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Overview of the Eurocontrol Safety R&D Plan

This document outlines the Safety Research & Development Plan for mid 2003 - 2006. It is an update of the former Eurocontrol Safety R&D plan, which was produced shortly before the tragic mid-air collision on 1st July 2002. This event, and the deliberations of the High Level Action Group on ATM Safety (AGAS) which followed it, led to a significant shift in Safety R&D priorities. This document is in three main sections: background, including the major aspects influencing safety R&D needs; the individual work items and associated major deliverables; and logistical aspects such as timing and resources.

1. Background to Safety R&D Plan

Safety in a period of change

The Safety R&D Plan is needs-driven, based on the needs of ATM now and in the next ten to fifteen years. It may of course be questioned why any R&D is needed at all. The answer lies in the tremendous changes that ATM is going through at this moment and in the near and mid-term future. Also, the recent tragic European air traffic-related accidents such as the Milan runway incursion accident, and the mid-air collision at Bodensee show that although ATM remains very safe compared to other industries, there is no room for complacency.

The changes in ATM mean that the very nature of the air traffic controllers’ job will alter significantly. With such changes come the potential advantages of more capacity, less delays, and more efficient and effective services. But added safety with such changes cannot be assumed, it must be ‘built in’, assessed, and assured.

In more concrete terms, European ATM needs to learn throughout the change process, so that necessary adjustments can be made as needed along the way, rather than waiting for accidents to tell us we got it wrong. New changes to ATM mean new methods and approaches to safety must be developed, as the old ones may no longer suffice. Safety must be considered at every step of the design and implementation process, leaving no room for ‘latent’ problems to take root only to surface later as accident causes. There will also always be key risk areas that emerge during the changes, and R&D must work to support better understanding and deeper treatment of such problems, so that their causes are effectively dealt with, otherwise they will resurface as operational and safety problems. Lastly, ATM needs to ensure that all the changes do not degrade the good safe performance culture that exists in the ‘Ops rooms’ in Europe.

Planning for Safety

Whilst safety now may be seen as an ‘emergent property’ of ATM, this cannot be assumed for the new or ‘next generation’ ATM system being developed. Safety should in fact be ‘planned’, and should be an explicit part of the ‘architecture’ for future ATM. This means showing how the changes can and will increase safety, and making sure it happens. To take a specific hypothetical example, datalink could
clearly help to overcome certain common communication error types seen today with conventional radio-telephony. But could it introduce new problems? And are there additional safety benefits we could realise if we looked deeper? And exactly how much risk reduction can datalink give us? These types of questions are strategic in nature, and amount to planning for safety. If we do not work on these questions, we risk over-estimating the safety impact of new systems, overlooking undesired side-effects and interactions which may detract from safety, and missing opportunities to radically improve safety. Answering these deeper issues requires focused R&D.

Safety R&D and Cost Pressures

In these times, following a number of setbacks in the aviation industry as a whole, cost pressures are also very much evident and impacting all of us. Therefore, there is a compelling argument for co-ordinating R&D efforts across Europe, so that resources are not wasted via duplication of effort, going down ‘dead-ends’, or having the right projects carried out with the wrong resources and capabilities. It is very much the time for focused collaborative efforts on ATM safety, requiring increased co-ordination of safety efforts across Europe.

This Safety R&D Plan is therefore built around the following eight high-level ATM System Safety Principles. The subsequent sub-sections then describe what needs to be done in more detail to satisfy these principles.

High Level Safety R&D Guiding Principles:

I - ATM must become a learning organisation
   Methods to collect data now exist, and data collection is occurring in many ANSPs. Safety learning mechanisms now need development.

II - ATM must have suitable methods with which to anticipate and protect itself against risks
   ATM needs to adapt risk assessment and management methods from other industries and develop new ones where required.

III - Safety must be built in at the early stages of ATM system design, right through to implementation
   Safety lessons and information need to be fed into the design process throughout the design life cycle, from concept development to transition to operations.

IV - ATM must improve safety in key near-term risk areas
   Level busts, runway incursions, safety net interactions, events at low vigilance periods – these are key risks where more understanding is needed to reduce risk.

V - ATM must plan for key longer term risk areas
   Airspace and traffic patterns are becoming more complex – ways to support the controller in increasingly complex traffic patterns need to be developed.
VI - ATM must be sure that the systems it is developing will deliver the required safety levels

The broad ‘roadmap’ in terms of changes is laid out (e.g. ATM 2000+, etc.). However, exactly how each roadmap ‘component’ adds safety individually and as a part of the whole of the future ATM system, needs to be assessed and assured so we will meet safe capacity targets.

VII - ATM must retain its ‘High Reliability’ status and its ‘safe culture’

Safety culture needs to be assured for proposed fundamental ATM changes such as Single Sky, and delegation of separation tasks to the cockpit.

VIII – The above should be achieved effectively and cost-efficiently

There needs to be co-ordination of a focused effort between different R&D Centres, to avoid duplication of work or following dead ends, and to make best use of combined available resources, facilities and competencies.

The following section describes the safety R&D project areas in more detail.

2. Safety R&D Project Descriptions

Safety Learning

In a period of change, it is important to record and study safety-related events, to ensure that we are still safe and not awaiting an accident. Such an approach enables ATM to be proactive based on recent experience. It enables ATM to be a learning organisation, especially if learning is shared between different member states.

Many ANSPs now have safety event recording practices and tools, and safety R&D has augmented these particularly with the development of the Automatic Safety Monitoring Tool (ASMT). However, collecting data is only the first step. Analysing it, integrating it, and deciding which events are telling us something more important, detecting new trends: these things are not as simple to do as they may seem. Furthermore, using the data to improve design practices, so that future designs build on previous safety experience (so we do not repeat mistakes), and for improving risk assessment practices so that they remain in touch with the real types of failures/errors that actually occur, is not straightforward.

Therefore, a project has begun called SAFLEARN, which will develop the safety learning process, demonstrating how it can work, developing a safety learning process for the ATM industry. A part of this approach will be to develop safety event trend detection, a form of ‘early warning’ for the industry. This means that if after the introduction of some change, whether a new interface, tool, or procedure, that certain incidents appear to occur, then rapid feedback can be given to the organisation concerned, and other organisations considering the change for their system. The term ‘rapid’ here means in the order of 3 – 6 months, as this is a reasonable timeframe within which to detect the events, identify a trend, and raise the potential issue. This approach is useful and is used in the nuclear power industry for example, as throughout most industries, accidents are usually preceded by certain ‘precursor’ events which have the same basic pattern of the accident. This was true for the Three
Mile Island nuclear power plant accident in 1979, and arguably a Japanese ATM incident in 2001 had a number of the hallmarks of the Bodensee mid-air collision.

The ACAS (Airborne Collision Avoidance System) Monitoring Cell already to some extent does this type of analysis. However, taking this ‘early-warning’ idea one step further, there are new systems being put in place where more detailed monitoring would be useful to manage safety. Mode S, for example, is being introduced, and Datalink is planned for introduction. The early years of introduction of such systems and ‘infrastructure’ to ATM will be critical in determining their success, and the degree to which they can support safe increases in capacity. In safety and reliability theory, there is something called the ‘bathtub curve’, which means that the most unstable and unreliable times for a new system are at first operational implementation, and then when the system is nearing the end of its operational lifetime. There is therefore an argument for setting up an independent monitoring cell to learn in real-time safety aspects associated with the phased introduction of Mode S and Datalink in particular, using ACAS and ASMT (Automatic Safety Monitoring Tool)-type reports as well to determine their safety impacts.

The main deliverables therefore are as follows:

- A safety learning system able to learn from operational experience of safety-related events, disseminating lessons for operational, design and assessment purposes
- An early warning system capable of detecting negative safety trends
- A monitoring and analysis function to review safety performance of newly introduced ATM functions and detect early trends of potential safety significance

**Safety Modelling**

Eurocontrol HQ (EHQ) have developed a comprehensive Safety Assessment Methodology (SAM) with which to assure the safety of future projects. However, because of the changes ongoing in ATM, and the fact that ATM has only embarked on significant risk assessment endeavours relatively recently, ATM’s technique ‘toolbox’ is not complete – there are certain areas in which better techniques or tools are desirable. This research area is called SAFMOD, and refers to development or adaptation of safety modelling or assessment methods to ATM. A joint review by Safety R&D and Safety at Eurocontrol Headquarters (EHQ) in 2002-3 identified a number of areas in which new approaches should be developed. For example, we need to predict human errors with new systems, preferably at the design stage, so that mitigation measures can be installed, or so that the errors can be ‘designed out’ of the future system. Such tools for human error identification are now being developed in R&D projects.

As another example, ATM now has a quantitative target level of safety for setting safety requirements for new projects. This quantitative aspect means that certain key human errors identified in risk assessments should also be quantified. Such quantification of human error probabilities is routine in some industries, but very new to ATM. Therefore, this is one area where R&D is needed to develop a new approach for ATM.
Two further near term examples are the need for ensuring that new systems about to be implemented are still safe, and the need to consider unplanned interactions between new systems. The first concerns the fact that most systems change between final design and construction, and actual implementation. During ‘transition’ to operations, there may be local adaptations to make the system work and adapt to the actual operational culture in which it is being implemented. These ‘finishing touches’ can have safety implications (positive and negative), and should be managed. A form of ‘Operational Readiness Testing’ is therefore needed. This would establish that agreed safety levels and mechanisms have not been degraded unintentionally, and that the safety assessment’s assumptions made during the design phase are shown to be valid as the system is adapted to local working practices, and becomes ready for operation.

Many of the changes to ATM are seen as step-wise changes, or adding ‘the next tool’ to the ATM system. Such a progressive approach is ‘measured’ and its safety can be managed more effectively, but it has a risk that unplanned interactions between different planned system changes to ATM can occur. In particular, there is a danger of a ‘compartmentalised’ approach to safety, in that each individual tool or change to ATM is individually assessed, but that the possible and unintentional links to other systems are not addressed. The danger is that two projects, for example, each assume the other one is looking at safety at the system’s boundaries, but in fact neither of them are. This is an area in fact wherein ATM may need to develop a new approach, since other industries are fairly well bounded (e.g. nuclear power plants, offshore platforms, etc. are relatively ‘closed systems’: ATM is not). What needs developing therefore is a creative way of looking for hazards at the edges of systems’ boundaries, to ensure no unplanned hazards could occur, and also that one system will not simply ‘export’ its risk to another adjacent system.

The four technique development projects mentioned above are seen as necessary in the short term but others will be identified as the SAM itself evolves. In addition however, there is a need to consider how the risks from all the various ATM changes will add up and interact. Such an ‘integrated risk assessment’ would show not only the interactions, but also the dependencies between different ATM sub-systems. The resulting integrated risk ‘picture’ could also help determine the relative benefits of each proposed change, and perhaps show where safety needs most improvement.

The deliverables are therefore as follows:

- A review of the needs and priorities for ATM SAM technique development
- Human error identification methods
- Human reliability quantification methods
- Operational readiness testing approach for the ‘transition’ phase
- A means of identifying hazards across system boundaries
- An integrated risk picture for current and future ATM

**Safety in Design**

There already exists substantial guidance on what to do and what not to do in design, e.g. in the area of human factors. But such information tends often to be piecemeal, and can result in difficult trade-offs for designers who are trying to develop a coherent system and operational concept of use. Safety should be specified at the start of a
project, and threaded through the design phases, embedded in the system’s architecture, and reflected in the allocation of functions between human and machine (and between pilot and controller), its software, its HMI and its working practices. However, few projects achieve this in practice, because the data and processes to do this are diverse and not always easily adapted to specific projects without significant effort and expertise. This means that ‘in-built’ safety is often sporadic, or piecemeal, or simply added on later to relatively mature designs. To rectify this, a project called SAFBUILD aims to develop better ‘Safety-in-Design' practices and processes. SAFBUILD will culminate in a ‘design safety decision support system’ that will help designers of future systems make the right (safe) design decisions. This information database and decision-support system, will then be encapsulated within a generalised change management process, applicable to a range of design projects and processes.

A significant part of SAFBUILD is also looking at how to get more explicit safety insights from real-time simulations (in the project called SAFSIM). This will help simulations, whether based at the Eurocontrol Research Centre (ERC) or at the Central European Air Traffic Services (CEATS) Research & Development Simulator (CRDS, Budapest) or elsewhere, to be able to make more explicit and comprehensive statements about the safety properties and adequacy of new systems or tools.

Additionally, there is now more effort to assure safety even at very early design stages, such as the concept stage. It is at such a stage that early safety assessment can have a large impact, in recognising certain risks or safety advantages, and then dealing with them appropriately throughout the rest of the design phases. A project to do this, called SAND (Safety Assessment for New Designs), has been developed and is now running, based at the ERC, where much of Eurocontrol’s concept design work takes place. SAND and SAFBUILD will also take inputs from SAFLEARN, so that experience from incidents can inform assessment and design practices, thus completing the safety learning processes. This is shown in Figure 1 below.
Figure 1: The Safety Learning Cycle, incorporating SAFLEARN, SAFBUILD (which includes SAFSIM), and SAND

The main deliverables for this work area will be as follows:

A design safety decision support system that can help new designs more easily integrate safety into their processes and products. 
Guidance on extracting safety insights from real-time simulations (e.g. for possible use in safety cases)
A method for assessing and assuring the safety of new ERC concepts

**Key Risk Areas – near term**

Two Key Risk Areas (KRA’s) currently are level busts and runway incursions. For both of these, initiatives to reduce them have already been taken and are being implemented. However, in both cases, the understanding of the causes, and the difficulty of actual reduction, means that there is a need for further investigation and development of further measures to tackle them. Work on level busts has already started, and it is anticipated that R&D will commence on runway incursions in 2004.

The Bodensee accident highlighted the danger of ‘interactions between safety nets’, including the controller, TCAS (Traffic Alert & Collision Avoidance System), STCA (Short Term Conflict Alert), and pilot ‘see and avoid’ actions. Whilst these are intended to be successive and therefore ‘independent’ barriers, clearly they can in certain circumstances interact negatively, as the Bodensee mid-air collision tragically demonstrated. Controller involvement in short time-scale and emergency events needs to be explored, and guidance produced. This work will also consider the relative advantages of down-linking to the controller the fact that a TCAS Resolution Advisory (RA) instruction has been given to the aircrew.

A further potential key risk area is the performance of controllers in low vigilance conditions. Such conditions can either occur in very quiet periods, or else can be periods of relative quietude shortly after very busy periods. In both cases, controller situation awareness appears to drop, and can lead to operational errors. Evidence for this phenomenon needs to be assessed and weighed, and then appropriate study undertaken.

The above four areas are those that will be addressed in the short – medium term, however, this ‘thread’ of the safety R&D plan is aimed at addressing key risk areas, so it is likely that others will arise and be dealt with in a longer timeframe.

The deliverables are therefore as follows:

Enhanced understanding of the causes of level busts, and new mitigation measures
Enhanced understanding of the causes of runway incursions, and new mitigation measures
Safety benefits study of TCAS RA Downlinking to the controller
Longer term study of safety nets and their possible interactions in very short-time-scale events, and consideration of future safety net development needs
Evaluation of the effects of low-vigilance conditions on safe controller performance, and development of counter-measures if appropriate

**Key Risk Areas – longer term**

One particular longer term key potential risk area has been identified, namely that of operational complexity. Years ago, a common controller concern was ‘workload’, whereas now many controllers are concerned by the increasing complexity of traffic patterns.

Complexity can be defined objectively (e.g. in terms of density of traffic, number of movements and instructions required, etc.) and subjectively, according to controllers’ feelings of complexity or difficulty. It is common to hear a controller say that one single aircraft in a particular situation can lead to more complexity (and workload) than ten routine aircraft.

Complexity is likely to lead to different types of problems and errors, such as secondary conflicts, and losses of situation awareness. Such effects become of more safety concern as capacity increases, since in densely occupied airspace there is ‘less room to manoeuvre’, and less room for error generally.

There is therefore a need to better understand complexity, but such study must be in an operational context, as it is difficult to simulate true operational complexity reliably. It is therefore intended to study the ‘limits of complexity’, and to develop ‘complexity coping guidance’, in liaison with one or more operational centres. This would help airspace designers and controllers alike in preventing and dealing with difficult situations. The deliverable would therefore be as follows:

Study of controller perceived complexity, including determining major complexity-causal factors, coping strategies, guidance on airspace design to avoid and/or assess complexity, and an understanding of complexity limits for controllers.

**Safety Roadmap**

If capacity doubles by 2015, safety also needs to at least double in the same timeframe. It cannot simply be assumed that this can be achieved by trying harder. There needs to be a strategic planning of safety benefits of the various changes being introduced in the gate-to-gate ATM process, so that these safety benefits are realised. The R&D strategy proposed is to develop a ‘roadmap’ based on the ATM change philosophy (e.g. ATM 2000+), and assess the relative benefits of each of these changes. This work will build on the earlier cited ‘integrated risk assessment’ project mentioned within the SAFMOD project. It will act as a ‘balance sheet’ for safety, to see how we can reach the target, and then how we actually proceed according to the target, via predictions from risk assessments and operational experience (SAFLEARN) as such systems are actually implemented. Then, if we ‘fall behind’ our targets, new initiatives need to be sought and developed to redress the balance. In this way, safety can be truly managed.
The **Safety Roadmap** project will therefore develop the approach and show how it can work, after which time it will become a safety management tool. This particular R&D project will involve collaboration from other member states, and also the US via the FAA-Eurocontrol Action Plan (15) on safety signed in June 2003.

Safety ‘investment’ in the future must not only consider technology however, it must also determine what the optimal safety role and responsibilities of the controller should be. This is particularly important since at present a significant part of ATM safety rests in the hands of controllers.

The deliverables will therefore be as follows:

- A Safety Roadmap to determine how increasing safety will be progressively achieved, and as a means to monitor safety performance
- A clarification of the future safety role and responsibilities of the controller

### Safety Culture Assurance for Proposed Fundamental Changes in ATM

ATM is currently seen by other industries as a ‘High Reliability Organisation’ (HRO), although it is not fully understood why ATM is so safe. Safety, in the levels seen in ATM, is something of an ‘emergent property’, built on the professionalism within the industry, and decades of trial and error in evolving best practices and procedures. It is obviously desirable that ATM retains this hard-won HRO status. The most likely way it could lose this characteristic is via fundamental change, i.e. changes at the core of ATM. Change is seen as one of the main generalised causes of accidents. Therefore, Safety R&D should consider the major fundamental changes that might affect ATM in the future, and ensure that these changes will not result in losing the emergent property of safety. Otherwise, we risk ‘throwing the baby out with the bathwater’, and becoming a less-safe industry.

radical changes to the controllers’ tasks,  
radical changes to the responsibilities of the controller, and  
radical changes to the airspace itself.

These changes are planned in the form of automated tools, (limited) delegation of aircraft separation duties to the cockpit, and the Single Sky initiative.

The first, namely the implementation of automated tools, is via an incremental approach to the introduction of such tools. Arguably this process has been ongoing for some time, via the introduction of Secondary Surveillance Radar, Short Term Conflict Alert, Graphic User Interfaces (GUIs) for new Ops Rooms, and planned near-term implementation of some medium term conflict detection support (e.g. Rome and Malmo). This trend will continue potentially via Mode S, Datalink, Arrival Managers, Departure Managers, and Conflict Resolution Assistance. Since this is a relatively slow and incremental process, the assurance of the safety of these changes is dealt with via individual safety assurance assessments, and there will also be a need to assess the integrated impact of the combined tool set on ATM’s HRO status. This can be handled by an integrated risk assessment approach as mentioned earlier (SAFMODE). Nevertheless, it may be that such changes need a specific ‘change
management process’ to ensure that they retain good aspects of safety culture, and in particular safe working practices. Such changes would benefit for example from application of the newly developed ‘Human Factors Case’ approach.

However, the other two fundamental changes are qualitatively different. Changes to the responsibility of the controller, e.g. delegating (some) separation responsibility at least partly to the cockpit, goes to the very core of what it means to be a controller. This could affect the attitudes and motivation of controllers, and disturb the formal and informal practices that make ATM safe. If the high degree of safety in ATM is recognised to be an emergent property, it is not a ‘given’ that such new changes will automatically retain the positive behaviours and attitudes that make ATM a HRO. We cannot necessarily specify the exact behaviours that we need to retain, because we do not necessarily know precisely what they are. At this level of description of safe behaviour, what is needed is an approach that measures the operational culture, and captures the mechanisms by which this culture embodies safety. This is known as the safety culture approach. Safety culture is defined as ‘the way things (in this case safety) are done around here’, and tools exist to measure safety culture in different operational situations.

Safety culture analysis and measurement should therefore be applied to the fundamental change that is represented by delegation of responsibility for separation to the cockpit. Such an approach aims to determine if (and how) such significant shifts are impacting safety culture, and whether compensation needs to occur, and what such compensation would entail. This is an imprecise area, but scientific methods do exist to tackle it.

Similarly, proposed fundamental changes to the airspace such as Single Sky could affect the safety cultures currently embodied in different ANSPs. Single Sky, as with separation responsibility delegation changes and automation, could of course improve safety, but even if this is the case, we need to understand how safety is changing. For Single Sky, there will be an interesting and relevant first step by bringing eight national airspaces together in the CEATS project. These neighbouring countries will have compatible procedures, but will differ in certain local operational practices and attitudes. Safety culture assessment and modelling could help the transition towards CEATS, helping to make it a smoother one, anticipating and thereby avoiding potential inconsistencies in approaches to safety.

In summary for this ‘thread’ of safety R&D, safety culture is seen as key to maintaining and improving safety. Safety culture measurement of ANSPs is not an R&D issue, it is a safety management one, as the tools already exist to perform such analyses. However, assuring future safety culture in the face of certain fundamental changes (namely delegation to the cockpit for separation, and Single Sky) is a R&D matter, partly because of the novelty of the subject matter, and partly because to an extent such safety culture assessment is trying to be prospective. Therefore, two project needs are identifiable: to assure safety culture of the delegation of separation assurance to the cockpit, and the Single Sky concept, the latter using the formation of CEATS as a first approximation. The deliverables are therefore as follows:

Safety culture study of Airborne Separation Assurance concepts, and determination of means to assure a positive safety culture
Safety culture evaluation of CEATS as a first approximation to Single Sky, and determination of means to assure an overall safe culture given different working practices.

**Safety R&D Co-ordination**

The R&D for ATM safety needs to be effective and efficient, and of course also needs to be relevant. The Safety R&D Team (SRT, based at the ERC in Bretigny) work together with a number of other Eurocontrol units. These include Safety Enhancement (SAF: supporting safety now and in the near term), Safety Domain (SSM: looking after future safety), Safety Regulation, Human Factors (HUM), Maastricht Upper Airspace Centre (MUAC), CRDS, and the Institute of Air Navigation Services (IANS). The SRT support a number of projects in Eurocontrol, especially those based at the ERC, and also send representatives to key ANSP stakeholder groups, e.g. the Safety Team, Safety Improvements Sub-Group (SISG), and the Safety Assessment Methodology Task Force (SAMTF). These involvements and internal co-ordinations help to ensure that the research remains abreast of developments within the organisation, and is in touch with Air Navigation Service Provider (ANSP) stakeholders’ concerns and priorities.

What needs to be done, however, is to gather together the range and diversity of European ATM Safety R&D Centres and researchers (whether within ANSPs or independent), to foster collaborative efforts towards common safety goals. It is intended to commence this activity in 2004, in part supported by European Commission funding. Additionally, collaboration should take place between European and US initiatives in particular. These approaches will lead towards a collaborative safety R&D community, and will support the realisation of safe future ATM in a cost-effective way. The deliverables for safety co-ordination are therefore as follows:

- Development, acceptance and collaborative work within the framework of a Eurocontrol-FAA Action Plan on Safety (AP 15)
- Development of a European ATM Safety R&D forum for efficient and effective collaboration on safety R&D projects and initiatives

3. **Logistical Aspects**

**Resources**

The above has outlined the main aims of the different safety R&D ‘threads’ that support the eight principles defined earlier. Resource estimates have been made for the individual project items, though at the time of this document funding has not been secured for all items. Where in fact items cannot be funded internally in Eurocontrol, other funding sources will be sought, though of course cannot be guaranteed. Where funding cannot be found, this could lead to Eurocontrol asking one of the other R&D centres to consider carrying out the work, as part of a collaborative effort as described in safety R&D thread 8.
**Timing**

Table 1 below gives an outline of the timing anticipated for the projects outlined in Section 2, along with ancillary details.
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<td>04 - 05</td>
<td>ERC / SAF / SSM</td>
<td>Barry Kirwan</td>
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¹ All Eurocontrol e-mail addresses follow the same format: first name.family name @eurocontrol.int e.g. barry.kirwan@eurocontrol.int
² It is not yet determined which safety culture study will start first.