SEVENTH FRAMEWORK PROGRAMME

ASCOS safety certification

MINUTES OF MEETING

ASCOS – EASA Technical Information Meeting

Meeting Title			
Date 04-09-2013	Meeting Time 15:00 – 16:30	Meeting Location EASA, Cologne	
Meeting called by	Rodrigo Priego (EASA)		
Work Package	WP7		
Type of meeting	ASCOS – EASA Technical Information Meeting		
Facilitator	Rodrigo Priego (EASA)		
Prepared by	Lennaert Speijker (NLR)		
Attendees	Name	Organisation	Remark
	Rodrigo Priego	EASA	
	Lennaert Speijker	NLR	
Additional distribution	Gerard Temme	CFLY	
	Monique Heiligers	CFLY	
	Alex Rutten, Michel Piers, Alfred Roelen	NLR	
	Ken Engelstad, Michel Masson	EASA	
	Nuno Aghdassi	Avanssa	
	Susana Bravo Munoz, Jean-Pierre Heckmann	APSYS	
	Jean-Pierre Magny	JPM	
	Ricky Curran, Heiko Udluft	TUD	

Agenda

Agenda Topic		
Time	Main Speaker	Description Title
15:00	Rodrigo Priego (EASA)	Preliminary Proposal for EME 1.2
	Lennaert Speijker (NLR)	Potential ASCOS contribution to EME1.2
16:30	Meeting closure	

Document Change Log

Version	Author(s)	Date	Affected Sections	Description of Change
1.0	L.J.P. Speijker	31-10-2013	All	First approved version

1 Introduction

Main objective of the (informal) meeting was to try bring the ASCOS activities (coordinated by Lennaert Speijker, NLR) in line with EASA plans to create a foresight cell to support its decision making (the latter is also referred to as EME1.2, for which Rodrigo Priego is now the action holder). A specific topic is to discuss how ASCOS preliminary results could be used for the EME1.2 activity, coordinated by EASA.

2 Meeting content

The main objective of European Aviation Safety plan (EASp) actions EME1.1 and EME1.2 is to prioritize safety improvements efforts on the basis of foresight incorporating emerging and future risks, which may exist within specified time frame. This was intended to be achieved by applying the EME1.1 Methodology on the vision of the future delivered by EME1.2 (Appendix A of the minutes). Preferably this would help EASA to decide which EASp issues[1] (operational, systemic and/or emerging) and aviation domains require most efforts in the future. It was initially foreseen to develop a version of the EME1.2 methodology by the end of 2012. However, this task has been delayed. Current status (a preliminary proposal) is provided in Appendix A of these minutes.

It appeared that there is a relation between the EME1.2 objective and the work performed within the ASCOS WP3, which is led by APSYS (Susana Bravo Munoz). In particular the following tasks appear to be relevant:

- WP3.1 Total aviation system safety assessment methodology
- WP3.2 Risk models and accident scenarios
- WP3.3 Tool for risk assessment

Because these tasks rely on WP2.2 (Total aviation system baseline risk picture), there is also a relation with WP2, which is led by Avanssa (Nuno Aghdassi). Inputs from both WP2 and WP3 could be useful for the EME1.2.

While brainstorming, it appeared that there may be some possibilities to reach the main EME1.2 objective by combining some of the material developed within these two ASCOS WPs. The participants discussed how an initial methodology to support decision making could look like (details to be elaborated further). During the brainstorming, several preliminary ASCOS results were identified that could be used as inputs for the approach to be followed. For the purpose of clarifying the way of reasoning, these preliminary ASCOS results are all provided in the Appendices (B until E, derived from versions 1.3 of deliverables ASCOS D2.2, D3.1, and D3.2). In the following, potential core elements of a procedure to support construction of an EME1.2 method are given.

<u>Inputs:</u>

a. EASp issues (operational, systemic and emerging)
b. Areas of Change list and associated hazards (Appendix B)
c. Cross references between Areas of Change and aviation domains (Appendix C)
d. Total aviation system baseline risk picture (Appendix D)
e. Cross reference between CATS scenarios and EASp operational Issues (Appendix E)

[1] This can be either existing issues whose associated risk will change or new issues that will emerge in the given time frame.

<u>Proposed Initial Methodology</u>

1. Determine, for each of the Areas of Change, the target year of actual implementation (time frame)
2. Correlate Areas of Change with applicable accident scenarios and associated EASp operational issues
3. Correlate hazards, associated with Areas of Change, with accident scenarios & EASp operational issues
4. Assess for each hazard, associated with FAST Areas of Change, likelihood/severity of consequences
5. Estimate increase or decrease of all accident scenario frequencies, relative to the baseline risk picture
6. Determine future risk pictures for all accident scenario frequencies per flight
7. Determine future risk pictures for the EASp issues (operational, systemic and/or emerging)
8. Prioritize EASp issues[1] related to future risk pictures (using highest estimated frequencies)
9. Prioritize the aviation domains by identifying all the Areas of Change associated with the prioritized EASp operational issues and using cross references between Areas of Change and aviation domains.

<u>Main output:</u>

1. Prioritisation of EASp issues[1] (and associated accident scenarios) for specified time frames
2. Prioritisation of the aviation domains that would require most effort within the specified time frames.

It was recalled that ASCOS agreed to apply the EME1.1 methodology within ASCOS WP4 (this was one of the results of the ASCOS – EASA Workshop that took place on 19 April 2013). It is now also agreed that ASCOS will try to further elaborate the above proposed initial methodology **(*<u>Action 1</u>*)**, and will run an illustrative test scenario to clarify how the main outputs could possibly be obtained with the above ASCOS inputs **(*<u>Action 2</u>*)**. The method would initially rely on expert judgement. Clearly validation of this method is not within scope of this initial exercise (and most likely also not within scope of ASCOS), which may take some time to perform.

ASCOS will apply a proposed certification process within four case studies (each deals with a specific proposed change that would lead to enhancement of safety). The definition and content of the ASCOS case studies was discussed. Lennaert explained that no definite decision was made regarding the content of the ASCOS case studies. EASA is invited to discuss internally if there would be a preference for certain changes **(*<u>Action 3</u>*).**

3 Meeting Wrap-up

The meeting was closed around 16:30. Both Rodrigo Priego (EASA) and Lennaert Speijker (NLR, the ASCOS Coordinator) will discuss the outcome of the meeting further with relevant persons (in EASA and ASCOS respectively). It is possible that these discussions lead to adaptations of the initial proposed methodology.

*Post meeting note: implementation of **Action 1** is being considered in ASCOS WP3.3. The implementation of **Action 2** (run test scenarios) can be performed in ASCOS WP4, provided that the tool for risk assessment (as developed in WP3.3) meets all the required functionalities as specified in a separate note drafted by the NLR.*

4 Meeting Material

#	Documentation	Point of Contact	Source
1	EME1.2 Preliminary Proposal	Rodrigo Priego (EASA)	EASA
2	AoC list and associated hazards	Lennaert Speijker (NLR)	ASCOS D3.1
3	Cross references AoCs vs. aviation domains	Lennaert Speijker (NLR)	ASCOS D3.1
4	Total aviation system baseline risk picture	Lennaert Speijker (NLR)	ASCOS D2.2
5	Cross references CATS and EASp operational issues	Lennaert Speijker (NLR)	ASCOS D3.2

5 List of Actions

List of Actions			
#	Action Items	Responsible	Deadline
1	Implement the initial methodology, described in these minutes	ASCOS WP3.3	1 January 2014
2	Run some illustrative test cases with some example inputs	ASCOS WP4.X	1 October 2014
3	Discuss internally and possibly provide some proposed changes within the total aviation system that may serve as content for the certification case studies to be performed in ASCOS WP4	EASA	1 January 2014

Appendix A Preliminary proposal for EME1.2

The Agency has a strong interest in gathering information of any changes affecting the aviation system and therefore would like to create a foresight cell to support its decision making.

EME1.2 proposal

Adapt or create a methodology to develop a common possible picture of the future. Such methodology should envisage cooperation with other bodies such as EUROCONTROL, SAE or ACARE.

Internal brainstorming

Our initial idea was to start creating a data base of changes affecting the aviation system for example based on the one developed by FAST. The changes could be categorised but should include as a minimum a title, a description as accurate as possible, a timeline, indicators to be watched to see if they are implemented and an evaluation of the magnitude of the change.

More details on the above:

- Affecting the aviation system: therefore not only limited to change originating from aviation
- Description: an identification of risk is not requested
- Timeline: horizon at which the change could be expected to be effective
- Indicators: this should indicate the level of maturity of the change (e.g. scientific articles, presentation at conferences, research, prototype, industrialisation)
- Magnitude of the change: e.g. affect the whole system, local effects, affects one discipline, etc.

The database would be reviewed every year or every two years to establish main trends: general trends, scientific progress, changes in the aviation system.

Such trends could be used to develop/ modify our strategy, evaluate how risks could develop with time and identify what kind of expertise we need to be prepared to face those changes. Such trends would in particular bring a more robust basis for the “emerging” risks section of the EAS plan.

We cannot of course work in isolation and should share this picture with stakeholders in particular those that have a prospective activity such as ACARE but also SAE and organisations specialised in foresight.

Appendix B Areas of Change list and associated hazards

1. Introduction of new aircraft aerodynamic and propulsion configurations

1. Technology advances outpacing the development of mitigations for unintended, emerging safety risks.
2. Flight and operational capabilities incompatible with current safety risk management methods.
3. Unfamiliar flight characteristics and control response.
4. Heterogeneous aircraft flying in common airspace.
5. Unpredictable wake vortex characteristics.
6. Evacuation delays.

3. Changes in design roles and responsibilities among manufacturing organizations

1. Inadequate transfer of expertise and/or inadequate interface management.
2. Lessons learned from past experience may not be sufficiently covered by FARs and CSs.
3. Dependence on single, specialty suppliers for a class of components by a number of manufacturers may create common-cause failures.
4. Potential loss of a larger systems view and understanding of the total aircraft design.

5. Introduction of new runway-independent aircraft concepts

1. Failure to yield aircraft rights of way.
2. Jet blast hazards in ground effect.

6. New supersonic and hypersonic transport aircraft

1. Exposure of passengers and flight crew to significant radiation levels due to high altitude flight.
2. Mixed traffic in terminal environment.
3. Unknown/unexpected loads and thermal stresses.

9. Accelerating scientific and technological advances enabling improved performance, decreased fuel burn, and reduced noise

11. Air traffic composed of a mix of aircraft and capabilities

1. ATC coordination problems when low-technology aircraft are mixed with high technology aircraft in high-technology airspace.
2. Loss of separation of mixed technology aircraft sharing same airspace.
3. NextGen/SESAR hazard condition: Several issues arise in a controller's sector, many involving mixed equipage. Controller reviews the events and prioritises response to them. Associated human performance hazard: Controller misprioritises response order of events.
4. NextGen/SESAR hazard condition: TMC Reroute is de-conflicted by automation probe. Sector controller resolves any remaining predicted problems with the reroutes as necessary. Associated human performance hazards: Sector controller overly reliant on automation and TMU to resolve sector issues. Controller fails to identify/resolve predicted problems in a timely manner.

13. Reliance on automation supporting a complex air transportation system

1. Flight crew spending excessive time in a monitoring role potentially compromising their ability to intervene when necessary.
2. Failure of the flight crew to remain aware of automation mode and aircraft energy state.
3. Unfamiliar modes of aircraft automation may result in a perfectly normal flying aircraft suddenly taking on characteristics that the pilot has seldom or never previously encountered.
4. Latent flaws in the displays or primary flight control system may go undetected, because not enough human-in-the-loop testing is performed.
5. Pilots may not be adequately trained to understand the philosophy of the automation design and of degraded automation functionality.

6. Inadequate software verification.
7. NextGen/SESAR hazard condition: Surface automation updates departure schedule based on time taxi clearance issued via data communications. Associated human performance hazard: Local Controller places aircraft in position to allow arrival aircraft to clear runway. Controller delays issue of takeoff clearance due to automation schedule disagreement.
8. NextGen/SESAR hazard condition: Local Controller issues takeoff clearance by voice when automation schedule advises controller of appropriate departure time. Associated human performance hazard: Controller issues a voice amendment, but does not enter amendment into ground surface automation.
9. NextGen/SESAR hazard condition: Weather or restricted airspace results in congestion that controllers must develop amendments for en route aircraft. Associated human performance hazards: Controller successfully develops route amendments, but fails to issue en route amendment to pilot. Controller issues voice amendment to en route aircraft that disagrees with route entered into automation.
10. NextGen/SESAR hazard condition: Ground controller coordinates runway crossing with local controller. Associated human performance hazard: Ground controller fails to coordinate runway crossing with local controller and authorises aircraft to cross runway (extremely high risk).

14. Advanced vehicle health management systems

1. Sensor failures producing single point failure of multiple devices.

18. New cockpit and cabin surveillance and recording systems

1. Diversion of scarce safety resources away from accident prevention to post-mortem forensics.
2. Crews “flying by the book” though that may not be the appropriate response in unexpected situations.

19. Emergence of high-energy propulsion, power, and control systems

1. Catastrophic failure of high-power gearboxes.
2. Penetration of pressurised fuselages by failed open-rotor fan blades.
3. Explosions due to undetected accumulation of combustible gases.
4. Burst hydraulic lines.
5. Failure of electro-mechanical actuators and signal/power transmission cables.
6. Failure of high-power alternators and power distribution systems.
7. Increased vulnerability to lightning strikes and sunspot effects.
8. Unexpected thermal runaway/overheating and combustion.
9. Deep discharge may short-circuit the cell, in which case recharging would be unsafe.

21. Advanced supplementary weather information systems

1. NextGen/SESAR hazard condition: Last minute flight plan changes are negotiated as necessary based on the weather changes. Associated human performance hazard: GA pilot fails to incorporate weather information into go/no-go decision.
2. NextGen/SESAR hazard condition: Post-departure, the pilot monitors weather updates as provided by automated Weather Advisories. Associated human performance hazard: GA pilot ignores recommended weather advisory.
3. NextGen/SESAR hazard condition: Post-departure, the pilot monitors weather updates as provided by automated Weather Advisories. Associated human performance hazard:
    a. GA pilot ignores recommended weather advisory.
    b. Commercial pilot ignores recommended weather advisory.

22. New cockpit warning and alert systems

1. Proliferation of caution/warning systems and alerts overwhelming the perceptual and cognitive abilities of the flight crew in critical phases of flight.

2. Changing crew workload.
3. Decreased flight crew situational awareness.
4. Failure to harmonise/optimise certification requirements for caution/warning systems including coordination and prioritization for multiple alert conditions.
5. Differences among automation use policies among different airlines may affect caution/warning implementations.
6. NextGen/SESAR hazard condition: Conformance Monitor generates excessive false / nuisance alerts. Associated human performance hazards:
    a. Flight crew ignores accurate conformance alert and fails to issue corrective instructions for a true alert.
    b. Flight crew becomes overly reliant on automation, fails to notice deviation when not alerted.
    c. Flight crew fails to confirm validity of conformance alert.

27. Next-generation in-flight entertainment and business systems
1. Hazardous effects of internal and external high-energy radiated fields emitted from these systems.
2. Inadequate certification processes for flight-critical aircraft systems and required maintenance procedures.

31. New glass-cockpit designs in general aviation aircraft
1. Failure of glass panel power supplies.
2. Inability to successfully revert to backup manual flight instruments.
3. Obsolete databases not containing new obstacles and departure/arrival routes.
4. Information overload.
5. Excessive heads down time.

33. Entry into service of Very Light Jets
1. Wake turbulence upset of lighter aircraft when co-mingled with heavier, faster jets
2. Increase in traffic.

36. Increasing implementation of Electronic Flight Bag (EFB) for efficient and safe operations
1. Obsolete databases not containing new obstacles and departure/arrival routes.
2. Cyber attack on database integrity.
3. Heads-down distraction of crew pre-occupied with EFB.
4. Low time between failure compared with certified equipment.
5. Poor visibility/contrast of display.
6. Failure of mechanical mount/electrical connection in cockpit.
7. Failure due to pressurization cycles.
8. Susceptibility to radiated fields in cockpit.
9. Failure of battery power.
10. Disconnect between aircraft/cockpit technology and airline infrastructure.

39. Increasing use of composite structural materials
1. Failure to detect sub-surface damage and de-lamination.
2. Shedding of micron-sised particles due to fatigue and chafing into cabin air with poorly understood health risks to lung tissue.
3. Damage due to lightning strikes

41. Ongoing electronic component miniaturization
1. Susceptibility of line replaceable units to ionizing radiation.
2. Fire hazard due to overheating.
3. Inadequate physical separation of miniaturised systems, increasing the risk of common cuase failure.

43. Highly-integrated, interdependent aircraft systems

1. High and low criticality functions sharing computing and data bus resources instead of being physically separated. Software-based isolation and independence is much more "fluid" and difficult to assure than relying on hardware.
2. Lost or erroneous inputs can result in a cascade of effects on the aircraft.
3. Inadequate self-checks to verify software for accuracy and integrity due to system complexity.

47. Changing human factors assumptions for implementing technology

1. Inaccurate assessment of total system safety due to failure to take credit for the human contribution to recover from adverse events.

51. Delegation of responsibility from the regulating authority to the manufacturing, operating or maintaining organization

1. Inconsistencies in compliance with certification and training regulations and the lack of FAA/EASA standardization.

53. Trend toward privatization of government ATC systems and airports

1. Pressures to reduce staff and equipment expenditures to minimum levels.

58. Shift toward performance-based solutions and regulations

1. The full safety implications of the introduction and interaction of these performance-based systems and regulations are not fully understood.

64. Remote Virtual Tower (RVT) operational concepts

1. Reduced sensory information upon which clearance decisions are based.
2. Inadequate awareness of other conditions on or around the airport that may affect flight operations (such as nearby weather formations).
3. NextGen/SESAR hazard condition: As departing aircraft taxi to runway, ground controller overly relies on observing automation to monitor conformance. Associated human performance hazard: Ground Controller fails to issue corrective instruction to resolve conflict because of lack of alert from surface automation. Ground controller is overly reliant on remote conformance alert.

66. Societal pressure to find individuals and organizations criminally liable for errors in design and operations

1. Reduction in normal incentives to perform research that may reveal possible design defects and operational errors.
2. Reluctance to file safety reports, thus reducing the possibility of learning from occurrences.
3. Industry members taking a more defensive rather than co-operative attitude towards regulators.
4. Disturbance of the open atmosphere in which industry and authorities jointly discuss safety issues.

67. Economic incentives to form partnerships and outsource organizational activities

1. Degradation of prior, robust, aviation cultures that were previously based on personal relationships.
2. Sudden ruptures in economic relationships including just-in-time supply chains, and available safety resources due to world market upheavals.
3. Failure to detect emerging issues resulting from faulty or broken reporting systems in dispersed organizations across world economic centers.

68. Global organizational models

1. Safety problems escaping notice due to lack of coordination.
2. Degradation of prior, robust, aviation cultures that were previously enabled by geographic proximity.

69. Evolution in lines of authority, command and responsibilities within the air transport system

1. Indirect or unclear lines of authority leading to confusion as to who is ultimately responsible for monitoring safety and implementing needed improvements
2. Hazards associated with bureaucratization:
   a. Delays in decision making;
   b. Poor communication among levels;
   c. Funding allocations;
   d. Opaque visibility of operational issues at higher levels of the organization.

73. Increasing complexities within future air transportation systems

1. Interactions among various stakeholders are not given adequate attention.
2. Gaps and overlaps in organizational responsibilities.
3. Stove-piped safety analyses.

78. Increasing sise of maintenance, ATM, and operations databases

1. Risk managers becoming overwhelmed by data.
2. Necessary data not reaching the appropriate parties.
3. Inaccurate maintenance data that is critical for calculations such as weight/balance and fuel loads.

The following important characteristics for shared databases may not be common among stakeholders

a. Parameter nomenclature, instrumentation accuracy, recorder resolutions and sampling rates
b. Filtering and processing of the data, while airborne and by the ground station
c. Data acquisition units across different aircraft fleet
d. Data sources for the same or similar parameters
e. Algorithms and techniques for deriving parameters
f. Event and incident definitions
g. Unit standards and conversion calculations
h. User operational environments
i. Safety and reporting cultures
j. Use and knowledge of statistical systems
k. Identification of which data should be shared.

80. Reduction in numbers of aviation personnel familiar with previous generation technology and practices

1. Knowledge of why aircraft are designed as such, how key maintenance is to be performed, and why the operational rules are as they are not being retained by individual or organizational memory.
2. Difficult to access legacy data storage systems
3. Inability of some operators to attract and retain senior people to mentor, guide and direct the less experienced and maintain safety systems.
4. Wholesale retirements within the current generation of aviation professionals.
5. Shortage of qualified inspectors and flight examiners.

82. Technologies and procedures enabling reduced separation

1. Uncertain availability of technologies and procedures enabling reduced separation especially space-based navigation/timing assets.
2. Uncoordinated ground flow control and departure/approach flows due to separation of functions.
3. NextGen/SESAR hazard condition: As departing aircraft taxi to runway, ground controller overly relies on observing automation to monitor conformance. Associated human performance hazard: Ground Controller fails to issue corrective instruction to resolve conflict because of lack of alert from surface automation. Ground controller is overly reliant on conformance alert. ASDE-X (based on transponder codes) is not currently used for ground separation purposes.
4. NextGen/SESAR hazard condition: Departing aircraft deviates from issued taxi route. Surface automation provides conformance alerts and is overly sensitive with a high rate of nuisance alerts.

Associated human performance hazard: Ground Controller ignores accurate conformance alert and fails to issue corrective instructions for a true alert.

5. NextGen/SESAR hazard condition: Arriving aircraft deviates from control instructions. Controller performs conformance monitoring with assistance from automation. Automation is overly sensitive with a high rate of nuisance alerts. Associated human performance hazard: Controller ignores accurate conformance alert and fails to issue corrective instructions for a true alert.
6. NextGen/SESAR hazard condition: Automation identifies candidates for delegated spacing. Associated human performance hazard: Automation indentifies incorrect candidate.
7. NextGen/SESAR hazard condition: Automation used to sequence aircraft. Associated human performance hazard: Controller fails to notice flaw in automation sequence.
8. NextGen/SESAR hazard condition: Pilots establish linkage with paired aircraft. Associated human performance hazard: Pilot fails to establish linkage. Pilot establishes linkage with incorrect aircraft.
9. Failure or lack of available backup systems.
10. Failure of systems in in-trail aircraft to detect and warn of high-strength wake vortices.
11. Inaccurate modeling of wake location and strength.

86. Evolution in the type and quantity of information used by ATM personnel

1. Errors due to lack of effective information integration and monitoring.
2. Unintended uses of new ATC information systems.
3. Failure to trust modern ATC information systems.
4. Failure of current facility displays to support information generated by systems such as ADS-B – incompatible developmental timelines.
5. Multiple operational modes available in ATC hardware leading to loss of awareness of the system status and mode confusion or distraction.

87. Changing design, operational, and maintenance expertise involving air navigation system (ANS) equipment

89. Increasing heterogeneity of hardware and software within the ANS system

1. Proliferation of new ANS technologies along side legacy systems may complicate maintenance, preclude software reuse, increase training requirements, and increase the potential for human error.
2. Lack of a unifying technical architecture.
3. Different or incompatible communication protocols/data formats, and user interfaces.
4. Support of many older systems is not being provided at the OEM level.

93. Increasing reliance on satellite-based systems for Communications, Navigations, and Surveillance (CNS) Air Traffic Management functions

1. Changes to existing procedures in certain non-normal conditions to maintain adequate safety margins
2. Exclusive reliance on single CNS technologies.
3. Intentional interference, jamming or spoofing.
4. Failure of CNS systems to communicate changes arising from dynamically reconfigured airspace.
5. Failure of satellite electronics, radio/satellite communication and ground infrastructure due to solar weather effects.
6. Failure of CNS satellite due to impact of (man-made) space debris.

95. Changing approaches to ATM warning and alert systems

1. Proliferation of caution and warning systems and alerts may overwhelm the controllers in periods of heavy workload.
2. Failure to prioritise alerts prior to implementation of such systems.
3. NextGen/SESAR hazard condition: Conformance Monitor generates excessive false / nuisance alerts. Associated human performance hazards:

a. Controller ignores accurate conformance alert and fails to issue corrective instructions for a true alert.
b. Controller becomes overly reliant on automation, fails to notice deviation when not alerted.
c. Controller fails to confirm validity of conformance alert.

96. Increasing interactions between highly-automated ground-based and aircraft-based systems

1. Potential incompatibilities between ground based and aircraft based systems that could affect safety.
2. Unclear delegation of separation responsibility to aircraft.
4. Lack of coordinated development of the safety case arising from uncoordinated implementation schedules between airborne systems and ground-based systems.
5. Lack of synchronization between aircraft and ground databases such as terrain and airspace boundaries and time signals.
6. Failure of procedures and hardware to synchronise flight plans in aircraft avionics and those in ground systems during turnaround at the gate.

97. Introduction of artificial intelligence in ATM systems

1. Potential for controller error if these systems are given limited control of ATM functions such as separation assurance independent of the human.
2. Actual or potential loss of separation where alerts and additional warning times are inadequate due to computational delay.

99. Increasing dependence on in-flight electronic databases

1. Reduced ability to cross-check information.
2. Failure of process to upload current databases during pre-flight.
3. Potential for entering incorrect data through the FMC/FMGS.
4. Cyber attack corrupts database or makes it inaccessible.

100. Increasing operations of military and civilian unmanned aerial systems in shared military, civilian, and special use airspace

1. Loss of separation between passenger aircraft and UAS
2. Inadequate coordination between military and civilian UAS in civilian airspace
3. Inadequate failsafe UAS designs and operations
4. UAS loses control link and is not visible to ground based automation/ANSP.
5. Control link failure between UAS and ground station; equipment failure; intentional takeover
6. System latency: Time delay in telemetry update or lag in aircraft response to PIC commands or guidance from observer.
7. Hazards associated with possible use of TCAS for separation assurance given that TCAS was developed as a last resort airborne collision avoidance system:

101. Redesigned or dynamically reconfigured airspace

1. Conventional hazard analysis impractical. For example, it is simply not possible to exhaustively enumerate all of the possible interactions that might take place in a dynamically reconfigured airspace of any considerable complexity.
2. Coordination issues with other facilities.
3. Controller awareness of constantly changing airspace boundaries.
4. Possible frequency issues at ATC facilities.

109. Increasing utilization of RNAV/RNP departures and approaches by smaller aircraft

1. Procedures are unfamiliar to pilots.
2. RNAV/RNP procedures may permit descent to ILS-like minimums into airports not having infrastructure such as runway approach and centerline lights.

3. NextGen/SESAR hazard condition: Pilot must navigate to RNAV/RNP route. Associated human performance hazard: Pilot deviates from departure route / navigates to wrong route.

113. Increased operations of lighter-than-air vehicles including dirigibles and airships

1. Inadequate sense-and-avoid capabilities during transit through altitudes occupied by commercial transport traffic for pilot-optional configurations.
2. Loss of control due to low-altitude wind shear.

114. Increasing operations of cargo aircraft

1. Increased traffic at less well equipped airfields
2. Operations at low traffic hours i.e. very late or at night (with associated noise issues)
3. Operations at higher and lower average take-off gross weights
4. Less concern for ride quality resulting in greater exposure to structural stress during turbulence.
5. Aircraft older than passenger-carrying aircraft (aircraft operate for a full "second" life after cargo conversion)
6. Load shifts.
7. Mismanagement of hazardous materials.

117. Very long-range operations, polar operations, and ETOPS flights.

1. Excessive crew duty times and inadequate crew rest
2. Passenger health issues (deep vein thrombosis)
3. Inadequacy of support and/or medical facilities at airports to which flights may be diverted and survival after a crash in cold environments
4. Inadequate fire suppression capability for duration of ETOPS
5. Different operational conditions (e.g. long duration at very low temperatures) may result in unanticipated system failures.

118. Emerging alternate operational models in addition to hub-and-spoke concepts

1. Inadequate infrastructure at smaller airports.
2. Hazardous new routes into these airports for noise abatement and other traffic concerns.

119. Increasing numbers of Light Sport Aircraft

1. Inadvertent flight into unapproved airspace.
2. Inadvertent flight into IFR conditions.
3. Malfunction or failure of consumer-level avionics utilised in such vehicles.
4. Loss of control of such aircraft due to inadequate pilot proficiency.

122. Accelerated transition of pilots from simple to complex aircraft

1. Failure of pilots to “stay ahead of the airplane” and anticipate effects of failures of basic systems supporting complex airframes
2. Failure to properly execute checklists associated with complex aircraft (post-takeoff checklist, for instance)
3. Failure to perform basic engine management during key phases of flight
4. Failure of a single crewmember to function appropriately in the event of incapacitation of a fellow crewmember.

125. Operation of low-cost airlines

1. Although this way of operating is not necessarily better or worse, the fact that it is different may result in unforeseen misunderstandings, (e.g., in safety oversight by the authorities), or when it comes to joint (low-cost and legacy airline) safety initiatives).

129. Growth in aviation system throughput

1. Adverse operational events due to complexity and unresolved international harmonization for regions experiencing the most rapid growth.
2. Shortcomings in execution of procedures due to changing of roles and responsibilities for pilot, controllers and others due to new concepts of operation.
3. Near misses, collisions, and runway incursions/excursions due to new systems such as traffic optimisers that will change operational paradigms and affect flight profiles and dispatch policies, procedures, and other aspects of aircraft operation.

133. Assessment of user fees within the aviation system to recover costs of operation

1. Reduction in flights and landings required to maintain proficiency
2. Reduction of utilization of fee-for-service capabilities such as VFR flight following and IFR services.
3. Less attention to “safety critical” functions based on user fees.
4. Lack of positive air traffic control for aircraft electing not to utilise fee-based services.

136. Increasing use of Commercial Off The Shelf (COTS) products in aviation

1. Unanticipated system failures.
2. Forced modifications
4. Counterfeit parts

138. Increased need to monitor incident and accident precursor trends

1. The increasing reliance on and acceptance of such systems will require comprehensive controls, procedures, and oversight to ensure that both data accuracy and integrity are maintained. This requires significant resources that cannot be spent in other safety initiatives.

139. Increasingly stringent noise and emissions constraints on aviation operations

1. Runway use policies creating potential for runway incursion/excursion and/or wrong runway take-offs/landing
2. New take-off and landing profiles which may reduce safety margins.
3. Noise curfews result in pressures to compress departures and arrivals into time slots near the beginning and end of curfew hours.
4. For Continuous Descent Approach (CDA) there are concerns with flying aircraft at reduced power at lower altitudes. The recovery rate for any kind of disturbance at lower altitudes is reduced significantly. At lower altitudes on less power, aircraft is more difficult to control due to air density. Bird strikes and engine stalls are much more likely at lower altitudes at reduced power and any last minute alterations could create result in loss of control.

141. Changes in aviation fuel composition

1. Engine failure/degradation due to:
   a. fuel specifications with differing properties such as lubricity, lower aromatic content, etc.
   b. cross contamination with incompatible fuels in pipelines.

144. Changing management and labor relationships in aviation

1. Loss of technical expertise in management ranks.
2. Realignment of relationships between management and labor resulting in role ambiguity and loss of technical oversight.
3. Poor resource allocation decision-making due to profitability concerns that are not cognizant of safety issues.
4. Exacerbated difficulty in staffing transitions and role redefinitions (including situational awareness training) resulting from investment, allocation decisions.
5. Labor-management disputes resulting in poor operational performance.

148. Increasing frequency of hostile acts against the aviation system

1. Cyber attacks on data links, databases, EFB's and iPads and digital/ electromechanical systems, jamming resulting in loss of RF signals used for critical CNS functions and FADEC operation.
2. Increasing sophistication and proliferation of explosive materials, biological/chemical toxic agents, and anti-aircraft weapons.
3. Increasing frequency of distraction, glare and temporary flash blindness from easily available and low cost of high-power lasers

161. Increasing numbers of (migratory) birds near airports

1. Greater likelihood of bird strikes

170. Increasing manufacturer sales price incentives due to expanding competitive environment

1. Delays in implementing a recommended mitigation (Service Bulletin)

174. New surface traffic flow management technologies

1. Database errors in surface traffic flow management technologies
2. Runway incursions/excursions due to lack of proper training, interface design, and usage
3. Equipage inconsistencies between aircraft and ground surface flow equipment

184. Increasing amount of information available to flight crew

1. Crew distraction resulting from information being presented on supplementary displays, requiring the crew to divide their attention
2. Flight crew confusion resulting from multiple modes being annunciated at one time
3. Poor retrofit integration with existing systems
4. Cluttering if information is presented on a single screen
5. Potential for information overload and excessive workload
6. Failure to display information in easily understood form, making monitoring difficult and complicating execution of emergency operating procedures
7. Failure to provide controls feedback and tactile cues to the pilot at critical stages of flight
8. Pilot does not see visual references at decision height but proceeds below minimums using enhanced/synthetic vision system.

185. Introduction of artificial intelligence (self learning) in aviation systems

1. Pilots not understanding intent and actions of AI avionics
2. Failure to achieve robustness, as defined under DO-178B guidelines - the very specific proof that under all application failure conditions, a single failure in one partition will not affect other partitions.

187. Shift in responsibility for separation assurance from ATC to flight crew

1. Intent and reasoning systems not well understood by the pilot
2. Unfamiliar, and unanticipated characteristics and interfaces
3. Lack of clarity when responsibility has been reassigned and how it may vary by phase of flight and type of airspace.
4. Breakdown in the fusion of current (radar) and near-term surveillance technologies (ADS-B In/Out) plus the procedures and phraseology that goes with them.
5. NextGen/SESAR hazard condition: Controller assists with weather avoidance, but overall responsibility remains with pilot. Associated human performance hazard: Sector controller fails to notice pilot request for assistance.
6. Computer-to-computer transfer of separation responsibility does not occur properly.

188. Introduction of new training methodologies for operation of advanced aircraft

1. Ineffective training methods resulting in lack of in-flight situational awareness, decision-making, and inadequate risk management.

2. Failure to identify risks beyond an emergent or abnormal procedure.

189. Shifting demographics from military to civilian trained pilots

1. Diminished basic airmanship including aircraft energy management and manual handling skills.
2. Lack of aircraft system knowledge and diagnostic skills by air crew
3. Inability to operate advanced aircraft in abnormal situations/attitudes, and recover from unanticipated situations when there is no checklist

200. Increased dependence on synthetic training in lieu of full-realism simulators

1. Part-task trainers and limited range of motion high-fidelity simulators may not sufficiently emulate loss-of-control situations to enable effective upset recovery training.
2. Negative transfer of training due to the lack of fidelity with the actual operational environment.
3. Airline crews learning tricks to fly the simulator and pass competency checks.

202. Shortened and compressed type rating training for self-sponsored pilot candidates

1. Emergency/abnormal scenarios are being combined together, even though the events are extremely unlikely to occur together based on the operational record.
2. Recent accident scenarios are emphasised and "routine" flight operations are being under-emphasised.
3. Shortened type rating may not provide opportunities to detect weaknesses in basic pilot skills among the candidates.

205. Operational tempo and economic considerations affecting flight crew alertness

1. Reduced flight crew alertness

218. Supplementary passenger protection and restraint systems

1. Devices could be susceptible to inadvertent activation, causing deployment in a potentially unsafe manner.
2. Rescue crews may inadvertently trigger gas generators used for air-bag-type protection systems.
3. Rocket-propelled recovery parachutes in some aircraft may be accidentally triggered by rescue crews
or may explode in post-crash fires.

220. Increasing functionality and use of personal electronic devices by passengers and flight crew

1. Degradation or failure of flight-critical firmware and hardware.
2. Interference with avionics or other systems in aircraft.

221. Introduction of sub-orbital commercial vehicles

1. Inadequate normal and emergency procedures for coordination with conventional vehicles.

222. Standards and certification requirements for sub-orbital vehicles

1. Failure to implement certification requirements in a timely manner due to pushback from industry.

223. Increasing frequency of commercial and government space vehicle traffic

1. Loss of separation between space and air traffic.

225. Entry into service of commercial, space-tourism passenger vehicles

1. Vehicle reliabilities not of the same order of magnitude as those of commercial aircraft.
2. Impact between deorbiting debris and commercial aircraft.

226. Changes in the qualifications of maintenance personnel

1. Acceptance of poor quality work either because of time limitations or because errors are not detected.

2. Reduction in the availability of certified maintenance personnel due to tightening of controls on maintenance procedures, limitation of working hours, vision tests, etc.
3. Reduction in the number of experienced maintenance inspectors.

230. Paradigm shift from paper based to electronic based maintenance records and databases

1. Degradation in maintenance quality of legacy aircraft which were previously paper-based but are transitioning to a computerised format
2. Inappropriate skill sets among maintenance personnel because of changing processes, tools, and techniques to support the new computerised systems
3. Poor task verification processes
4. Lack of coordination between maintenance and flight crews
5. Disconnect in processes for handling the formal aircraft log.
6. Failure of processes to fully inform crew of inadequate pre-flight aircraft status due to new electronic log entry formats; mismatches between manual, paper logs and electronic logs.
7. Loss of access to existing maintenance information during transition process to electronic records.
8. Cumbersome access to historic maintenance records required to be kept by aircraft owner.

236. Increasing use of virtual mockups for maintenance training and for evaluation of requirements

1. Maintenance errors arising from differences between the training environment and real line operations.
2. Failure to maintain configuration control between maintenance simulators and actual aircraft physical hardware.

241. Operational tempo and economic considerations affecting fatigue among maintenance personnel

1. Increased likelihood of fatigue among maintenance personnel.

242. Increasing single-engine taxi operations or taxi on only inboard engines of 4-engine aircraft

1. Excessive jet blast to achieve wheel un-stick.
2. Accidental single-engine take-off.
3. Creation of adverse thermal cycles in engine components.
4. Failure to develop standard operating procedures (SOP) and checklists to avoid cancelled take-offs and/or malfunctions.
5. Different failure behaviour (e.g. with respect to corrosion) of aircraft components on the side of the non-running engine/propeller due to absence of jet blast or propwash as a result of single-engine taxi.

243. Novel technologies to move aircraft from gate-to-runway and runway-to-gate

1. Runway incursions
2. Inadequate visibility from the flight deck
4. Failure to complete engine run-up and checklists
5. Damage to nose gear due to frequent coupling/uncoupling with propulsive tugs (for both towbar and no-towbar, wheel capture approaches).

244. High-density passenger cabin configurations

1. Lack of or poorly located cabin emergency equipment.
2. Reduced crashworthiness.
3. Presence of additional combustible or out-gassing materials in the cabin.
4. Passenger health issues.

245. Worldwide implementation of SMS

1. Failure to align the SMS policy with the working environment and conditions under which it has actually been developed resulting in ineffective SMS implementation.
2. SMS being used solely as a compliance exercise rather than as a genuine safety enhancement.

3. A potential risk in the implementation of SMS is an inconsistency between current SMS practices. In the future, the safety environment may drift away from the conditions under which the SMS was originally developed and approved.

246. World wide climate change trending towards warmer temperatures

1. Heat waves.
2. Increased precipitation duration and intensity.
3. More frequent and intensified winds and storms.
4. Rising sea levels and ocean acidity levels affecting operations of sea level airports.
5. Changed bird migration routes affect bird strike risk.

247. New aircraft recovery systems in general aviation and commercial aircraft

1. Flight closer to the edge of the flight envelope due to overconfidence in protections offered by full-aircraft recovery systems.
2. Flight into inappropriate meteorological or terrain conditions due to overconfidence in protections offered by full-aircraft recovery systems.
3. Rocket-propelled recovery parachutes in some aircraft may be accidentally triggered by rescue crews or may explode in post-crash fires.
4. Pilots incorrectly over-riding auto-pull-up systems; not unlike resisting stick shaker/pusher functions.

249. Increasing demands for limited radio frequency bandwidth

1. Unpredictable effects of closely-spaced frequencies utilised by different applications
2. Potential interference by digital packets serving different applications transmitted on same frequency.
3. UWB devices will likely generate enough interference to disrupt transmissions of other frequency users.

250. Shortage of rare-earth elements

1. Reduced availability of spare parts (electronics).

251. Introduction of new training methodologies for maintenance staff

1. Lack of ICAO guidance material on how competency based training can be applied to maintenance.

252. Smaller organizations and owners operating aging aircraft

1. Uncertainty about the quantity or type of maintenance and inspection required to ensure a high level of safety.
2. Structural failure due to fatigue cracking and corrosion.

254. Aging maintenance workforce

1. Shortage would suggest engineers are at risk of being overworked in order to maintain existing or increased tempo of maintenance operations.
2. Errors due to fatigue and related human factors issues.

255. New pilot licensing standards

1. Manual flying skills are being lost.

256. Decreasing availability of qualified maintenance staff at stations other than home base of operation

1. Lack of timely servicing of aircraft with potentially flight-critical component or system problems.
2. Poor quality aircraft servicing due to hiring of minimally-qualified staff.
3. Over-reliance on Minimum Equipment List (MEL) procedures as safety nets.
4. Incorrect information on the MEL within the airline operation center.
5. Inappropriate release of an aircraft by dispatch.

257. Reluctance among operators to implement voluntary proactive safety mitigations

1. Delays in implementing needed safety enhancements and/or mitigations indicated by in-service data trends due to fear of non-compliance with regulations and the resulting financial penalties.
2. Operators may ignore Service Bulletins from manufacturers unless backed by a requirement from the authority.

259. Shift in the demographics of newly-hired air traffic controllers compared with retiree skills and interests

1. Recruits may lack knowledge of aviation and flying found in retirees as a result of their aviation-related avocations (hobbies).
2. Process for selecting and placing new controllers does not sufficiently evaluate candidates' aptitudes because certain regulators do not effectively use screening test results or consider candidates' training performance to help determine facility placement.
3. Classroom lecture and testing process will make it easy to learn new material in order to pass the next test, and then forget the information learned - this is described as the "learn and dump" approach to training.

260. Increasing use of Controller Pilot Data Link Communication (CPDLC) for weather information and advisories/clearances

1. NextGen/SESAR hazard condition: Clearances are issued via data link where possible. Associated human performance hazards:
   a. Controller fails to issue clearance to pilot.
   b. Controller issues clearance to incorrect pilot
   c. Voice-issued amendment not entered into automation
2. NextGen/SESAR hazard condition: Controller sends clearance via DataComm. Associated human performance hazard: Controller fails to execute sending of clearance.
3. When approach and landing clearances are transmitted by data link to cockpit during this critical phase of flight, traffic watch ("heads-up") time may be reduced due to the fact that one pilot may be head down responding to and accepting DataComm clearance; especially below 10,000 ft. AGL.
4. Voice inflection, emphasis, and urgency will be absent in a text-based data communications system.
5. Loss of "party line" insight to clearance being provided to other aircraft. Spatial information on other aircraft locations provided on NAV displays does not replace intent information provided by listening to clearances provided to other aircraft.
6. Reliability and security of the CPDLC links may be compromised by cyber security vulnerabilities.

261. Operational tempo and economic considerations affecting air traffic controller alertness

1. Reduced air traffic controller alertness

262. Potential pilot shortages

1. Decreased pilot qualification requirements.

263. Shift from clearance-based to trajectory-based air traffic control

1. Synchronous garble and False Replies Unsynchronised In Time (FRUIT) preventing CPDLC messages from getting through.
2. ADS-B ground system failure; ground based automation does not receive ADS-B message
3. Inaccurate modeling of wake location and strength (drift, sink, persistence, severity)
4. Ground based conflict resolution not calculated.
5. Safety critical input data are incorrect, late or missing.
6. Software processes are too slow to reliably fulfill the automation requirements.
7. Breakout maneuvers, go-arounds, or missed approaches are not conflict free.
8. Controller misunderstands what the automation is doing with other aircraft in his/her sector.
9. Excessive controller workload due to TBO complexity.
10. Excessive controller workload due to TBO automation failure.

11. Pilot distractions: pilot makes mistakes when performing TBO navigation due to distractions from TBO related distractions (conformance alerts, etc.) in cockpit.
12. Pilot performs traffic avoidance maneuver to clear aircraft not accounted for in the current 4D trajectory.
13. Pilot performs weather avoidance maneuver not accounted for in the current 4D trajectory.
14. Pilot decision making when presented with weather information may not be uniform.
15. Aircraft emergency situations (off-nominal); aircraft has an emergency and must deviate from 4D trajectory.
16. Missed approach under TOB; unanticipated change to the 4D trajectory by the aircraft.
17. Received information from GPS incorrect or missing.

265. Socio-economic and political crises affecting aviation

1. Failure of States to carry out their safety oversight functions.
3. Overtaxing the capacity and safety infrastructure at airports and within the airspace structure.
4. Lack of both human and financial resources to execute safety oversight functions.
5. High costs of recruiting and retaining qualified technical personnel who satisfactorily meet the requirements of the positions including professionalism and integrity.
6. Failure to detect deficiencies due to inspector shortages.
7. Failure of a license/rating/certificate/approval holder to correct deficiencies identified by the civil aviation authority technical experts including faults, malfunctions, defects, and other occurrences that cause or might cause adverse effects on the continuing airworthiness of the aircraft.

266. Single-pilot cockpits for large commercial transports

1. Pilot incapacitation.

267. Increasing adoption of software defined radio systems in commercial aviation

1. SDR generate a lot of heat, and the availability of cooling on an aircraft is limited.
2. Highjacking or disabling of the avionics by unauthorised personnel.
3. Controlled information available on the SDR network could be leaked if the network was tapped into.

268. Decrease in turboprop fleets and operations

269. Proliferation of voluntarily-submitted safety information

270. Initiation of collaborative air traffic management

271. Improved surface operations technologies and procedures

272. Increased traffic flows involving closely-spaced parallel, converging, and intersecting runway operations

1. Wake turbulence.
2. Runway incursions.
3. Loss of separation.

273. Increased throughput utilizing improved vertical flight profiles and aids to low-visibility operations

1. Failure to recognise the need for and to execute a missed approach when appropriate.

274. Widespread deployment of System Wide Information Management (SWIM) on-demand NAS information services

1. Compromise of information:
    a. integrity;
    b. availability;
    c. confidentiality.
2. Database obsolescence.

Appendix C Cross reference between AoCs and aviation domains

AoC number	ATM/ANS	Aircraft & Airworthiness	Operations & FCL	Aerodrome
1		X		
3		X		
5		X		
6		X		
9		X		
11	X			
13	X		X	
14		X		
18			X	
19		X		
21	X			
22			X	
27		X		
31		X		
33	X	X		
36		X	X	
39		X		
41		X		
43		X		
47		X		
51		X		
53		X		X
58	X	X	X	X
64	X			
66	X	X	X	X
67	X	X	X	X
68	X	X	X	X

AoC number	ATM/ANS	Aircraft & Airworthiness	Operations & FCL	Aerodrome
69	X	X	X	X
73	X	X	X	X
78	X	X	X	X
80		X	X	
82	X			
86	X			
87	X			
89	X			
93	X			
95	X			
96	X	X		
97	X			
99			X	
100	X		X	
101	X			
109	X		X	
113		X		
114		X	X	
117		X	X	
118				X
119	X	X		
122			X	
125			X	
129	X	X	X	X
133	X		X	
136		X		
138	X	X	X	X
139	X		X	X

AoC number	ATM/ANS	Aircraft & Airworthiness	Operations & FCL	Aerodrome
141		X		
144	X	X	X	X
148	X	X	X	X
161				X
170		X		
174	X			X
184			X	
185		X		
187	X			
188			X	
189			X	
200			X	
202			X	
205			X	
218		X		
220		X		
221		X		
222		X		
223	X			
225		X		
226		X		
230	X	X	X	X
236		X		
241		X		
242		X		X
243				X
244		X		
245	X	X	X	X

AoC number	ATM/ANS	Aircraft & Airworthiness	Operations & FCL	Aerodrome
246		X	X	X
247		X		
249	X		X	
250		X		
251		X		
252		X		
254		X		
255			X	
256		X		
257			X	
259	X			
260	X			
261	X			
262			X	
263	X			
265	X	X	X	X
266			X	
267		X		
268		X		
269	X	X	X	X
270	X			
271				X
272	X			
273	X			
274	X			

Appendix D Total aviation system baseline risk picture

ESD	ESD name	Accident end state code	Accident end state name	Number of occurrences[2]	Number of occurrences not assigned to accident scenario and distributed over total number of end states[3]	Frequency per flight
1	Aircraft system failure during take-off	ASC01d1	Runway excursion	2	0.39	$2.19 \cdot 10^{-8}$
2	ATC related event during take-off	ASC02d1	Runway excursion	0	0.39	$3.57 \cdot 10^{-9}$
3	Aircraft directional control by flight crew inappropriate during take-off	ASC03d1	Runway excursion	2	0.39	$2.19 \cdot 10^{-8}$
3	Aircraft directional control by flight crew inappropriate during take-off	ASC03d3	Runway excursion	2	0.39	$2.19 \cdot 10^{-8}$
4	Aircraft directional control related system failure during take-off	ASC04d1	Runway excursion	3	0.39	$3.11 \cdot 10^{-8}$
4	Aircraft directional control related system failure during take-off	ASC04d3	Runway excursion	1	0.39	$1.28 \cdot 10^{-8}$
5	Incorrect configuration during take-off	ASC05d1	Runway excursion	1	0.39	$1.28 \cdot 10^{-8}$
5	Incorrect configuration during take-off	ASC05d3	Collision with ground	1	0.05	$9.64 \cdot 10^{-9}$
6	Aircraft takes off with contaminated wing	ASC06c1	Collision with ground	2	0.05	$1.88 \cdot 10^{-8}$
8	Aircraft encounters windshear after rotation	ASC08d1	Collision with ground	0	0.05	$4.59 \cdot 10^{-10}$
9	Single engine failure during take-off	ASC09d1	Runway excursion	3	0.39	$3.11 \cdot 10^{-8}$
9	Single engine failure during take-off	ASC09d3	Runway excursion	2	0.39	$2.19 \cdot 10^{-8}$
10	Pitch control problem during take-off	ASC10d1	Runway excursion	2	0.39	$2.19 \cdot 10^{-8}$
10	Pitch control problem during take-off	ASC10d3	Runway excursion	0	0.39	$3.57 \cdot 10^{-9}$

ESD	ESD name	Accident end state code	Accident end state name	Number of occurrences[2]	Number of occurrences not assigned to accident scenario and distributed over total number of end states[3]	Frequency per flight
10	Pitch control problem during take-off	ASC10e1	Collision with ground	0	0.05	$4.59 \cdot 10^{-10}$
11	Fire, smoke, fumes on-board aircraft	ASC11c2	Aircraft continues flight damaged	12	0.00	$1.10 \cdot 10^{-7}$
11	Fire, smoke, fumes on-board aircraft	ASC11d1	Collision with ground	0	0.05	$4.59 \cdot 10^{-10}$
11	Fire, smoke, fumes on-board aircraft	ASC11e1	Personal injury	2	0.00	$1.84 \cdot 10^{-8}$
11	Fire, smoke, fumes on-board aircraft	ASC11e2	Aircraft damaged	78	0.00	$7.16 \cdot 10^{-7}$
12	Flight crew member spatially disoriented	ASC12c1	Collision with ground	1	0.05	$9.64 \cdot 10^{-9}$
13	Flight control system failure	ASC13c1	Collision with ground	2	0.05	$1.88 \cdot 10^{-8}$
14	Flight crew incapacitation	ASC14c1	Collision with ground	1	0.05	$9.64 \cdot 10^{-9}$
15	Ice accretion on aircraft in flight	ASC15c1	Collision with ground	0	0.05	$4.59 \cdot 10^{-10}$
16	Airspeed, altitude or attitude display failure	ASC16c1	Collision with ground	4	0.05	$3.72 \cdot 10^{-8}$
17	Aircraft encounters thunderstorm, turbulence or wake vortex	ASC17c1	In-flight break-up	7	0.00	$6.43 \cdot 10^{-8}$
17	Aircraft encounters thunderstorm, turbulence or wake vortex	ASC17d1	Collision with ground	1	0.05	$9.64 \cdot 10^{-9}$
17	Aircraft encounters thunderstorm, turbulence or wake vortex	ASC17e1	Aircraft continues flight with injury	30	0.00	$2.76 \cdot 10^{-7}$
18	Single engine failure in flight	ASC18d1	Collision with ground	1	0.05	$9.64 \cdot 10^{-9}$
18	Single engine failure in flight	ASC18d3	Collision with ground	8	0.05	$7.39 \cdot 10^{-8}$
18	Single engine failure in flight	ASC18e1	Aircraft lands off runway	6	0.00	$5.51 \cdot 10^{-8}$
19	Unstable approach	ASC19d1	Collision with ground	11	0.05	$1.02 \cdot 10^{-7}$

ESD	ESD name	Accident end state code	Accident end state name	Number of occurrences[2]	Number of occurrences not assigned to accident scenario and distributed over total number of end states[3]	Frequency per flight
19	Unstable approach	ASC19d3	Collision with ground	6	0.05	$5.56{\cdot}10^{-8}$
19	Unstable approach	ASC19f1	Runway excursion	21	0.39	$1.96{\cdot}10^{-7}$
19	Unstable approach	ASC19g2	Runway excursion	4	0.39	$4.03{\cdot}10^{-8}$
19	Unstable approach	ASC19g3	Aircraft continues landing roll damaged	11	0.00	$1.01{\cdot}10^{-7}$
21	Aircraft weight and balance outside limits during approach	ASC21c1	Collision with ground	1	0.05	$9.64{\cdot}10^{-9}$
23	Aircraft encounters windshear during approach or landing	ASC23d1	Collision with ground	4	0.05	$3.72{\cdot}10^{-8}$
23	Aircraft encounters windshear during approach or landing	ASC23d3	Collision with ground	1	0.05	$9.64{\cdot}10^{-9}$
23	Aircraft encounters windshear during approach or landing	ASC23f1	Runway excursion	1	0.39	$1.28{\cdot}10^{-8}$
25	Aircraft handling by flight crew inappropriate during flare	ASC25d1	Runway excursion	15	0.39	$1.41{\cdot}10^{-7}$
25	Aircraft handling by flight crew inappropriate during flare	ASC25e1	Runway excursion	4	0.39	$4.03{\cdot}10^{-8}$
25	Aircraft handling by flight crew inappropriate during flare	ASC25e2	Aircraft continues landing roll damaged	49	0.00	$4.50{\cdot}10^{-7}$
26	Aircraft handling by flight crew inappropriate during landing roll	ASC26c1	Runway excursion	40	0.39	$3.71{\cdot}10^{-7}$
27	Aircraft directional control related system failure during landing roll	ASC27c1	Runway excursion	25	0.39	$2.33{\cdot}10^{-7}$

ESD	ESD name	Accident end state code	Accident end state name	Number of occurrences[2]	Number of occurrences not assigned to accident scenario and distributed over total number of end states[3]	Frequency per flight
31[1]	Aircraft are positioned on collision course in flight	ASC31d1	Collision in mid-air	4	0.00	$3.67 \cdot 10^{-8}$
32[1]	Runway incursion	ASC32d1	Collision on runway	7	0.00	$6.43 \cdot 10^{-8}$
33	Cracks in aircraft pressure cabin	ASC33c1	In-flight break-up	0	0.00	0
33	Cracks in aircraft pressure cabin	ASC33c2	Aircraft damage	0	0.00	0
35	TAWS alert	ASC35d1	Collision with ground	4	0.05	$3.72 \cdot 10^{-8}$
36[1]	Conflict on taxiway or apron	ASC36d1	Collision on taxiway or apron	120	0.00	$1.10 \cdot 10^{-6}$
38	Loss of control due to poor airmanship	ASC38c1	Collision with ground	0	0.05	$4.59 \cdot 10^{-10}$

[1] *To ensure correct use of the exposure data, collisions between two aircraft are considered as two separate occurrences.*

[2] *Note that only 502 occurrences and 51 types of accident end states codes have been filed in the above Table while 1055 occurrences corresponding to 79 types of end states codes have been identified in Appendix A of ASCOS D2.2. The reason for the difference is that only 502 occurrences actually led to 'accidents' (the other occurrences led to at most 'serious incidents'). Only occurrences with accident end state are used to quantify 'risk frequencies per flight'.*

[3] *One 'collision with ground' accident that could not be assigned to an accident scenario has been equally distributed over all 'collision with ground' end states. Seven 'runway excursion' accidents that could not be assigned to an accident scenario have been equally distributed over all 'runway excursion' end states.*

Appendix E

		EASP category				
ESD	**Initiating event**	**Runway excursion**	**Mid air collision**	**CFIT**	**LOC-I**	**Ground collision**
1	Aircraft system failure during take-off	√				
2	ATC related event during take-off	√				
3	Aircraft directional control by flight crew inappropriate during take-off	√				
4	Aircraft directional control related system failure during take-off	√				
5	Incorrect configuration during take-off	√			√	
6	Aircraft takes off with contaminated wing				√	
8	Aircraft encounters wind shear after rotation				√	
9	Single engine failure during take-off	√				
10	Pitch control problem during take-off	√				
11	Fire, smoke, fumes onboard aircraft				√	
12	Flight crew member spatially disorientated				√	
13	Flight control system failure				√	
14	Flight crew incapacitation				√	
15	Ice accretion on aircraft in flight				√	
16	Airspeed, altitude or attitude display failure				√	
17	Aircraft encounters thunderstorm, turbulence, or wake vortex				√	
18	Single engine failure in flight				√	
19	Unstable approach	√			√	
21	Aircraft weight and balance outside limits during approach				√	
23	Aircraft encounters wind shear during approach or landing	√				
25	Aircraft handling by flight crew inappropriate during flare	√				
26	Aircraft handling by flight crew inappropriate during landing roll	√				
27	Aircraft directional control related systems failure during landing roll	√				
31	Aircraft are positioned on collision course in flight		√			
32	Runway incursion					√
33	Cracks in aircraft pressure cabin				√	
35	TAWS alert			√		
36	Conflict on taxiway or apron					√
38	Loss of control due to poor airmanship				√	