA

TYPE OF PROJECT
Collaborative project

Important knowledge gaps exist around fire behaviour of carbon fibre reinforced polymer materials for primary structures, and the risks related to fire, smoke & fumes in the modern cabin environment. The overall project objective is to contribute to increase safety (i.e. reduce the number of fatalities) with respect to fire, smoke & fumes-related issues, and to prevent any staff or passengers safety problems due to inappropriate air quality.

P7 will improve understanding of fire behaviour of composite materials and explore new generations of mitigating solutions. It will also study possible risks associated with on-board (including cabin) air quality. This will be done by addressing knowledge about the thermo-mechanical, thermo-chemical and thermo-physical decomposition of materials in new generations of aircraft systems, and its measurement when, for instance, low contamination level or very fast changing ones are considered.

The technical work of the project mainly consists in developing better methods to measure and assess material properties and behaviours, analysing composite behaviours under various temperatures, flames, and load conditions, and evaluating the state of the art numerical models and methods.

In the first place, the project addresses the enhancement of knowledge about the fire behaviour and performance of carbon fibre reinforced polymer primary structure materials,

in order to better predict safety and survivability issues in case of fire incident, e.g. in post-crash situation. Such predictions rely on physical models and numerical tools, which need to be developed on the basis of exhaustive material (characterization) and components (validation) experimental tests. P7 aims at producing a comprehensive experimental database for a reference material to be shared by the European research community as a basis for material model development of the fire behaviour/degradation of carbon fibre reinforced polymer materials.

In addition, P7 aims at the development of novel and innovative material solutions with high potential for mitigating risks of fire, smoke & fumes in the cabin environment. To achieve this aim, candidate highly resistant materials are to be tested, to address their mechanical properties with respect to fire exposure. Three different kinds of material solutions were selected to be studied: Fibre Metal Laminates, hybrid non-woven, and geopolymer matrix based materials. The scope and magnitude of the test plan defined for the experiments and the data content respect industrial safety requirements and usage of state of the art simulation tools.

A third research subject for P7 is the effects of new materials, technology and fuel systems on the on-board air quality. The scope is contributing to maintain, and possibly enhance, on-board air quality in aircrafts. This is done by investigating opportunities offered by technology developments that could give insight into any effects that introduction of new materials could have. Indeed, aviation regulations both in the US (FAR) and EU (CS) state that aircraft air must be free from harmful or hazardous concentrations of gases or vapours. Specific allowable limits have been applied for ozone, carbon monoxide and carbon dioxide. However, there is no requirement for real-time monitoring of any substances on an aircraft.

Over the years, flight crews and passengers have voiced concerns about suffering apparent acute and chronic health effects, which some have attributed to exposure to substances during flight. With the objective of enhancing on-board air quality, sensing technologies and an industrial framework for monitoring air quality have to be investigated. The research P7 performs follows this path.

PROJECT RESULTS

The fire behaviour of primary structure composite materials (such as epoxy resins and standard carbon fibre reinforced polymer) is a complex multi-physical problem. In order to better understand and model that fire behaviour, a full characterisation of the material behaviour is required regarding each physic involved: physical properties (such as specific heat or thermal expansion), chemical properties (such as chemical kinetics) and thermo-mechanical properties (such as thermal dependency of fracture properties). To produce a comprehensive experimental database, P7 selected the T700GC/M21 material as reference, because many published results already exist about its standard mechanical behaviour, which the project can build on. Therefore, the experimental database produced in the project is a first step towards fully coupled multi-physics simulations of the fire behaviour of primary structure composite materials.

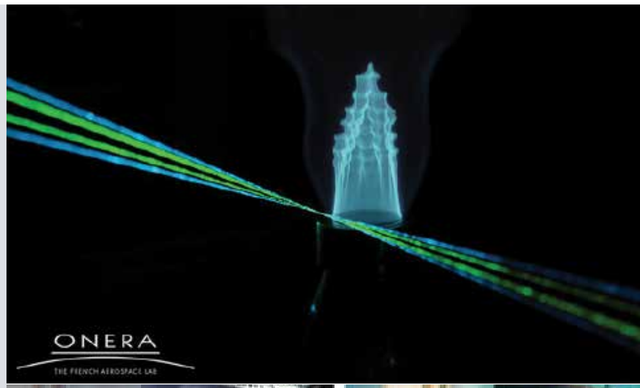
In addition, the project conducted tests on Fibre Metal Laminates, Hybrid Non-Woven and Geopolymer matrix based composite materials. Some performance improvements or limitations were demonstrated, for example improved smoke density and toxicity for Fibre Metal Laminates; poor performance in case of fire for Hybrid Non-Woven without fire retardants; promising smoke density and toxicity, heat release rate and mechanical properties for carbon fibre reinforced Geopolymer matrix based. Data gathered within this research will help improving solutions to mitigate risks of fire, smoke & fumes on aircrafts.

Finally, P7 performed a synthesis of literature study concerning general reference information on cabin air quality. The study covers cabin air quality's main characteristics, regulation and testing, benchmarking with other similar areas (e.g. buildings and vehicles interiors), and investigating composite material potential emissions. In addition, the study provides an overview of the sensor technologies (including documented inflight measurement techniques) that could potentially contribute to on-board air quality monitoring solutions for gases and particles.

FOCUS ON

By studying the fire behaviour of primary structure composite materials (such as epoxy resins and standard carbon fibre reinforced polymer), P7 is making a step towards the development of predictive multi-scale and multi-physical composite material models. In addition, the project addresses other societal challenges beside Aircraft Safety, like application of bio-sourced and recycled composite materials. This is done within its research on improved solutions to mitigate risks of fire, smoke & fumes.

Finally, P7 performs an investigation on the effects of new materials, technology and fuel systems on the on-board air quality that falls under a larger media concern today: global air quality. Therefore, the results obtained by the project may be relayed or appropriated by civil society in the coming years.



Above: Non intrusive fire dynamics measurement by LDV (Laser Doppler Velocimetry)
Below: Glass/Phenolic and Carbon/Polysialate panels during fire test

Notes

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