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FAST SECOND PHASE FINAL REPORT

EXECUTIVE SUMMARY

1. Background:

In early 1998, the JAA agreed to launch the JAA Safety Strategy Initiative (JSSI). The purpose of JSSI is to develop a focused safety agenda to achieve continuous improvement of the JAA safety system.

Two complementary approaches are being used to develop the focused agenda:

- One approach based on past accident analysis "(historic approach").
- The Future Aviation Safety Team approach ("predictive approach") based on an analysis of ongoing or future changes affecting the aviation system, is aimed at revealing unidentified hazards.

The first phase of FAST activities led to the agreement in September 2000 on a generic methodology and on a list of nearly 150 on-going or future areas of change affecting the Aviation System.

The purpose of the second phase was to prioritise and select, using the Analytical Hierarchy Process (AHP), the areas of change that will be analysed to identify the potential hazards that they may generate.

2. Phase two work summary

This second phase was conducted through three workshops of an expert panel with a broad scope of expertise.
The first workshop was dedicated to a presentation of JSSI and FAST (to set the scene) and to an introduction to; and practical exercises on the Analytical Hierarchy Process. It also defined a homework exercise to reduce the number of areas of change to be prioritised.
The second and third workshops were dedicated to perform the actual prioritisation and selection of areas of change.
Two other FAST meetings were necessary to perform a prototyping exercise and to draft this report.

3. Explanation of the process

The basic principle of the Analytical Hierarchy Process is to divide the problem to be solved in smaller elements, perform pair-wise comparisons and synthesise the results. There are several ways to establish such a hierarchy. The following one was used:

- Organise the list of areas of change into 11 categories (e.g. Aircraft, Air Navigation Services, etc.)
- Perform pair-wise comparisons between those 11 categories using as a criteria their “importance” for Aviation Safety.

- Perform pair-wise comparisons within each category using matrices of maximum 7 columns and 7 rows using same criteria as above.
- Synthesise the above elements to achieve the complete prioritisation.

To address concerns about normalisation of matrices, the following was performed after seeking advice of AHP experts:

- Perform a second time the pair-wise comparison of the categories when a better understanding of their contents was achieved.
- Use weighting criteria to take into account the fact that the matrices used within each category were of different sizes.
- Check that all areas of change were considered during the AHP process.

4. Prototyping Exercise

A prototyping exercise using the top two areas of change was done in order to develop guidelines for identifying hazards for each area of change.

5. Results:

- The above process led to an agreed prioritisation of areas of change (Top 20 concept).
- Guidelines for identifying hazards for each area of change were agreed.
- Strawman scope of work for the top two areas of change were agreed.
- FAST members are also convinced of the potential of AHP which may be used for other purposes than FAST and propose that discussions be held between JAA; RLD (Dutch Authority) and NLR (Dutch Aerospace Research Laboratory) to explore the possibility of putting in place an AHP infrastructure.

6. Future work:

Based on these reports, FAST recommends that the next step should be to convene experts panels to fully apply the methodology of appendix 4 and 5 of this report to the top two areas of change:

- AC13 (reliance on flight deck automation)
- ANS1 (emergence of new concept for airspace management).

Work on AC13 should start in October 2001, however, start of work on ANS1 should be postponed until early 2002 to allow EUROCONTROL to solve their resource issue.
The purpose of subsequent phases, if agreed by the JSSI Steering Group, will be to extend these analyses to additional areas of change.

FAST SECOND PHASE FINAL REPORT TO JSSI STEERING GROUP

1. Background and perspectives

1.1 JAA Safety Strategy Initiative:

In early 1998 the JAA agreed to launch the JAA Safety Strategy Initiative (JSSI). The purpose of the JSSI is to develop a focused safety agenda to achieve the JAA aim for safety which reads:

The JAA aims at continuous improvement of its effective safety system leading to further reductions of the annual number of accidents and the annual number of fatalities irrespective of the growth of air traffic.

JSSI involves Authorities and interested parties and other bodies such as ICAO, EUROCONTROL, US Commercial Aviation Safety Team (CAST). This co-operation is fundamental to achieve a worldwide safety agenda and to avoid duplication of efforts. For instance, up to know CAST has taken the lead for the "historical approach" and JSSI has taken the lead for the "Future Aviation Safety Team (FAST).

Two complementary approaches are being used to develop the focused agenda:

- One approach based on past accident analysis ("historic approach") which has led to the identification of an initial list of 7 focus areas: Controlled Flight Into Terrain; Approach and Landing; Loss of Control; Design Related; Weather; Occupant Safety and Survivability and Runways Incursions.
- The Future Aviation Safety Team approach ("predictive approach") based on an analysis of ongoing and future changes affecting the aviation system, is aimed at revealing unidentified hazards.

1.2 Achievements at the end of FAST first phase

At the end of the first phase of work (September 2000), the following achievements were available:

- A generic methodology had been defined.
- This generic methodology was supported by well established tools for prioritisation activities (Analytical Hierarchy Process) and for hazards assessment (Functional Hazard Assessment; Formal Brain Storming)
- Nearly 150 areas of change grouped in 11 categories had been identified.

A report dated 15.09.2000 describing this first phase of work was agreed with some modifications by the JSSI Steering Group (StG) (Appendix 1 sums up the StG discussions) Based on these achievements the JSSI StG gave a "green light" for the second phase of work to be performed between September 2000 and July 2001.
The purpose of the second phase was, through a series of Workshops to prioritise the 145 areas of change; select the "Top Ten" areas and define the specific methodologies to be used to reveal the hazards potentially generated by the selected areas of change.

1.3 Perspectives

The third and fourth phases of work are tentatively scheduled as follows:

- Apply the full methodology (up to recommending interventions), to two selected areas of change (Summer 2001- Summer 2002)
- Apply the full methodology to the remaining areas of change of the "top twenty"(Fall 2002-Fall 2003)

The purpose of this paragraph is only to put the second (present) phase of work in perspective and detailed proposals for phase three can be found in para 5 of this report. In

a similar manner a report will be presented at the end of phase three and the JSSI StG agreement to perform phase four will be requested.

2. Second phase: work summary

2.1. Preparatory meeting

A preparatory meeting was organised on November 15/ 16 to define agendas; identify the expertise needed in the workshops.
In addition, during that meeting the need for better external communication was identified:
It was noted that no questions were being raised during the presentations made at several conferences. The frequent confusion between hazards and areas of change was highlighted.

Consequently, the Future Hazard Working Group proposed and the JSSI StG agreed, that its name be changed to Future Aviation Safety Team (FAST).
FAST also developed the tentative schedule described in paragraph 1.2.

2. 2 The three Workshop's

The first workshop:

The first workshop was held in the Victoria Hotel in Amsterdam (NL) on January 4/5 2001and was organised as follows:

- Present the JAA; JSSI, and FAST (Co-chairs; F. Coudon; E. Schwartz)
- Present the Analytical Hierarchy Process (AHP) (S. Smith)
- Perform practical applications of AHP.
  Rank the 11 categories of areas of change (S. Smith)
- Agree on our homework assignment intended to reduce, for practical purposes, the list of 145 areas of change (AOC) to less than 100 using a specific criteria.

During that workshop comments were also received to expand the list of areas of change. It was agreed to accept further comments during the period between the first and second workshop as it is very important to start AHP with a list that is acceptable to all.

2.2.2 The second Workshop

The second workshop was hosted by EUROCONTROL (Brussels) on February 6/ 7/ 8, 2001and was organised as follows:

- Agree on the list of areas of change which are to be prioritised.
  A list of 86 areas was agreed following homework

.

- Prioritise this list of 86 using AHP. This first round showed the benefits of AHP however its results were questioned for several reasons described in para 3.

The Co-chairmen and S. Smith agreed to develop a process for the third workshop that would lead to agreement on the prioritisation.

2.2.3 The third Workshop

The third workshop was hosted by EUROCONTROL (Brussels) on March 6/ 7/ 8, 2001and was organised as follows:

- Agree on a prioritised list of areas of change. A “top 20” list was agreed by FAST.
- Discuss how to address interactions between areas of change.

- Discuss how future work should be organised.
- Discuss the most appropriate way to present results.

It was agreed that an interim report should be presented at the JSSI StG meeting of 23rd May.

Note: The process to achieve the "Top 20"list is described in para 3

2.2.4 Workshop participants

An expert panel with a broad scope of expertise was achieved.
Participation can be summed up as follows:

- Authorities: UK CAA (also representing the Research Committee); Hungarian CAA; RLD; ENAC-Italy; DGAC-F; FAA.
- International Organisations: European Commission (DG Tren and Joint Research Centre); EUROCONTROL; Central JAA; International Federation of Airworthiness.
- Aircraft Manufacturers: Airbus, Boeing, Bombardier; AECMA/ Fokker Services.
- Operators: Continental Airlines; Air Transport Association of Canada; AEA/Swissair; IAOPA.
- Research organisations: ERAA/ NLR; NASA.
- Passengers association: IAPA

Crew associations were invited and the European Cockpit Association (ECA) nominated representatives but unfortunately their participation failed to materialize. However several members of FAST (including the Secretary from European Space Agency (retired) are practising pilots.

2.3 Post Workshops meetings:

Two FAST meetings were held to analyse the result of the workshops, prepare the final report on phase 2 and to make proposals for phase 3. (May 21 and 22 in Hoofddorp and June 27 to 29 in Paris)
In particular the June meeting was devoted to a prototyping exercise using the top two areas of change. The prototyping exercise is described in more detail in paragraph 4 of this report.

2.4 Presentation to various bodies and conferences

FAST activities were also presented to various bodies and in several conferences.

CAST and the JSSI Steering Group were regularly briefed.

JSSI activities (including FAST) were presented at the 4th European Aeronautics days in Hamburg (30 January 2001).
The Commission released during that conference the report of the Group of Personalities proposing a vision for Aeronautics 2020.

JSSI activities (including FAST) were presented at the 13th European Aviation Safety Seminar in Amsterdam (13 March 2001).
This presentation generated a positive article and editorial in Flight Magazine.

FAST was also presented at the first workshop of an activity intended to develop scenarios for 2020. This workshop was organised by the External Advisory Group of the DG Research. (19 March 2001)

JSSI activities (including FAST) were also presented during a thematic workshop of the JAA/FAA annual conference (6 June 2001)

3. Explanation of the process

3.1 Introduction

Initially, two workshops were to be held, later a 3rd one was added, to give room for improvisation, for the added new and revised Aera's of Change and to allow a ranking of all Area's of Change rather than just the top 50%. To understand this, first a brief explanation of the analytical hiearchy process is order.

3.2 Analytical Hierarchy Process #1

Before starting with the actual ranking, the list of 145 Aera's of Change were organized into 11 categories e.g. Aircraft, Air Navigation, etc, see below:

Category (abbreviation)	**Number of changes per category**
Aircraft (AC)	27
Maintenance, Repair & Overhaul	6
Operations (OP)	12
Crew (C)	18
Passenger (P)	7
Organisation (O)	6
Authority (AUTH)	4
Air Navigation System (ANS)	23
Airport (AP)	7
Environment (E)	31
Space Operations (S)	4
Total	**145**

The next step was to perform pairwise comparisons between these 11 categories using as criteria their "importance" for Aviation Safety.
In the process, this ranking of the 11 categories was done 2 more times, that is during workshop #1 and it was repeated during workshop #3, primarily because the workshop realised the importance of the best ranking possible to arrive at good overall Aera of Change ranking results. Other considerations were:
•Better knowledge of process
•Aera of change wording better understood
•revised Aera of Change wording
Every time there were small changes, but the top 4 rankings remained the top four. Also the consistency increased.

The follow up steps were:

- Perform pairwise comparisons within each category using matrices of maximum 7 columns and 7 rows using same criteria as above
- Synthesize the above elements to achieve intended priorization.

Before we did this, we gave the workshop members homework. The objective was to reduce the 145 Area's of Change, which in the meantime had grown to 155+ to a more manageable set.

3.3 Homework

The homework assignment was set up to reduce the total to two more manageable groups by asking the workshop members to rank each Aera of Change under the following criteria:

- Anything ongoing or very soon
- Affecting the whole system
- Very rapid changes
- Many interactions
- Effects not well understood

Conditions:
•If most met: rank 1
•If some met: rank 2
•If few met: rank 3
•No opinion: rank N/A

We reminded each workshop member that:
•Changes are not hazards and that hazards are not risks
•Propose duplication in categories only when really necessary;

3.4 Additional area's of change

During each workshop, we had new Aerea's of Change and we moved Aerea's of Change from one category to another. The following table provides an overview:

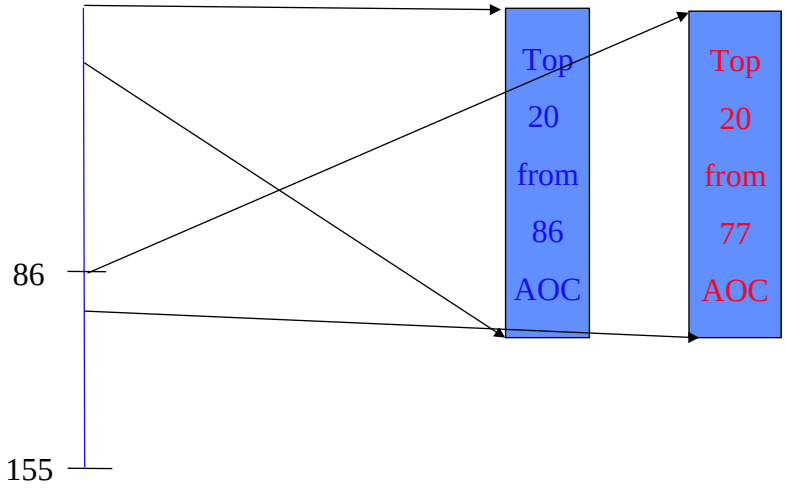
New AOC's	Moved AOC's
AC28: Incentive to achieve Fast-Track Certification.	**MRO7:** Incentive to outsource maintenance and modification of an aircraft (copied from AC28).
AC30: Major realisation of routine acquisition and analysis of aircraft FDR and other forms of hard data such as radar tracks	**MR08:** Maintenance complexity for next generation integrated aircraft (was AC 24)
MRO10: Complexity of Buyer furnished equipment (BFE) within BFE.	**MRO9:** Aging avionics, powerplants electical and mechanical systems and structure (was AC26)
OP13: Requirement for co-ordination with a new generation of sport flying devices	**MRO12:** Increased frequency of installation of unapproved part on aircraft.
AV5: Increased number and scope of incident investigation by official transportation Safety Board.	
AV6: Emergence of re-organised national aviation authorities.	
E32: Increasing complexity of the aviating system combined with rapid turnover of staff	
E33: Increased population of various species of large flocking birds.	

In addition:

- We improved the wording of 40-50% of the AOC's
- One new AOC: Increasing transfer of maintenance tasks from SSA/certification-->MRB process was assigned to another JSSI ad-hoc working group, i.e. to Design Related, because of synergy with already identified maintenance interventions there.
- One of the workinggroup members proposed that a revised JAR/FAR25.1309 safety target, 10-7 -->10-8 is required to improve future safety. It was decided to move this action to the JSSI steering group. A discussion paper is now under development for discussion at a future JSSI steering group meeting

3.5 Two sets of area's of change

During the 2nd workshop, we ranked the initial 86 Aerea's of Change, during the 3rd we ranked the second group of 77 Aera's of Change. These groups relate as follows:



The initial ranking of these two groups and the comparison led to considerable discussion, the most significant items of which are as follows:

- "An area of change may generate only a few hazards or none at all".
- AC10 (variation of sophistication of hardware and software within individual aircraft type) on top: maybe with automation on the increase, this is the number one area of change to generate hazards.
- We should trust our results
- AC10 requires further clarification, examples given were a) changes in Aircraft systems Functions not fully understandable by pilots, b) misleading situations resulting from identical identical instrument layouts hiding different behaviour and c) configuration management and coordination of actors involved in application of changes.

We then had to deal with the two groups of AOC's, it was decided to delete the second group of 77 AOC's based on the following rationale:

- Some AOC rankings still show "outlayers" with relatively high mathematical numbers.
- MRO7 (AC23: initiative to outsource maintenance and modification of aircraft) still very high

While there appear two new AOC's on top [AC28-Fast track certification & AC30-Major use of data e.g. FDR] we did not add them to the initial 86, assuming:

- Will be dealt with by authorities and manufacturers in an appropriate way as necessary.
- Stakeholders in data analysis & use will provide sufficient balance of power for reasonable process.

Following the above discussion, FAST checked that all areas of change were considered during the AHP process.

3.6 Analytical process #2

As stated under item 4.2 the follow up steps were:

- Perform pairwise comparisons within each category using matrices of maximum 7 columns and 7 rows using same criteria as given under item 4.2
- Synthesize the above elements to achieve intended priorization.

For a more detailed explanation of the AHP process, see appendix F

To address concerns about the normalization of matrices and after consultatation of AHPexperts:

- weighting criteria's were used to account for for different matrix size (Note: attention to detail is essential in the AHP process)
- The group verified that all Aera's of Change were adequately considered in the AHP process

3.7 Results

The results can be summarized as follows:

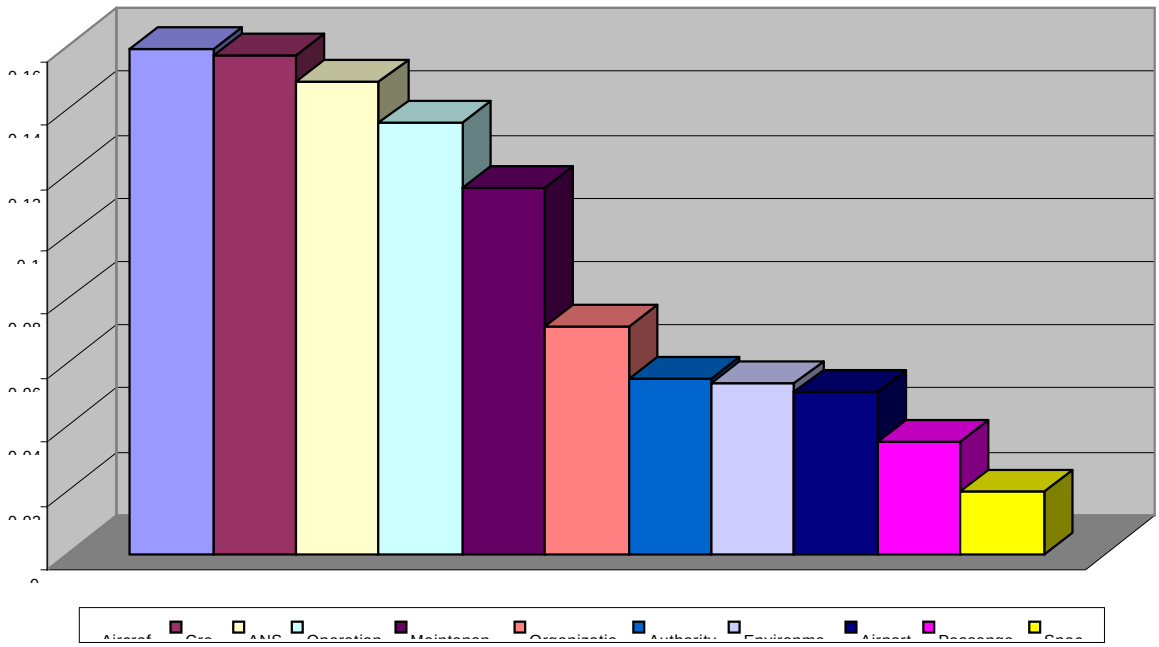
3.7.1 The top 9 Area's of Change are:

Alternative	**Priority**	
AC13	0,030883	Reliance on flight deck management
ANS10	0, 028068	Emergence of new concepts for airspace management
C1	0, 02732	Introduction of new technologies with unforeseen human factors aspects
AC11	0, 026069	Proliferation of heterogeneous aircraft with widely-varying equipment and capabilities
OPS5	0, 023487	Discrepancies in pace and approach in development and implementation of airborne vs. ground-based technology systems
ANS2	0, 023429	Increasing number of aviation operations
ANS7	0, 022921	Introduction of new technologies with unforeseen human factors aspects
AC10	0, 02188	Variation of sophistication of hardware and software within an individual aircraft type
AC26/MRO9	0, 02107	Ageing avionics, powerplants, electrical and mechanical systems, and structures, moved from AC26

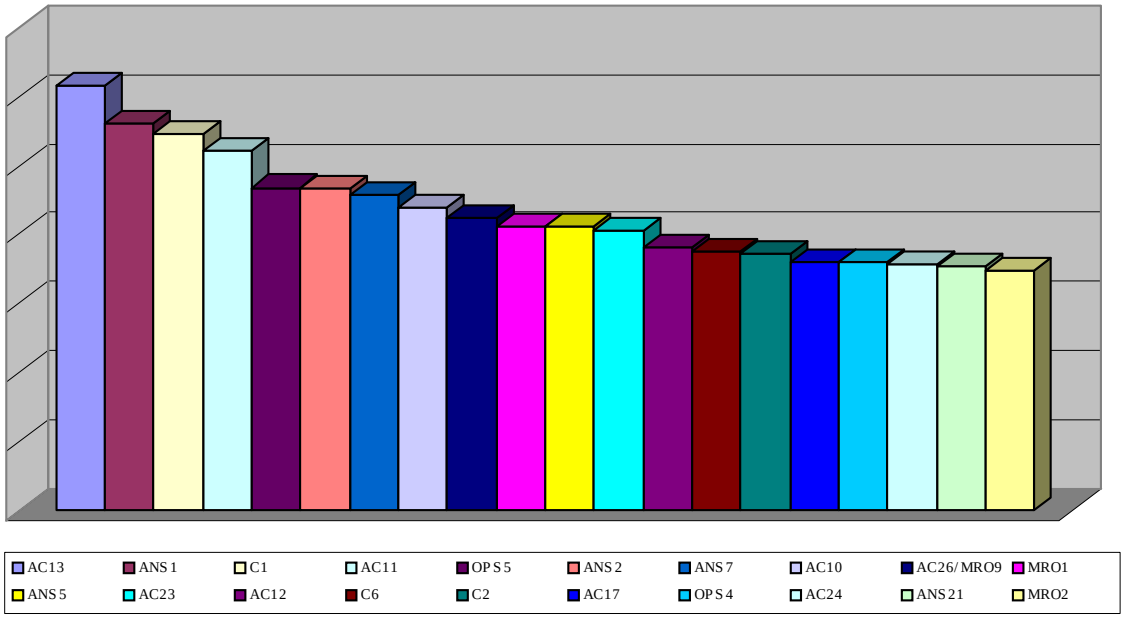
3.7.2 The top 10 trough 20 area's of change ranking is:

MRO1	0, 020579	Lack of qualified maintenance personnel
ANS5	0, 02051	Decreased separation standards
AC23	0, 020158	Incentives to outscore aircraft maintenance and modifications, also extra covered under MRO7
AC12	0, 019004	Pressure for standardisation in cockpit controls, displays, and automated systems interfaces among aircraft
C6	0, 018683	Shift in responsibilities for collision avoidance from ATC to crew
C2	0, 018554	Information inequality among aviation system participants in situations requiring shared decision-making
AC17	0, 018023	Reliance on active flight controls
OPS4	0, 017946	Increasing numbers of aircraft operations at lower altitude and/or in adverse weather conditions
ANS21	0, 01782	Maintenance complexity for next generation integrated aircraft
ANS21	0, 017653	Discrepancies in the pace and direction of development of ground vs. in-flight CNS systems
MRO2	0, 017418	Lack of maintenance expertise among operators and outsource providers

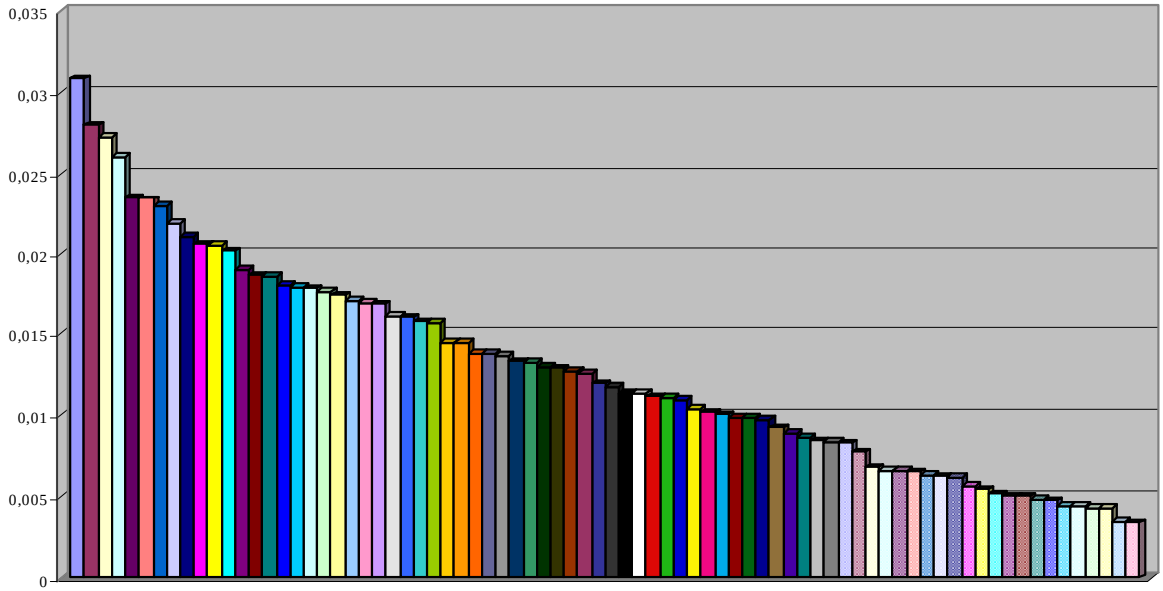
3.7.3 The final ranking of the 11 categories that was used to arrive at these rankings is as follows:



3.7.4 Finally, two other figures are given, that is first the top 20 area's of change as they are distributed over the 11 categories:



And finally, the distribution of the first 75 Area's of Change over the 11 categories:



3.8 Observations on the results

Summary:

- Working group + FAST team agreed with top 20 ranking
- Whole group has confidence in AHP method
- FAA/Steve Smith vital in AHP process: a good, knowledgeable AHP trainer/coach is essential.
- Broad & long experience and diverse backgrounds of the workshop people guarantee dependable results.

5. Prototyping Exercise:

The purpose of the prototyping exercise was to:

- Develop guidelines for identifying hazards for each area of change
- Validate them on AC13 (Reliance on Flight Deck Automation) and on ANS 1 (emergence of new concepts for airspace management).

The prototyping exercise was planned as follows:

(a) Draft guidelines to be prepared in advance of the meeting
(b) Review at the meeting the draft guidelines to achieve common understanding
(c) Two presentations (one on AC13, one on ANS1) to be made at the meeting to help defining the area of change to be considered.
(d) Split into two sub-groups and implement the draft guidelines
(e) Compare notes and produce revised (and improved) guidelines.

In practice the implementation of the draft guidelines was only made with AC13 based on a presentation of the A38O Flight Deck.
The presentation on ANS1 discussed the new concepts (free routing and free flight) for airspace management and was only used to prepare a scope of work for the ad-hoc Team that should analyse the area of change.
The prototyping exercise resulted in appendix 4 of this report.

Main discussion points were related to:

- Convene an expert group to identify hazards (in particular training and timetable)
- Review and validate the area of change characteristics (in particular scope).
- Develop the sub-methodology to identify hazards: the sub-methodology should be adapted to the area of change to be analysed. Therefore the ad-hoc team may develop new methodologies. However it needs to take due account of existing ones. Two tools (catalogue of available Hazards/Risks Assessment and catalogue of questions) will be developed for that purpose.
- Identify hazards resulting from interactions between areas of change: guidelines and application procedures will be developed.

Finally two strawman scope of work have been agreed: one for AC13, one for ANS1.

5. Results of second phase

5.1 Ranking of areas of change

The ranking resulting from the process described in paragraph 3 is included in appendix 3.
Appendix 3 contains the revised matrix of area of changes incorporating comments received during the workshop. It also contains a new column providing the ranking of areas of change.

5.2 Improvements to the FAST methodology

Appendix 4 contains the guidelines for identifying hazards for each area of change. These guidelines correspond to steps 3 a, b, c of the existing FAST generic methodology. Appendix 5 contains this generic methodology for ease of reference.

5.3 Analytical Hierarchy Process (AHP)

The use of AHP was successful. However the success was highly dependant on the dedication of our FAA colleagues, in particular Steve Smith.
As we intend to use AHP in several steps of FAST, there is a need to find the necessary resources to use AHP on a regular basis.
In addition AHP can also be used for many other purposes such as prioritisation of regulatory work programme.
Informal contact between NLR, RLD and JAA have occurred to see how cost could be shared: ideally there is a need for dedicated decision process including facility, specialists, software and hardware and training for users.

5.4 Scope of work for AC13 and ANS1

5.4.1 AC13 - Reliance on Flight Deck Automation

The reason we rely on Flight Deck Automation is that there is an upper limit to the ability of the flight crew to handle tasks related to their four key responsibilities:
-Aviate
-Navigate
-Communicate
-Manage Systems.

With the increasing complexity of modern aircraft and operational environments, the automation must be relied upon to handle the additional tasks which would *initiate** the crew. Automation may be capable of increasing the quality and quantity of tasks performed by the flight crew.

5.42 ANS1 - Emergence of new concepts for Airspace management:

The emerging concepts for airspace management may be described as follows:

-To remove as many restrictions as possible
-To allow pilots to choose routes, speed and altitude if possible.
-To move towards shared responsibility between air and ground for separation assurance.
To redefine the roles of controllers and pilots The foreseeable implementations are:

-Free routing
-Free flight

6. Future Work

Based on this report, FAST recommends that the next step should be to convene experts and to fully apply the methodology of appendix 3 and 5 to the top two areas of change:
AC13 (Increasing crew reliance on flight deck automation) and
ANS 1 (Emergence of new concept for airspace management).
Work should start in October for AC13, however start of work on ANS1 should be postponed until early 2002 to allow EUROCONTROL to solve their resource issue.
The purpose of subsequent *phases , if agreed by the JSSI Steering Group, will be to extend these analysis in additional areas of change.

APPENDIX 1
SUMMARY OF JSSI STEERING GROUP DISCUSSIONS
ADOPTION OF FUTURE HAZARDS WG REPORT DATED 15 SEPT 2000

The report dated 15 september 2000 from the Future Hazards WG has been approved provided the categorisation past/future hazards is deleted and several sentences are clarified.
The categorisation past/future was found confusing. The co-Chairmen explained that this categorisation was developed at the conceptual phase of Future Hazards(FH), but to progress, they offered to delete it from the report because it is not used in the methodology (which focuses on changes). The concept past/future will still be explained in the report but the terminology past/future will not be used.
Other points of discussion can be summed-up as follows:

- It was suggested that the report should start by describing an aviation safety model (e.g. Reason's model) to set the scene for the Future Hazards concept. The co-Chairmen believe that this suggestion should be followed
- It was suggested that the Future Hazard methodology could also be used by the actors (e.g. manufacturers, airlines,…). The co-Chairmen agreed and explained that the WG proposes to use it at the level of the whole Aviation System. This suggestion should be considered further.
- The insistence to qualify the methodology as a data-driven one was questioned. The co-Chairmen explained that the WG had to face scepticism and used the RVSM overland Europe to explain that some analogies can be found with RVSM North Atlantic but that the traffic conditions were different.
- The conclusion paragraph was found to be not homogeneous. The co-Chairmen agreed it contains a summary of activities (number of meetings), a summary of achievements (methodology, matrix) and a recommendation (request to do further work). Perhaps should it be called findings and recommendation instead of conclusion.
- The title "Future Hazards" was also discussed. Suggestions were made to change it, but finally it was decided to keep the title because people are getting used to it.
- It was feared that the task would be enormous. The co-Chairmen replied that the methodology prioritises and select at various steps. They also mentioned that the number of interventions identified today in CAST is around 750.
- It was remarked that by focusing rightly on the most important areas of change , the WG might leave out other areas which would be easy to address. The WG will give further consideration to this suggestion.

2) The JSSI Steering Group also agreed that the WG should start tasks 3 and 4 of its terms of reference. The intended schedule was found ambitious and the Steering Group stressed the need for careful preparation of the workshop. In particular, it was emphasised that the calling notice for the workshop should clearly describe its purpose. The duration of the first workshop (two days) was justified by the need

to explain the Future Hazards methodology and the AHP process in sufficient detail so that people would feel confident.

The following course of action was agreed:

- A calling notice would be sent very soon with replies before 10th November. The calling notice should describe the work (report could be annexed), describe what the FHWG need, describe the two workshops and their purpose and make clear that we are looking for high level people and that their commitment would be limited to these two workshops.

  Therefore, the meeting 15/16 November would be kept but would be used essentially to finalise clearly the organisation of the two workshops.

  The first workshop would be as scheduled 3/4/5 of January (the third day might not be necessary). The second workshop would be in March.

  This means a two/three months delay but this was felt to be more realistic.

Appendix 2: Details of the AHP process

4.2 AHP, the matrices and pairwise rankings

An example of such a matrix, in this case a 6x6 is given below:

	AC16	AC19	AC21	AC28	AC29	AC30
AC16	1					
AC19		1				
AC21			1			
AC28				1		
AC29					1	
AC30						1

The associated wording of the area's of change are given below:

AC16	Unification of CAO and loss of influence of rules of the art not incorporated in the CAO	
AC19	New higher energy propulsion and control systems	Advanced systems such as prop-fans and hydrogen-fueled aircraft and high-pressure hydraulic systems may be used in future aircraft. The introduction of very large engines for twinjet application may introduce special operational considerations. Increasing reliance on automation will increasingly remove the operator from immediate control of the power of a system.
AC21	Implementation of advanced supplementary cockpit weather information systems	When new cockpit weather information technologies are adopted, there may be more aircraft following the same favorable weather routes and traffic density will rise accordingly. Advanced training may be required for effective use of these new information sources.
AC28	**Incentives to achieve** fast track certification	**Unusually fast certification, e.g. 36 month's from launch to certification base freeze to full certification, stressing the limits of design analysis, flight- & ground test analysis, necessary iterations and human communication capability. At the same time: a) safety should be improved and b) there will be increased pressure to validate certification approaches based on past certifications.**
AC29	**Requirement** for coordination with a new generation of sport-flying devices.	**In the past decade the number of hang gliders, paragliders and their motorized versions have been and are still increasing significantly. These devices are commanded frequently by people lacking the basic knowledge of the airspace structure**
AC30	**Major increase in the routine acquisition and analysis of aircraft FDR and other forms of hard data such as radar tracks (new item)**	**Many airlines and authorities have found that computer-aided scanning and analysis of FDR data on a routine basis to be a powerful safety tool by identifying exceedences or reduced margins and assisting the safety risk managers (domain experts and field practitioners) in understanding the causes. Recordings to assist in investigation of accidents and incidents (that may include flight deck video, CVR, etc.) are fundamentally different that the daily, routine monitoring and analysis of FDR data.**

The pairwise comparisons were to be made using the following scales

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally
3	Weak Importance of one over another	Experience & Judgment slightly favor one over another
5	Essential or Strong Importance	…Strongly favor one over another
7	Very Strong and Demonstrated	…Strongly favored and its dominance demonstrated in practice
9	Absolute Importance	Evidence favoring one over another is of the highest possible order
2,4,6,8	Intermediate values between adjacent scale values	When compromise is needed

Experts familiar with the AHP process note four types of questions that are raised with regard to the process:
Primary effect, that there is a tendency for a bias towards the first examined items.
Recency effect, i.e. influence of the latest information over what went before
Out of role behaviour, i.e. assume knowledge of others
Personal bias→influences group descision making.

In all the workshops, each of the above events happened. We have also observed that when more time is taken-and we added a third workshop partly for this reason-the effect diminished. Also, time and time again we warned each other on these effects, and above all said to the workshop participants: thrust your results, “do not fight the Matrix”.

What did the AHP process do for us:

- The pairwise comparisons provided a means to calibrate a numerical scale where measurements and qualifications do not exist.
- Thanks to the mathematical process, AHP allows a measure of consistency, which enabled us to validate and strengthen the conclusions. Odd results, due to loss of concentration and/or inexperience could easily be rectified.
- The wide range of senior aerospace experts in the working group gave breadth to the conclusions and allowed trade off’s

- It created a dialogue, we discovered real relations (e.g. discussion on AC10 wording when it initially arrived on top), and allowed a compromise among the various judgements representing the diverse experience.
- We arrived at common rankings, inspite of widely varying individual rankings.

APPENDIX 3

Rank-Ordered List of Top 95 Areas of Change Affecting The International Aviation System

B. Smith, NASA Ames Research Center, R. Visser & R. den Hertog, Fokker Services, S. Smith, FAA, Version 7.3, 21 May 2001

AHP Ranking	Item	Description of Change Area	Comments on Aircraft Category	ONSET TIMEFRAME	VALIDATION TOOL	MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	Item SPACE
0.030883	**AC13**	Reliance on flight deck automation	Commercial transport aircraft flight deck automation has been well received by pilots and the aviation industry as a whole. Accident rates for advanced technology aircraft are generally lower than those of comparable conventional aircraft. Nevertheless, pilots, scientists, and aviation safety experts have expressed concerns about flight deck automation: fear that pilots may place too much confidence in automation, concern that they might lose manual flying skills, and views that pilot-automation interfaces may be poorly designed. Recent accidents involving advanced technology aircraft have served to underline those concerns. Recent research has identified human factors issues and cultural perspectives with respect to automation, which provide a reasonably complete set of data and other objective evidence related to those issues. Increasingly aircraft systems are being designed to automatically reconfigure themselves in the event of system failures without notifying the crew of early trends indicating anoma	ongoing	airline experience with B757/767 & A310 aircraft	X	X	X		X	X	X				**AC13**

0.028068	**ANS1**	Emergence of new concepts for airspace management	In a future "Free Flight" environment, authority/responsibility may alternate between the flight deck and the ground as a function of traffic density, conflict proximity, or workload. Maintaining awareness of this will be a critical safety issue. New runway approach concepts including Global Positioning Systems (GPS), angled, curved, AILS, etc. may create special safety considerations for managers of the airspace system.	2005	proposed regulations & legislation, revised equipment requirements	X	X	X	X	X	X	X		X	X	X	**ANS1**
0.02732	**C1**	Introduction of new technologies with unforeseen human factors aspects	Increasing pressure to replace humans with automated systems may characterize future design philosophies. There may be an increasing need to adequately design systems from the start to take advantage of human flexibility and creativity and to augment human abilities with computers. This has been (and is still) the focus of many activities (human factors, man-machine interface, cockpit design, autopilot and FMS certification criteria). Methodologies are being developed by manufacturers with the participation of human factor specialists. Current FAA-JAA Harmonization activities are in progress to develop cockpit design evaluation criteria. There may be an increasing frequency of "passive command syndrome" and "habit interference." There may be a greater likelihood that crews will unconsciously relinquish command responsibilities momentarily to automated systems. The unknown effects of aircraft-pilot coupling (APC) may result in a perfectly normal, well flying aircraft suddenly taking on characteristics t	2003	human factors community, manufacturer representatives, application for certification for new equipment	X	X	X		X	X	X	X		X		**C1**

0.026069	**AC11**	Proliferation of heterogeneous aircraft with widely-varying equipment and capabilities		ongoing	consequences of introduction of advanced aircraft into fleet mix, airline data		X	X	X	X	X	X	X	X	X		**AC11**
0.023487	**OP5**	Discrepancies in pace and approach in development and implementation of airborne vs. ground-based technology systems	Technology employed for ATM may not keep pace with technology and capabilities of advanced aircraft entering fleet. Future ATC systems need to be designed to take advantage of the characteristics of advanced-technology aircraft. Ground and airborne systems are becoming more and more integrated and, for the purpose of certification, consideration is currently being given to new procedures that would take into account such closer integration (e.g. existing international standards are addressing this subject). "In theory, software development should be identical to other engineering processes – we would examine known and relevant risks, and restrict our ambitions to what we knew we could handle. In practice, software invites fiendish complexity." G.F. McCormick, 'When Reach Exceeds Grasp'	1990 & ongoing	comparisons of demand vs. capacity, change in number and severity of ATC delays	X	X		X		X	X	X	X	X		**OP5**
0.023429	**ANS2**	Increasing number of aviation operations	By 2015 it is estimated that air traffic from all sources will double. These new operations may create additional bottlenecks in certain areas. Regional wars and new airspace system designs may also contribute to redistributed traffic flows. Technology advances providing aircraft with the ability to fly through or around regions of adverse weather may result in increasing frequency of penetrations of adverse weather and/or increased traffic through favorable weather regions. An appropriate set of agencies should be looking at the resulting traffic loads. Risk of runway incursions may also increase as a	ongoing	ATM data & ATM 2000 strategy	X		X	X	X	X	X		X	X		**ANS2**

			result.															
0.022921	**ANS7**	Introduction of new technologies with unforeseen human factors aspects	Increasing pressure to replace humans with automated systems may characterize future design philosophies. There may be an increasing need to adequately design systems from the start to take advantage of human flexibility and creativity and to augment human abilities with computers. This has been (and is still) the focus of many activities (human factors, man-machine interface, control console layout, etc.). Methodologies are being developed by manufacturers with the participation of human factor specialists.		human factors community, manufacturer representatives	X		X	X		X	X					**ANS7**
0.02188	**AC10**	Variation of sophistication of hardware and software within an individual aircraft type		1990 & ongoing	consequences of introduction of advanced aircraft into fleet mix, airline data		X	X	X		X	X	X				**AC10**
0.02107	**MRO9**	Aging avionics, powerplants, electrical and mechanical systems, and structures, moved from AC26		ongoing	accident/incident reports, anecdotal, airline/authority & aircraft manufacturer data	X		X	X		X	X	X		X		**MRO9**
0.020579	**MRO1**	Lack of qualified maintenance personnel	The shortage of qualified maintenance personnel may result in lower quality servicing and reduced reliability of both new and aging aircraft. This may result in more operation with Minimum Equipment List and could affect the reliability of ETOPS operations. This is primarily an economic/liability problem as well as having human factors aspects. Tightening of controls on maintenance procedures such as limitation of working hours, eyesight tests, etc. will reduce the availability of maintenance personnel. Design standards must be improved to reduce	2000	data from authorities and aeronautical organizations	X		X	X		X	X		X			**MRO1**

			maintenance in service. "Hard-timing" of aircraft becomes a possibility with its economic penalties.																		
0.02051	**ANS5**	Decreased separation standards	Between runways, between aircraft, between landing operations, RVSM reductions? Risk of runway incursions may also increase as a result.	ongoing	proposed regulations	X	X	X	X		X	X		X	X		**ANS5**
0.020158	**AC23**	Incentives to outsource aircraft maintenance and modifications, also extra covered under MRO 7		1990 & ongoing	emerging regulations & airline experience with B727F STC & AD		X	X			X	X					**AC23**
0.019004	**AC12**	Pressure for standardization in cockpit controls, displays, and automated systems interfaces among aircraft		ongoing	manufacturer data		X	X	X		X	X	X				**AC12**
0.018683	**C6**	Shift in responsibility for collision avoidance from ATC to crew	TCAS/ACAS and Airborne Information for Lateral Spacing (AILS) approaches to close parallel runways in Instrument Metrological Conditions (IMC) may be used more frequently in the future. AILS is an important concept because under IFC conditions it may increase the capacity of parallel runways to be equivalent to those of VMC conditions. AILs is related to free flight (CE -13) because it shifts the responsibility for decision making regarding lateral separation and appropriate evasive maneuvers from ACT to the flight deck in the event of a blunder. A key element of AILS is the flight deck display that will ultimately suport AILS. The crew may be faced with increased responsibility for collision avoidance in all phases of flight.	2005	new regulations and self-separation procedures	X		4			2	3	4	1		X	**C6**

0.018554	**C2**	Information inequality among aviation system participants in situations requiring shared decision-making	There may be an increased requirement for effective and timely decision-making in a multi-agent context (multiple aircraft, ATC, AOL, automation). Shared decision making may be error prone, and may be even more difficult if made under time pressure and if automated aids are involved. Problems may increase further if there are information inequalities within the system (e.g. some of the participants know more than others). There may be increased dependence on information systems to present timely data to pilots/air traffic controllers. The volume growth of available information sources may overload the information sharing networks and result in delays in transmission of information upon which critical decisions are being based.	ongoing	qualitative comparisons between existing and proposed technologies	X	X	X			X	X	X				**C2**
0.018023	**AC17**	Reliance on active flight controls	Functional interfaces between pilot-in-the-loop/autopilots and fly-by-wire-flight controls may produce unforeseen benefits and problems.	2003-1010	monitoring of Boeing & Airbus initiatives		X	X	X		X	X	X	X			**AC17**
0.017946	**OP4**	Increasing numbers of aircraft operations at lower altitude and/or in adverse weather conditions	Smaller aircraft operating at lower altitudes are particularly vulnerable to icing phenomena, and these aircraft may eventually constitute a larger percentage flight operations. There is a need to establish the true icing environment and to provide better training for recognition of icing hazards and mitigation procedures. In addition, anti-icing design requirements for smaller aircraft such as advanced general aviation and small commuter aircraft need to be be better defined.	ongoing	ATC data	X	X		X	X	X	X	X		X		**OP4**
0.01782	**MRO8**	Maintenance complexity for next-generation integrated aircraft, moved from AC24		ongoing	emerging regulations & airline experience with B747 at Stanstead	X		X	X		X	X	X				**MRO8**

0.017653	**ANS21**	Discrepancies in the pace and direction of development of ground vs. in-flight CNS systems	Aircraft and ATC systems have undergone significant advances in recent decades. However, the results of the Advanced Technology Safety Survey Report suggest that some of these developments have occurred in an uncoordinated fashion and that issues of systems compatibility between airborne and ground-based systems have not always been addressed.	ongoing	ATC & manufacturer data, air/ground conflict resolution data	X	X	X	X		X	X		X				**ANS21**
0.017418	**MRO2**	Lack of maintenance expertise among operators and outsource providers	International harmonisation of aircraft maintenance guidelines should incorporate the highest safety standards. The harmonisation of aircraft maintenance standards should only proceed when it can be demonstrated that there is adequate provision of safety monitoring by the relevant authorities. Minimum international standards of training, health and safety, job security, and trade union rights should be established for aircraft maintenance workers.	ongoing	data from authorities and aeronautical organizations	X		X	X	X	X	X			X			**MRO2**
0.017065	**MRO5**	Reliance on automation for fault detection, diagnosis, resolution, and tracking	The shift from paper to electronic record keeping and "virtual reality" maintenance tools and techniques used to support service of legacy and advanced aircraft may bring a host of complex issues related to quality of maintenance.	1978 & ongoing	aviation technology providers, authority & airline data	X		X	X	X	X	X	X	X	X			**MRO5**
0.016919	**ANS19**	Complex interactions among highly-automated ground-based and flight-deck systems	There may be a future need for systems level integration of ground- and flight-deck systems. The lack of complete and enforced systems architecture integration may permit undesireable incompatibilities to develop among existing ATC air and ground based systems and may do so for future systems. Overcoming these incompatibilities may result in greater system development, integration, and maintenance costs, and reduced	2005	ATC data, certification criteria, proposed technical standards	X	X	X	X	X	X	X		X				**ANS19**

			overall systems performance.																				
0.016905	**MRO3**	Application of Maintenance Resource Management techniques	Human factors in maintenance is being regognized as being increasingly important. This area includes a wide range of subjects including ergonomics, visual and cognitive skills, team dynamics, and shift change issues.	ongoing	data from authorities and aeronautical organizations	X		X	X		X	X					**MRO3**
0.016172	**AC1**	Introduction of new aircraft types	Improvements to the modern airplane may occur as a result of breakthroughs in many fields permitting evolutionary improvements in performance, improved computational capabilities permitting multidisciplinary analysis and design, and use novel ideas to redesign the airplane.	ongoing	application for certification and/or aircraft projects in advanced developmental stages		X	X	X	X	X	X	X	X	X		**AC1**
0.016078	**OP3**	Integration of regional jets, with possibly more advanced avionics, in todays operational environment	Increased operations of regional jet aircraft into smaller airports via previously little used airway routes may result in additonal demands on ATC and may result in increased noise impact on local communities. Advanced avionics features may translate into aircraft which will better integrate with advanced ATC systems.	2005	contents of type certificates, comparison of technical characteristics	X	X		X		X	X	X				**OP3**
0.015775	**AC20**	Implementation of advanced synthetic-vision technologies		2002-2007	monitoring technology development programs for business, commercial & military aircraft		X	X	X	X	X	X	X	X			**AC20**
0.01572	**OP2**	Requirement for performance validation and self-checks of complex systems	The possible lack of resources for Independent Verification and Validation (IV&V) of increasingly complex critical software/hardware systems may introduce possible safety hazards.	2003	contents of ops/flight manuals	X	X		X		X	X	X	X			**OP2**

0.014519	**AC2**	Introduction of Very Large Aircraft (VLA, >600 passengers)		2005	application for certification		X	X	X	X	X	X	X	X	X		**AC2**
0.014475	**C5**	Widening gap between skills, abilities, and attitude toward technology and automation among future crew members and design philosophies used in the past for development of current aircraft	Since today's fleet will be in use for many years, it must be recognized that there may be discrepancies between the expectations of how these aircraft will be operated that were in the minds of the designers and the actual operational approaches and techniques used by newer, younger pilots having different attitudes toward automation than senior aircraft designers and operators. Flight crew are increasingly serving as translators/interpretors of information originating from multiple sets of equipment of widely varying vintage.	2000 & ngoing	manufacturere, airline, and pilots' association data	X		X			X	X	X				**C5**
0.01383	**OP8**	Integration of operations of freighter aircraft with increasingly variable cargo characteristics	These aircraft may operate from less well equipped airfields by operated by second-tier airlines. However, these operations raise other serious issues (operations at low traffic hours i.e. very late or at night , with associated noise issues, cargo conversion and operation of aircraft for a full "second" life - see above mentioned aging aircraft issues, etc.) Current accident statistics (1990 - 1999) indicate hull losses of freight aircraft comprise approximately 22% of those involving commercial aircraft. Freighter aircraft may operate at higher average take-off gross weights, may be flown differently (less concern for ride quality resulting in greater exposure to turbulence), and may be generally older than passenger-carrying aircraft.	ongoing	data from authorities and aeronautical organizations	X	X		X		X	X	X	X	X		**OP8**

0.013789	**AC8**	Introduction of fly-by-light, power-by-wire aircraft control systems		2005-2008	monitor results of technology sutdies in this area		X	X	X			X	X							**AC8**
0.013713	**AC3**	Sharing of design responsibility with and delegation of design roles to partner organizations for all aircraft types		2000-2010	firm orders for new aircraft		X	X	X	X	X	X	X	X	X					**AC3**
0.013359	**ANS15**	Reliance on out-dated equipment	Future air navigation systems will feature international agreement on a "next-generation" plan for more efficient communication, navigation, surveillance and air traffic management (CNS/ATM), based heavily on satellite technology. The much more accurate positioning of aircraft in the airway due to Global Positioning System technologies may also require changes to existing procedures, e.g. a 45 degree turn prior to an emergency descent to prevent collision with an a/c exactly under it.	ongoing	maintenance data	X	X	X	X	X		X	X		X	X				**ANS15**
0.013308	**MRO12**	Increasing frequency of installation of un-approved parts on aircraft, moved from AC25											X			X				**MRO12**
0.013026	**ANS8**	Information inequality among aviation system participants in situations requiring shared decision-making	There may be an increased requirement for effective and timely decision-making in a multi-agent context (multiple aircraft, ATC, AOL, automation). Shared decision making may be error prone, and may be even more difficult if made under time pressure and if automated aids are involved. Problems may increase further if there are information inequalities within the system (e.g. some of the participants know more than others). There may be increased dependence on information systems to present timely and coordinated data to air traffic controllers. The volume	ongoing	qualitative comparisons between existing and proposed technologies	X	X	X	X		X	X							**ANS8**

			growth of available information sources may overload the information sharing networks and result in delays in transmission of information upon which critical safety decisions are being based.																		
0.012926	**AC22**	Changing approaches to cockpit warning and alert systems		ongoing	airline experience with B757/767, A310 & F100 aircraft		X	X	X		X	X	X	X			**AC22**
0.012777	**ANS17**	Dependence on secure data links for performing ATM/CNS functions	The increase in data link traffic arises from the introduction of more modern aircraft and airline systems and ground applications, including the Automatic Terminal Information Service (ATIS) and departure clearance. This continuing high growth of data link worldwide underlines the need for the introduction of the increased capacity and flexibility and security of the next generation of data link services.	2005	ATM data, certification criteria, proposed technical standards	X		X	X		X	X		X			**ANS17**
0.01261	**C11**	Unresolved cultural aspects of Crew Resource Management (CRM)	In certain cultures, the problem of over-acceptance of pilot authority may also be a problem.	ongoing	accident/incident database	X	X	X			X	X	X				**C11**
0.012017	**ANS16**	Reliance on satellite-based systems for CNS functions	Future air navigation systems will feature international agreement on a "next-generation" plan for more efficient communication, navigation, surveillance and air traffic management (CNS/ATM), based heavily on satellite technology. The much more accurate positioning of aircraft in the airway due to Global Positioning System technologies may also require changes to existing procedures, e.g. a 45 degree turn prior to an emergency descent to prevent collision with an a/c exactly under it.	2005	ATM data, certification criteria, proposed technical standards	X	X	X	X	X	X	X		X			**ANS16**
0.011777	**C7**	Obsolescence of current training methodologies for operation of advanced aircraft		2000	flight training school & aircrew performance data			X			X	X	X	X			**C7**

0.011409	**ANS12**	Variation of sophistication of hardware and software within the ANS system		1990 & ongoing	introduction of advanced ANS hardware and software systems		X	X	X		X	X					**ANS12**
0.011397	**ANS10**	Loss of ATM equipment design and operational expertise	The underlying knowledge of why ANS systems are designed as such, how key maintenance is to be performed, and and why resulting ATC operational rules are as they are is being lost due to long design cycle times, extended hardware life, and the slow pace of moderization. Unforeseen uses of the systems may also present special challenges in order to maintain safe operations. Failure to document and archive design data, initial specifications, test data, and lessons learned may also increase safety risk. Modern analytical tools such as fuzzy logic and neural nets must be used with care since in most cases these tools have narrow functionality. Artificial intelligence may be useful for creating design data bases containing previously successful design details and principles.	ongoing	ATM data, certification criteria, proposed technical standards	X		X	X			X		X				**ANS10**
0.01116	**C8**	Loss of average pilot airmanship qualities	Diminished basic airmanship may become a potential safety and operational issue including failure of pilot training to provide knowledge required for operation of advanced aircraft in abnormal situations/attitudes. Highly automated aircraft that self-adapt to various failure modes may be more difficult to fly by inexperienced crew in emergency situations especially if the response characteristics of the aircraft to multiple failures has not been adequately addressed in crew training.	ongoing	flight training school & airline data	X	X	X	X		X	X	X	X	X			**C8**

0.011085	**AC18**	Improvements in flight data recording and additional cockpit surveillance systems		ongoing	monitoring of NTSB/FAA initiatives, notice of proposed rule-making		X	X	X		X	X	X					**AC18**
0.011007	**ANS22**	Evolution of Flight Management System databases	GPS and digital terrain elevation data may be incorporated into future FMS databases. The integrity of the computerized navigation and performance systems rests on the quality of the FMC/FMGS databases. Avionics and airframe manufacturers and regulatory authorities have recognized the potential for entering incorrect data through the FMC/FMGS. The final safety net in the process of checking the accuracy of the database information currently lies with the pilot who should cross-check electronic data against printed data. Evidence suggests that human performance during such cross-checking tasks deteriorates over time. This deficiency needs to be addressed by both aircraft manufacturers and regulatory authorities if then goal of a paperless cockpit is to be realized. Future flight guidance databases may have no printed data against which the pilot can cross-check information.	ongoing	manufacturer and authority data	X	X	X	X		X	X		X				**ANS22**
0.010402	**OP11**	Very long-range operations or Polar operations	Flights greater than 7000 N.M may become increasingly more frequent. Concerns about inadequacy of support and/or medical facilities at airports to which flights may be diverted and survival after a crash in cold environments.	2002	manufacturer and authorities data	X	X		X	X	X	X	X	X				**OP11**
0.010205	**C12**	Increased instances of mixed crew flights		ongoing	airline & pilots' association data		X				X	X	X	X	X			**C12**
0.01009	**MRO6**	Increasing quantity of available maintenance data	It will be a continuing challenge to extract useful information from the exponentially increasing amounts of maintenance data in heterogenous databases used in support of legacy and advanced aircraft.	1978 & ongoing	airline data	X		X	X		X	X						**MRO6**

0.009888	**OP10**	Additional ETOPS flights	Economic pressures may result in Extended Range Twin-Engine Operations with increasingly longer time limits.	ongoing	data from authorities	X	X		X	X	X	X	X		X		**OP10**
0.009849	**C3**	Increasing amount of information available to flight crew	Future flight decks may contain, or be expected to interact with, software "intelligent agents." The characteristics of these agents may differ significantly from most software tools in use today. They may be very complex in function, and may include intent and reasoning systems not well understood by the pilot. They may approach a semi-autonomous status in the eyes of those interacting with them. They may have unique, unfamiliar, and unanticipated characteristics and interfaces. This could lead to the potential for a great deal of error especially if these systems are given limited control of the vehicle independent of the crew. The clearest analog of this problem today may the Flight Management System (FMS); its level of complexity, and the lack of awareness by the crew of the operational subtleties of the various control modes and when the FMS switches modes.	2005	airline and pilots' association data	X	X	X		X	X	X	X				**C3**
0.009712	**ANS9**	Increasing amount of information available to ATM personnel	There may be an increased expectations for aircraft performance and traffic situation awareness by ATM personnel. However, most ATC facilities will require new displays for presentation of these data. This may create potential errors due to lack of effective information integration/monitoring. Too many operational modes may be available in ATC hardware leading to loss of awareness of the system status and mode confusion/distraction.	2005	ATM and controllers' association data	X	X	X		X	X	X					**ANS9**

0.009274	**E1**	Pressure to improve aviation system throughput and flight safety	Major increases are expected in the capacity of airports worldwide, through improvements in the air traffic management system and the introduction of new vehicle classes that can potentially reduce congestion. Increased expectations for improved "operational efficiency" or measures to mitigate "capacity limitations" are two sides of the same coin. Airlines continue to pressure aviation authorities to provide the infrastructure to support this expansion. Pressure for profitability within airlines may also be a significant contributor to this phenomenon.	ongoing	media, ground delay measures	X	X	X	X	X	X	X	X	X		X	**E1**
0.008966	**AC27**	New demands on aircraft systems for support of next-generation personal, in-flight entertainment, and business systems		2000	trend analysis for existing and future aircraft types		X		X	X	X	X					**AC27**
0.008649	**AP2**	Introduction of new surface traffic flow management technologies	The sustained growth in air traffic and limitations in existing airport infrastructure have in recent years put a strong emphasis on the development and standardization of future advanced surface movement guidance/control systems. This effort will eventually be converted into concrete results to meet the rising demand of operational users. The objective of the technologies is to increase the traffic-flow capacity at airports, while maintaining the required safety level.	2005	data from aviation research organizations	X		X	X	X	X	X	X		X		**AP2**
0.008449	**ANS4**	Requirement for centralized control of ATM	Pressure to centralize control of ATM across international boundaries will require new paradigms for state sovereignty and airspace utilization, and may tax the ability of less-developed countries to keep pace with technological advances.	ongoing	proposed regulations & legislation, revised equipment requirements	X		X	X	X	X	X		X	X		**ANS4**

0.008401	**E29**	Loss of aircraft design and operational expertise		1985 & ongoing	data from authorites and aeronautical organizations, ATR72/Roselawn & SF340/Schipol events		X	X	X	X	X	X	X				**E29**
0.008293	**AP1**	Increased demands on airport and community infrastructure due to increased volume of air traffic	Due to projected increases in air traffic, both airport and supporting community infrastructures may be stressed. Advanced aircraft may have the ability to both fly in worse weather conditions than today's fleet and self-navigate around regions of adverse weather. These capabilities may increase required airport throughput. Technology advances may have ramifications for ground-vehicle traffic (not so much baggage carts and fuel trucks) such as cars, taxi cabs, buses, and trains transporting passengers to and from the airport in low visibility conditions. Growing airport surface traffic poses an increased risk of runway incursion.	ongoing	authority data		X		X	X	X	X	X	X		X		**AP1**
0.007767	**E9**	Rapid pace of software and technology development	In the next century, the speed with which information management and technology systems are created, their associated accessibility to individuals, governments, and industry, and potential myriad uses may cause fundamental changes in each nation's air transportation system.	ongoing			X	X	X	X		X	X	X	X			**E9**
0.006816	**ANS3**	Pressure for air traffic flow management (ATFM) technology development activities		ongoing	ATC data			X	X	X	X	X	X		X	X		**ANS3**
0.006634	**P1**	Trend toward increasingly aggressive/assertive behavior	Harassment and assault of crew members was reported to have increased from 54 cases in 1993 to 94 in 1995, according to spokepersons for a union that represents 39,000 flight attendants.	1998 & ongoing	airline data		X		X	X		X	X	X	X	X		**P1**

0.006622	**E10**	Proliferation of hardware and software tools to monitor performance of aviation system	Increased need to monitor incident and accident precursor trends and identify non-standard performance.	ongoing		X	X	X	X	X	X	X	X						**E10**
0.006554	**E20**	Vulnerability of data links to security breaches and/or transmission failures	Increased likelihood of jamming resulting in loss of RF signals used for critical CNS functions and FADEC operation	ongoing	manufacturer data	X	X	X	X		X	X	X	X		X			**E20**
0.006378	**ANS13**	Need for maintenance of complex integrated ANS systems		ongoing	ATM data & ATM 2000 strategy		X	X	X		X	X							**ANS13**
0.00303	**AC28**	Incentives to achieve fast track certification																	**AC28**
0.00299	**C4**	Introduction of artificial intelligence	Future flight decks may contain, or be expected to interact with, software "intelligent agents." The characteristics of these agents may differ significantly from most software tools in use today. They may be very complex in function, and may include intent and reasoning systems not well understood by the pilot. They may approach a semi-autonomous status in the eyes of those interacting with them. They may have unique, unfamiliar, and unanticipated characteristics and interfaces. This could lead to the potential for a great deal of error especially if these systems are given limited control of the vehicle independent of the crew. The clearest analog of this problem today may the Flight Management System (FMS); its level of complexity, and the lack of awareness by the crew of the operational subtleties of the various control modes and when the FMS switches modes.	2010	application for certification	X	X	X		X	X	X	X	X	X	X			**C4**

0.00284	**ANS20**	Introduction of artificial intelligence	Future ATM tools may achieve enhanced functionality using software "intelligent agents." The characteristics of these agents will differ significantly from most software tools in use today. They may be very complex in function, and may include intent and reasoning systems not well understood by the controller. They may approach a semi-autonomous status in the eyes of those interacting with them. They may have unique, unfamiliar, and unanticipated characteristics and interfaces. This will lead to the potential for a great deal of error especially if these systems are given limited control of the ATM functions independent of the human. The clearest analog of this problem today may be the airborne FMS; its level of complexity, and the lack of awareness by the flight crew of the operational subtleties of the various control modes and when the FMS switches modes.	2010	ATC & manufacturer data, application for certification, propsed technical standards	X	X	X	X	X	X	X		X				**ANS20**
0.00278	**AC14**	Reliance on automated vehicle health management systems		1978 & ongoing	airline experience with B777 & A320 aircraft, contents of operations/maintenance manuals	X	X	X	X	X	X							**AC14**
0.00271	**AC30**	Major utilization of routine acquisition and analysis of aircraft FDR and other forms of hard data such as radar tracks (new item, however, partly redundant with AC18)																**AC30**
0.00261	**AC4**	Introduction of new design concepts for general aviation aircraft		2005-2008	application for certification of experimental aircraft	X	X	X		X	X	X	X	X				**AC4**
0.0026	**AC19**	New higher energy propulsion and control systems		2005 - 2010	propulsion and control systems manufacturer data	X	X	X	X	X	X	X	X	X				**AC19**

0.00259	**OP9**	Increased numbers of high-speed, low-level flight operations	Research indicates that there is an increased frequency of low-altitude flocking of smaller birds near airports. There may be an increasing need for strategies/technologies to prevent or mitigate effects of multiple bird strikes. See related item E33.	ongoing	ATC data	X	X		X		X	X	X	X	X		**OP9**
0.00242	**AC21**	Implementation of advanced supplementary cockpit weather information systems		2005	monitoring technology development programs for business, commercial & military aircraft	X	X	X	X	X	X	X	X	X		**AC21**		
0.00233	**AC15**	New aerodynamic and structural concepts including adaptive or "smart" components, nanotechnologies, and advanced composites		2010	experimental programs	X	X	X		X	X					**AC15**		
0.00222	**OP1**	Pressure for centralized control of user operations	International coordination of operations and management of fleet operations may be required in the future.	ongoing	new international standards, international airline alliances	X	X		X	X	X	X	X		X		**OP1**	
0.00219	**OP12**	Movement away from hub-and-spoke operations concepts toward alternate operational models	City-pair' operations may increase in frequency with the introduction of regional jets. These faster, quieter, more comfortable regional jets that are less expensive to acquire/maintain and that can land on shorter runways than turboprops may alter the way airlines operate. Airline decisions to adopt these different operational models may affect many other areas of aviation.	ongoing		X	X		X	X	X	X	X	X	X		**OP12**	
0.00191	**ANS11**	Gap between skills, abilities, and attitude toward technology/automation of future air traffic controllers and the past design philosophies used in development of present ATM systems	Since today's ATM systems will be in use for many years, it must be recognized that there may be discrepancies between the operational concepts that were in the minds of the designers and the actual operational approaches and techniques used by newer, younger controllers having different attitudes toward automation than senior designers and operators.	2000 & ngoing	manufacturere, ATM, and controllers' association data	X		X			X	X					**ANS11**	

0.0019	**OP6**	Introduction of uninhabited aircraft for observation, atmospheric sensing, data communications, and possible cargo transport	Such aircraft may operate not only from civil airports and in civil airspace but also may originate from controlled military airspace. The ground control system and the aircraft should be considered as one system with new certification challenges. Unmanned Aerial Vehicles (UAV's) are proliferating and the probability of mid-air collisions between unmanned air vehicles and passenger aircraft may increase. Low-level battlefield UAV's may not be a real threat to civil aircraft, but the danger of large high-altitude military/civil sensing and relay UAV's crossing passenger aircraft flight corridors may become a real future hazard. The unique aspects of micro- and large-scale UAV's may bring special operational and certification requirements.	2005	demand for certification criteria for unihabited aircraft, applications for LUA approvals	X	X		X		X	X	X	X	X	X		**OP6**
0.00187	**AC9**	Incentives to improve performance and increase fuel economy		ongoing	establishment of certification criteria	X	X	X	X		X	X						**AC9**
0.0018	**ANS14**	Loss of maintenance expertise for state-of-the-art ANS systems	The international harmonisation of ANS maintenance standards should incorporate the highest safety standards. The international harmonisation of these standards should only proceed when it can be demonstrated that there is adequate provision of safety monitoring by the relevant authorities. Minimum international standards of training, health and safety, job security, and trade union rights should be established for ANS maintenance workers.	ongoing	data from authorities and aeronautical organizations	X		X	X	X	X	X			X			**ANS14**
0.00177	**ANS18**	Changing approaches to ATM warning and alert systems		ongoing	introduction of advanced ANS hardware and software systems	X	X	X		X	X		X					**ANS18**
0.00173	**AC5**	Introduction of new runway independent aircraft concepts		2003-2007	application for certification	X	X	X	X	X	X	X	X	X				**AC5**

0.0017	**ANS6**	Operation of low-technology aircraft in ATM environments featuring advanced capabilities	Although opinion polls demonstrate that the public has confidence in the safety of the commercial aviation system, increased media attention following general aviation accidents and incidents raises the awareness of aviation hazards and has the potential to erode this confidence. Articles on the safety aspects of both large and small airplanes are becoming more numerous. It is important for aviation system stakeholders to become pro-active in providing the media and the public with well-researched and factual information on the safety of the aviation system and general aviation's role in safety management.	ongoing	ATM data, capacity limited by lowest level of fit, propsed technical standards	X	X	X	X		X	X		X	X		**ANS6**
0.00168	**ANS23**	Requirement for coordination with military flight operations		2005	propsed regulations & data from authorities			X	X		X	X		X		X	**ANS23**
0.0016	**AC16**	Unification of Civil Aviation Organizations and loss of influence of rules of the art not incorporated in the Civil Aviation Organizations															**AC16**
0.00149	**C14**	Possible economic, operational, and safety requirement to optimize mix of flight crew		ongoing	proposed new regulations		X			X	X	X	X	X		**C14**
0.00137	**AC6**	Introduction of second-generation supersonic transport aircraft		2007-2012	studies by industry consortia	X	X	X	X	X	X	X	X	X		**AC6**
0.00135	**OR1**	Economic incentives to outsource organization activities		ongoing	airline data	X	X	X	X		X			X		**OR1**
0.0013	**C13**	Possible requirement for psychological screening of flight crews		2005	proposed new regulations		X			X	X	X	X			**C13**
0.00129	**OR3**	Shift away from clear lines of authority and command toward dilution of responsibilities within airlines		ongoing	airline data	X	X	X			X	X	X	X		**OR3**
0.00124	**C15**	Increasing life expectancy of crew members		ongoing	airline, medical & pilots' association data		X			X	X	X	X	X		**C15**

0.00123	**OP7**	Full scale introduction of operational airships	Airship development projects are currently under development in various countries with vehicle types ranging from small observation platforms to very large freight carriers. There is an extensive body of historical experiece with airship operations that should be used as the basis for future integration of increasingly larger and more numerous airships with fixed- and rotary-wing aircraft operations.	2001	data from authorities and aeronautical organizations	X	X		X	X	X	X	X	X	X	X	X	**OP7**
	AC7	Introduction of hypersonic aircraft	This class of vehicles may be used as hypersonic transports and satellite launch vehicles. Like the supersonic aircraft, the hypersonic aircraft may expose passengers, crew but also maintenance crew's (materials, e.g. magnesium, system filters on airplanes flying above FL400-500, picking up hazardous quantities) to significant radiation levels.	2015-2020	aircraft projects in advanced developmental stages		X	X	X	X	X	X	X	X	X	X	X	**AC7**
	AC24	Moved to MRO8																**AC24**
	AC25	Moved to MRO12																**AC25**
	AC26	Moved to MRO9																**AC26**
	AC29	Moved to OP13																
	MRO7	Incentives to outsource maintenance and modification of aircraft (copied from AC23)																**MRO7**
	MRO10	Complexity of Buyer Furnished equipment (BFE) within BFE																**MRO10**
	MRO11	Introduction of virtual mock up's used for training and for evaluation of maintenance requirements																**MRO11**

	OP13	Requirement for coordination with a new generation of sport-flying devices.																				**AC29**
	C9	Greater reliance on civilian-trained crews		ongoing		authority & aeronautical organization data			X			X	X	X	X							**C9**
	C16	Introduction of new prescription and over-the-counter medications		ongoing		medical association data			X		X	X	X	X	X	X						**C16**
	C17	Changing working environment for cabin crew	Cabin crew may be required to have an advanced set of skills to deal with medical, psychological, security, and food safety considerations that aren't part of today's training regimen. Crowd control may become a greater issue due to continued pressure to increase aircraft load factors.	ongoing		airline & flight attendants' association data	X		X		X	X	X	X	X							**C17**
	C18	Radiation over exposure	Single four-hour stratospheric flight provides radiation dosage equivalent to a chest x-ray.	ongoing		airline, medical & pilots' association data	X		X				X	X		X						**C18**
	P2	Introduction of unique psychological, medical and security passenger considerations for new aircraft types	Communities created aboard Very Large Aircraft may impose different requirements on cabin crew and aircraft design than previous generation aircraft. What is the threshold population for the creation of fundamentally different interactions among groups in a closed environment? The possible operation of VLA with few or no passenger windows and with only "electronic wallpaper" may aggravate psychological difficulties. Operation of supersonic or hypersonic aircraft at high altitudes may increase eposure to ionizing radiation for both passengers and crew.	ongoing		manufacturer studies	X	X	X	X		X	X	X	X	X						**P2**
	P3	Public pressure for improved cabin environment	Public and regulatory pressure may require improved air quality, reduced radiation levels, and seat pitch. New regulations may be introduced requiring minimum levels of passenger health prior to being granted flight privileges. During long flights there	ongoing		airline data	X	X	X	X		X	X		X	X						**P3**

			appears to be an increased risk for Deep Vein Thrombosis (DVT) and/or other medical conditions due to inactivity and confined seating.																
	P4	Introduction of additional passenger amenities	Sleeper berths, entertainment and communication systems, rest/exercise areas, etc.	ongoing	airline data	X	X	X	X		X	X		X	X		**P4**
	P5	Introduction of supplementary passenger protection and restraint systems	Passenger airbags, smoke hoods, etc.	2005	availablilty of technology, proposed regulations	X	X	X	X		X	X					**P5**
	P6	Increasing number of elderly passengers	Trend toward greater numbers of retirees using air travel for vacations, family visits, etc.. What special considerations must be made for the level of mobility of the elderly passenger?	ongoing	airline & transportation survey data	X		X	X		X	X		X	X		**P6**
	P7	Increasing use of personal electronic devices	Potential problem of future computers or devices with send/receive wireless communications capability that may almost never be switched off. The wide variation of potential radiation sources and their location in the passenger cabin relative to critical wiring and components may make it very difficult to precidct all possible effects and failure modes.	ongoing	airline data, cabin crew observations	X	X	X	X		X	X			X		**P7**
	OR2	Introduction of "virtual organization" operations concepts	Future commercial organizations may consist of geographically distributed functional nodes (under separate ownership) connected electronically with one another. The five major global airline alliances now control half of the passenger travel market, according to Airports Council International. Star Alliance, OneWorld, Delta/Air France, Wings and Qualiflyer have nearly 50 per cent of total world scheduled passenger numbers in 1998 based on ACI and IATA statistics.	ongoing	airline & authority data	X	X	X	X	X		X	X	X	X		**OR2**
	OR4	Emergence of low-cost organization/airlines	Low price airlines in the US and Europe, built primarily on the leisure market, are beginning to make	ongoing	airline & authority data	X	X	X	X	X		X	X	X	X		**OR4**

			significant headway in their efforts to attract the business traveler. It makes economic sense for small and medium size companies to prune the spiralling cost of fares charged by major carriers.																
	OR5	Increasing corporate and individual liability with each successive accident	The major affecting airline liability for passengers on international flights is the concept of unlimited liability in cases of passenger injury or death. This new agreement, known as the Montreal Convention, creates a two-tier level for the recovery of money damages based upon strict liability and increased money damages where fault of the airline is shown. The first tier provides for strict liability and caps money damages for injury and death at $135,000 irrespective of the airline's fault. The second tier provides unlimited liability for damages if the fault of the airline can be shown.	ongoing	new legislation or judicial precedents	X	X	X	X	X		X			X		**OR5**
	OR6	Privatization of government services such as ATM and airports	A growing number of countries have shifted their government-sponsored air traffic control systems into free-standing corporations directly funded by airlines and private-plane users. In Germany, New Zealand, South Africa and Switzerland, the new companies are owned by the governments but operate outside of civil service and procurement rules and outside of most governments' budgets. In Canada, and soon in Britain, the companies are partly or entirely owned by private investors. In all cases, the governments continue as air-safety regulators and have approval power over user-fee increases.	ongoing	authority data & proposed regulations	X	X	X	X	X		X	X	X	X		**OR6**
	AU1	International standardization of requirements and procedures	Failure to adopt consistent standards and conventions in the face of globalization and centralization within and across organizational/international	ongoing	emerging regulations	X	X	X	X	X	X		X	X	X	X		**AU1**

			boundaries may create future problems.															
	AU2	Delegation of responsibility from the regulating authority to the operating or maintaining organization	New approaches to organizational approvals lead to more and more delegation of responsibility and privileges to the design, manufacture and maintenance organization.	ongoing	emerging regulations	X	X	X	X		X		X	X			**AU2**
	AU3	Emergence of new regulatory philosophies and safety/risk management systems	Pro-active management of aviation safety risk will be made possible by developing technologies that enable efficient and effective feedback of the state of aviation systems operations and the frequency and severity of potential safety risks. System modelling technologies incorporating human behavioral models will enable reliable prediction of safety trends and effects of proposed safety interventions. Confidential and rapid electronic sharing of key information and decisions will foster effective risk management in the future. Objective and performance-based requirements may emerge as new regulatory philsophies (e.g. implying delegation of oversight responsibility to the operator.	ongoing	emerging regulations	X	X	X	X		X		X	X	X	X	**AU3**
	AU4	Possible privatization of government ATC systems and airports		ongoing	authority data & prposed regulations			X	X	X	X		X	X			**AU4**
	AU5	Increased number and scope of incident investigations by official transportation safety boards															**AU5**
	AU6	Emergence of re-organized national aviation authorities															**AU6**
	AP3	Changing characteristics of airport surfaces	New materials/compositions may be developed for runway, taxiway, and overrun surfaces in addition to improved runway surface friction management techniques.	ongoing	authority data & proposed new technical standards	X		X	X		X	X	X		X		**AP3**

	AP4	Trend toward siting of runways adjacent to bodies of water	Resulting approach and departure paths may result in greater exposure to over-water flight conditions and greater likelihood of interaction with and impact on wildlife. Risk assessments show that in the next 10 years there is about a 25% probability that a large jet transport will be involved in a fatal bird strike related accident in the U.S. or Canada.	ongoing	authority data & proposed new airport projects	X		X	X		X	X			X		**AP4**
	AP5	Requirement for improved security	Screening of ground personnel, baggage, etc.	ongoing	authority data & proposed new security regulations	X	X	X	X	X	X	X			X		**AP5**
	AP6	Increasing intensity of aviation operations at smaller, outlying airports		ongoing	authority data & proposed new regulations			X	X		X	X	X		X		**AP6**
	AP7	Airport modifications required to permit operation of new aircraft types		ongoing	authority data & proposed new aircraft			X	X	X	X	X	X		X		**AP7**
	E2	Use of novel, interlinked, intermodal transportation systems	The modes of transportation that comprise the transportation system have historically developed independently. Each mode is a separate system that consists of a network of infrastructure, terminals that connect with other modes, and vehicles that carry passengers and cargo. While today the modes operate in parallel and sometimes cooperatively, each largely retains its own distinct ownership, operating patterns, and financing sources, future transporation modes will increasingly require coordinated planning and linked functionality for improved efficiencies and reduced environmental impact.			X	X	X	X	X	X	X	X	X			**E2**
	E3	Change in public perceptions of aviation safety/liability and changes in judicial and legislative attitudes.	For several years, the airline industry has been warning that a massive increase in passenger traffic worldwide in the next 15 to 20 years could result in a public perception that flying has become more dangerous. If today's accident rate is not improved as more people fly, there could be a major airline crash somewhere in the world approximatley once a week in the next century. If accident and incident rates are not reduced, the public perception of greater risk could mean fewer travelers, less revenue for airlines, and lower sales for manufacturers. One effect could be	ongoing	media, political activity	X	X	X	X	X	X	X	X	X		X	**E3**

			pressure for improved evacuation requirements. An ancillary effect may be pressure to adopt politically expedient but inappropriate safety interventions.																		
	E4	Reduction in public funding for ATM/CNS services		ongoing				X	X	X	X	X	X	X			**E4**				
	E5	Pressure to assess user fees within U.S. aviation system to recover costs of operation of privatized entities		ongoing	FAA			X	X	X	X	X	X	X			**E5**				
	E6	Obsolescense of hardware and software systems in use both on the ground and in the air as well as space-based systems.	A basic rule of business is that companies must maintain some level of control over the evolution of software and hardware systems or they ultimately will fail. Custom or packaged software eventually reaches a point where it no longer is capable of performing at the level that an aviation organization requires. Ignoring this fact results in major expenditures (like Y2K problems) to replace software and often hardware. Modification of the organizational strategy and approach usually requires a change or reengineering of application software in order to maintain functional capability.	ongoing		X	X	X	X		X	X	X	X		x	**E6**				
	E7	Reduction of the market share of specialized hardware and software products utilized by aviation	Because other high-tech industries are on a rapid growth curve, the advanced products pruchased by the aviation sector of the economy now represent a smaller share of the overall production capability for these specialized products. This may create a situation where the aviation inductry may have a more difficult time obtaining the necessary componentry at favorable prices.	ongoing		X	X	X	X			X	X	X			**E7**				

	E8	Use of Commercial Off The Shelf (COTS) products in aviation	Economic pressures are driving many commercial and governmental operators within the aviation system toward purchase of COTS products. Although these products may have a favorable cost-to-performance ratio, they may not have been subject to the verification/validation rigor required to maintain safe, dependable operation of the aviation system.	ongoing		X	X	X	X		X	X	X	X			**E8**
	E11	Increasingly stringent noise constraints	Aircraft noise and emissions concerns may become the most important strategic obstacles for future development of air transport, eg.: a.) Ground-test run-ups of engines following repair or maintenance to the detriment of safety. b.) Policies on runway use, focussing on minimum noise nuisance rather than "into wind and long" may reduce safety margins (eg., Schipol). c.) Take-off and landing profiles to reduce noise (steep climbs at low speeds or decelerating/steep approaches) reduce safety margins. d.) Ever more stringent noise rules may not be achievable solely by quieter engines. Aerodynamic (airframe) noise is an increasingly important noise source. Comprmise of aerodynamic design (reduced vortical flowfields and less efficient high lift systems) could increase take-off and landing speeds.	ongoing	media, regulations, ICAO rule changes & proposed new standards	X	X	X	X	X	X	X	X	X			**E11**
	E12	Increasingly stringent emissions constraints	Pressure to conform to Kyoto Protocols to reduce global warming. Options for global control of emissions: changes in operational techniques, aircraft traffic management, regulations, environmental levies or the market based approach of emissions trading.	ongoing	media, regulations, ICAO rule changes & proposed new standards	X	X	X	X	X	X	X	X	X			**E12**
	E13	Change in fuel composition	Global environmental and safety concerns may require use of alternative fuels to address emisions	2005	oil company data, propsed new standards	X	X	X	X	X	X	X	X	X			**E13**

			and volatility concerns.																	
	E14	Requirement for harmonization of cultural diversity among operators of aviation system	Although English may the international language of aviation, even when pilots and controllers both speak English fluently, there are pitfalls in the nature of language and the ways that language is heard. Subtle miscues can subvert messages that seem clear to the sender. Pilots and controllers must be aware of, and avoid, common types of linguistic misunderstandings.	ongoing	policies of international bodies	X	X	X	X	X	X	X	X	X			**E14**
	E15	Economic globalization	International air transport is a world system and continuing air transportation globalization is both inevitable and necessary. A system, which operates to agreed standards – of safety, security, efficiency and which requires clearly defined commercial and operational rules.	ongoing	media, signs of conflicting regulatory requirements, economic statistics	X	X	X	X	X	X	X	X	X		X	**E15**
	E16	Trend toward mergers and corporate consolidations	Shareholder pressures to improve profit margins may force adoption of new, consolidated corporate structures.	ongoing	media, economic & related statistics	X	X	X	X	X	X	X	X	X		X	**E16**
	E17	Changing labor/management relations	Evolving legisation in various countries creates an elaborate system for resolving labor disputes in the airline industry. Among other things, this legislation may requre that an employer must maintain the status quo while negotiating with a union over a new collective bargaining agreement. Accordingly, an employer may be placed in a position where they cannot alter or change the terms or conditions of employment while negotiating with union represented employees.	ongoing	media, data from national aeronautic authorities/organizations	X	X	X	X		X	X	X	X		X	**E17**
	E18	Rapid and widespread distribution of information	Free-flowing information may increase vulnerability of information technology systems and require adoption of new data protection strategies.	ongoing	media	X	X	X	X	X	X	X	X	X			**E18**

	E19	Selective denial of CNS accuracy by governments																			**E19**
	E21	Increased likelihood of hostile acts against air- and ground-based elements of the aviation system	Increased political instability and terrorist activity. Increasing sophistication and proliferation of explosive materials, biological/chemical toxic agents, and anti-aircraft weapons. Review possible solutions to prevent hijacking and quick resolution options without fatalities, i.e. minimize impact of terrorist attack. Vulnerability to jamming and high-energy radiated fields may become an issue in the future.	ongoing	media & government sources	X	X	X	X	X	X	X	X	X		X	**E21**
	E22	Revolutionary scientific advances	Full-surface laminar flow, MEMS flow control technologies, adaptive flight surfaces, all-composite aircraft, ground-to-air power transmission, etc.	ongoing	consensus from scientific groups, research reports	X	X	X	X	X	X	X	X	X		X	**E22**
I	**E23**	Lack of commitment to basic research and technology development in both government and private sectors	It is clear that investments in basic research do have substantial economic benefits and that there remains an enormous reservoir of research opportunities for which there are no immediate commercial benefits. Without robust funding for basic research, many of these opportunities will not receive the attention they deserve. Potential future decreases in projected funding for research pertains to both basic and applied research in science and technology. The three sectors of the world economy that support basic research -- military, private industry, and federal -- all have downsized.	ongoing		X	X	X	X		X	X	X	X			**E23**
	E24	Effect of "political opportunism" on aviation	Inherent in moves to convince governments that a long and detailed list of product features should be legislated… rather than simply left to competitive forces.	ongoing	policies of individual states and international bodies	X	X	X	X		X	X	X	X			**E24**
	E25	Insufficient public funding for safety research	It is estimated that the funding for aviation safety related research has been cut by half in the past ten years.		government and safety institute data	X	X	X	X	X	X	X	X	X			**E25**

	E26	Potential disruptions resulting from unstable capital markets		ongoing	financial sector data		X	X			X						**E26**
	E27	Impact of rapid changes in the software and electronic hardware industry	Rapid turn-over of technologies with little thought being given to long-term product support nor to strategies for archiving/accessing data.	ongoing		X	X	X	X		X	X	X	X			**E27**
	E28	Increasing criminal liability leading to protective measures against an efficient safety system	Reduced pace of research in order not to uncover possible defects, hiding accountabilities, etc.	ongoing	legislatative action	X	X	X	X		X	X	X	X			**E28**
	E30	Economic pressures to reduce the authority of the pilot in command relative to airline dispatch coordinators		ongoing	airline & pilots' association data		X	X			X	X	X	X			**E30**
	E31	Changing cultural awareness of safety and roles of safety assurance personnel within user community	When cultures are congruent, there is no uncertainty or hesitation - we know how to proceed because the underlying values and beliefs are sending us convergent messages. But when cultures are in conflict, we become unsure of how to proceed or behave. The hesitation and uncertainty arising from divergent cultural messages can cause confusion, frustration, and even conflict, especially in emergencies and other time-pressure situations. In aviation, the result of cultural incongruity is compromised safety. Pilots and other employees on the aviation "front line" do not need conflicting messages on how to behave and proceed. If organizational or national cultures have the potential for the greatest impact on safety, and an integrated culture is preferable to one that is discordant, then strategies are needed which address two issues. The first more general approach aims at unifying and strengthening the organizational culture; the second aims to introduce safety as a shared	ongoing	accident/incident reports	X		X	X	X	X	X	X	X			**E31**

			value which will provide the underlyi																	
	E32	Increasing complexity of the aviation system coupled with rapid turnover of staff																		**E32**
	E33	Increased population of various species of large flocking birds																		**E33**
	S1	Introduction of new space vehicles	The operational characteristics of future space vehicles may require operators of wing-borne vehicles to adopt different ATM approaches.	2010	NASA, FAA, JAA	X	X	X	X	X	X	X	X	X	X					**S1**
	S2	Development of standards and certification for space vehicles	It is uncertain how commercial indemnification authority will be established in the future. It is also not clear how certification and regulatory bodies will be established with objective and targeted levels of safety. New SIDs, STARs, and emergency procedures will be required.	ongoing	NASA, FAA, JAA	X	X	X	X	X	X	X	X	X	X					**S2**
	S3	Increasing frequency of commercial and government space vehicle traffic		2005	NASA, FAA, JAA			X	X	X	X	X	X	X	X					**S3**
	S4	Introduction of space tourism and accompanying safety/reliability considerations	A key issue related to space tourism is the certification of the transportation systems and regulation of the commercial operations. In 1995, the National Aerospace Laboratory (NAL) conducted a survey in North America (U.S. and Canada) of 1020 households, which was the first actual market research of its type to be conducted in America. The results	2010	NASA, FAA, JAA	X	X	X	X	X	X	X	X	X	X					**S4**

			concluded that overall, 60% of those surveyed were interested in traveling to space for a vacation. This figure is comprised of more than 75% of those under 40..., 60% of those age 40 to 60, and more than 25% age 60-80.														