FUTURE AVIATION SAFETY TEAM
PHASE 3 OF WORK: INCREASED RELIANCE ON FLIGHT DECK AUTOMATION
EXECUTIVE SUMMARY
DRAFT ISSUE 10
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1.1 Introduction:

The Joint Aviation Authorities, Europe (JAA) and the Federal Aviation Administration, USA (FAA) sponsor a number of research groups aimed at improving aviation safety. The special group FAST (Future Aviation Safety Team) operates under the umbrella of the JSSI (JAA Strategic Safety Initiative). The JSSI aims at continuous improvements of effective safety systems leading to further reductions of the annual number of accidents and the annual number of fatalities irrespective of the growth of the air traffic

1.2 Background & Purpose of the report:

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:

a) One approach based on past accident analysis "(historic approach").
b) 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.

Phase 1 and 2 of FAST activities led to the agreement on a 1) Generic methodology**,** 2) a list of 157 on-going or future Areas of Change affecting the Aviation System.
Phase 3 provides:
1) an extensive list of Hazards related to the Area of Change of highest priority, i.e.” Increased reliance on flight deck automation" and
2) Recommendations related to this AOC.

This executive summary provides a <u>*synthesis*</u> *of the work done so far and invites the reader to further study both the main body- and the appendices of the report. To do so, references have been added on a fairly large scale.*

Part I of this executive summary gives the list of main Hazards and main recommendations for “increased reliance on flight deck automation”.
Part 2 gives a summary of the work performed during Phases 1 and 2 together with the proposed methodology for FAST.

Note: *This Executive Summary contains some coding such as AC-13 or Live 4.1. These are FAST coding for Areas of Change (AC stands for Aircraft) or Hazards (Live stands for Liveware)*

<u>EXECUTIVE SUMMARY PART I:</u> Increased Reliance on Flight Deck Automation

1.3 <u>Prioritized list of hazards:</u>

Using the process outlined in paragraph 5 (and depicted in Figure 3), 286 future hazards were identified and prioritized. The following is a list of the top group of 21 **prioritized hazards** that were organized using the following time frames: current; future near; future medium; future long. This organization is reflected in figure 4. The coding is the one used in paragraph 5:

1. Flight crews - Conflict between air / ground information sources:
Poor escape manoeuvre decision due to conflict between different information sources (e.g. TCAS, ATC verbal messages, data link) and lack of explicit prioritisation (LIVE 4.1)

2. Flight crews - Crew-automation interactions issues:
Abnormal/emergency situations combined with automation breakdown or failure (subtle or sudden) may create situations exceeding crew experience or training level (LIVE 6.11)

3. Flight crews - Crew-automation interactions issues:
Predominant use of automation may cause aircrew to have trouble performing traditionally simple operations such as manually switching to other runways, or overriding the autopilot in tight situations. Lack of aircrew training and/or experience coupled with manual flight in highly automated airplanes may lead to loss of aircraft control in unusual situations such as upsets, traffic avoidance or maneuvering. Loss of basic piloting skills through further automation may increase this problem further (LIVE 6.2)

4. Operations – Flight operations / interactions with automation:
Loss of automation behavior awareness due to complexity of automation modes. Pilot needs to know what the airplane “thinks” is going on (matching expectations) (SOFT 6.3)

5. Databases, software products & applications:
Failures in databases caused by wrong data or errors in updating the databases can affect the integrity and result in inaccurate, misleading (content errors), obsolete or inadequate information (HARD 7.4.1)

6. CNS/ATM/ATC and SCC – Adverse conditions / failure / emergency / crisis mgt issues:
Sabotage; Intentional damage or degradation of systems, either through physical means or through cyber attacks is a possibility (LIVE 15.5)

7. Flight crews - Crew-automation interactions issues:
A poor automation logic/interface may lead to decision-making based on false or misleading assumptions (LIVE 6.1.4)

8. Operating Procedures:
Inadequate processes for certification of computer software (including interactions with other software systems and artificial intelligence) onboard the aircraft and in the larger airspace system (SOFT 2.8)

9. CNS/ATM/ATC and SCC – Adverse conditions / failure / emergency / crisis mgt issues:
Sole reliance on an off board navigational information source such as GPS, combined with the unavailability of that system, causes CNS-ATM system failure and severe accident hazards simultaneously throughout the ATM System (LIVE 15.4)

10. Hazards inherent to new airspace paradigm and from a large, distributed and inter-related Air / Ground / Space (AGS) system:
Loss of situation awareness (global, local) (ENV 2.3)

11. Compatibility, integration, configuration management issues *(Including for HM Interfaces and Software applications):*
Failure or malfunction caused by incorrect functional interfaces (HARD 4.4b)

12. Databases, software products & applications:
Widespread power failures and software failure / error propagation increases the potential for unknown failure conditions (HARD 7.1b)

13. CNS/ATM/ATC and SCC – Operational issues:
Use of automation or of automated systems outside of intended function cause safety problems. Example: “climb in trail” with TCAS/ACAS, use of FMS as “sole means of navigation” (LIVE 14.1)

14. Hazards inherent to new airspace paradigm and from a large, distributed and inter-related Air / Ground / Space (AGS) system:
Failure to integrate onboard and ground systems, e.g. control functions, data link, personnel, responsibilities

- ATM/ATC and aircraft control functions (distributed multi-agent control system)
- Data link with many outside partners: ATM / ATC and SCC (under the Fully Automated Flight hypothesis)
- ATM / ATC / OPS / SCC (under the FAF hypothesis) / Flight Crew / Cabin Crew, including security and medical personnel (in particular for FAF) / Maintenance (in particular for FAF) (ENV 2.1)

15. Hazards inherent to new airspace paradigm and from a large, distributed and inter-related Air / Ground / Space (AGS) system:
Inability of individual & total system to deal with aircraft not behaving as expected, with sudden weather problem, airport closure, air or ground accident, etc. (more serious hazard regarding Fully Automated Flight) (ENV 2.5)

16. Flight crews - Absence of human agent (onboard):
When functioning, onboard sensors may not give ground crew sufficient information to correctly analyse and resolve situations (LIVE 5.4)

17. Flight crews - Crew-automation interactions issues:
Loss of strategic and tactical situation awareness, including automation & mode awareness and airspace system functions may occur if flight management, system management and control of flight is transferred completely or partly from on-board crew to ground based crew. (LIVE 6.1.2)

18. CNS/ATM/ATC and SCC – Adverse conditions / failure / emergency / crisis mgt issues:
Use of automation could allow controller/manager to exceed human recovery capabilities in the event of failure or automation breakdown. For example, CNS/ATM system failures could have more severe consequences when airplanes are more closely spaced, increasing the likelihood of collision when compared to current system (LIVE 15.2)

19. CNS/ATM/ATC and SCC – Crew / automation interactions issues:
Local or wide-area loss of control may result due to data-link failures, unintentional or intended interference or other factors (LIVE 13.2)

20. Absence of human agent (onboard):
Lack of mechanisms to replace human crosscheck of misleading or inaccurate data transmitted to & from the aircraft (in particular for Fully Automated Flight) may result in inappropriate actions being taken to ensure safety of flight. Lack of human redundancy (in particular for Fully Automated Flight) (HARD 2.2)

21. Absence of human agent (onboard):
Mechanisms to replace human sensing and processing of abnormal conditions: smoke, odours, vibration, noise, etc. (in particular for Fully Automated Flight) may be insufficient to cope with critical situations. (HARD 2.1a)

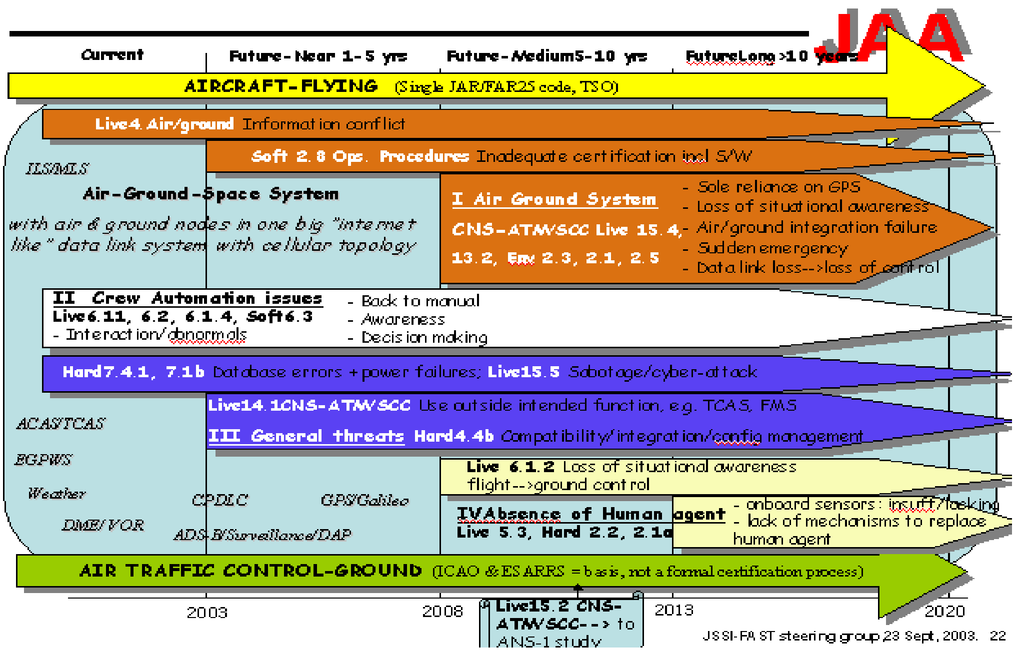
1.4 <u>Future hazard themes resulting from the study of the initial Area of Change:</u>

Detailed analysis of the future hazards developed from the study of the initial Area of Change, (Increasing reliance on flight deck automation), led to the following four themes of recommendations:

Theme I: Global Air-Ground-Space System Issues
Theme II: Flight Crew-automation Interactions Issues
Theme III: General Threats
Theme IV: Absence of Human Agent (On Board)

Details on these themes can be found in paragraphs 7.2 through 7.5 while 7.6 provide a summary

A graphical overview, including the timing in which these hazards are estimated to appear is provided in Figure 4.



<u>Figure 4.</u>

1.5 Technology Watch Items developed during the preparation of recommendations:

Monitoring advances in technology will help determine the possible realization and evolution of hazards. FAST has identified Technology Watch Items that should be closely monitored. If a particular Watch Item develops much sooner than anticipated, the corresponding hazards will appear sooner. Likewise if the Technology Watch item does not appear, the associated hazard may not appear. It is advisable to monitor the strategies developed by air navigation services such as the EUROCONTROL ATM 2000+ strategy and the strategic Research Agenda such as ACARE in Europe. Technology Watch Items in the following areas have been identified:

1. Aircraft and CNS/ATM technologies
2. Aviation processes
3. Security technologies
4. Scientific and Technological advances

Technology Watch Items are found in paragraphs 7.2.5, 7.3.5, 7.4.5 and 7.5.5 and a summary in paragraph 7.6.

1.6 Considerations on recommendations:

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On a strict logic stand point ("End to End analysis" of FAST); recommendations are the achievement of the process that in the end demonstrates its validity. FAST fully realised this and developed a method for recommendations to address the identified hazards found for "Increased reliance on flight deck automation", see paragraph 7.1.

Also, there is a huge difference between Historical and Predictive Safety initiatives in preparing recommendations. The presentation of recommendations concerning incidents and accidents that already happened is already a difficult exercise. Convincing the aviation community to accept preventative measures for events that never happened yet, require a specific approach that has resulted in a set of recommendations grouped by actor, time frame and priority.

For a detailed set of non-prioritized future work recommendations, see Appendix 12.

1.7 Recommendations:

Sets of prioritised recommendations were made and are outlined below, and chapter 7.7 details how this was done. The recommendations are grouped by Theme, i.e. Theme I Integrated Air-Ground-Space system, Theme II Flight deck Automation, Theme III General Threats and Theme IV Absence of Human Agent, by time frame, i.e. Current & Future Near, Future Medium and Future Long and by priority.

The resulting 27 recommendations can be divided per actor as follows:

Regulators:	7
Research Community	6
Manufacturers	5
CNS/ATM	3
Education & Training	2
Operators	2
Risk Monitoring	1
All	1

To enable the reader to link the hazards to the recommendations two tables have been created as follows:

- One to go from hazards to recommendations, see beginning of chapter 7.7
- Another one from recommendations back to hazards, see Appendix 17.

CURRENT & FUTURE NEAR [Today - 5 years]:

Theme II: Flight Crew Automation Interaction Issues **Score**

6. MANUFACTURERS: should decrease the number of different auto flight system modes and increase the integration of systems involving autopilot functionality.	18.0
7. MANUFACTURERS: should ensure aircraft type technical ground courses and operational training provide an adequate understanding of the processes of automation.	10.8
8. OPERATORS: should ensure that aircraft type technical ground courses and operational training adequately cover a good understanding of the processes of automation.	10.8

Justification:

The introduction of Glass Cockpit technology into modern airline aircraft has shown that there are a lot of issues associated with flight mode confusion as well as the complexity or perceived complexity of straightforward tasks by flight crew.
Fatal accidents and significant incidents and "near misses" have occurred due to mode confusion leading to loss of situation awareness and loss of control. Information regarding observed instances of flight crew mode confusion is well documented (e.g. CAST Safety Enhancement-36).

Many loss of control accidents/incidents involved cockpit displays of engine parameters, flight information and auto flight system mode status as contributory factors. The problems centred on not having sufficient, obvious and unambiguous information to the pilot to adequately assess the aircraft status and then to accomplish the appropriate action to resolve problems (CAST SE-34).

Changed training and operational requirements have also become important issues as well as the development and maintenance of manual flying skills. During times of high demand and low supply of experienced pilots (which is today the case for instance in South-East Asia), basic training of manual flight may be minimal and as low as a few hundred flight hours on light aircraft before beginning training on highly automated aircraft. And this in a very different weight class than the aircraft and simulators used during the training towards the license.

Predominant use of automation may cause aircrew to have trouble performing traditionally simple operations such as manually switching to other runways, or overriding the autopilot in tight situations. Lack of aircrew training and/or experience coupled with manual flight in highly automated airplanes may more easily lead to loss of aircraft control in unusual situations such as upsets, traffic avoidance or maneuvering. Loss of basic piloting skills through further dependency on automation may increase this problem further.

Finally, design changes, by nature, take a long time and cost a lot of money. Incorporating new safety features into new aircraft designs is technically feasible and desirable. However, it may take many years for these changes to have a significant impact on overall fleet safety, given the time it takes to develop a new aircraft and for these aircraft to become a significant part of the fleet (CAST SE-36). The FAST recommendations acknowledge this situation by asking for supply of good information and emphasis on training as long as modifications can or will not be available

Theme III: General Threats **Score**

1. REGULATORS: Regulatory agencies should ensure that organizations updating databases have an adequate system to validate updates and check the changes incorporated. The complete chain of the data base production and update process should be made visible, incl. checking routines, not only for the FMS, but also EGPWS, that is from land measurement all the way till on aircraft data base loading. Eurocae/RTCA efforts in this respect should be verified. Database software systems including those in the total AGS system should be looked at throughout the total life cycle, i.e., initial design through production to the ultimate updating and upgrading to the next generation.	19.2
9. RISK MONITORING: Reporting, tracking, evaluating of cyber attack/sabotage anomalies and take appropriate action in a global system.	13.1
4. RESEARCH COMMUNITY: Conduct research to identify methods to harden [RF] aircraft systems against cyber attack, robust encryption technology) and to improve integrity through better detection of deviation from initial performances.	12.3
5. RESEARCH COMMUNITY: Research into secure transmission and reception capabilities. Learning from military experience.	12.3
2. REGULATORS: Ensure functional and S/W design assurance with respect to security; therefore establish new set of requirements with respect to identified threat (combination of Integrity, availability, reliability, continuity).	9.8
3. REGULATORS: Require standards developed by standardization bodies (ARINC, RTCA, EUROCAE, etc) or equivalent, be used in datalink applications.	9.2

Justification

Use of systems outside intended use

Operators today sometimes use systems for tasks for which they were not intended or certified.

Four examples:
- Use of FMS as sole means to determine V speeds.
- Use of FMS as sole means of navigation.
- Use of TCAS to maintain separation.
- Use of TAWS as primary means of navigation.

There are many reasons why that occur. Some of the main reasons why systems are improperly used are as follows:
- The designers of the system make it possible to do so.
- Operators are under pressure to meet efficiency requirements and so are tempted to misuse systems.
- Pilots percieve the technology as so compelling that they may use ad-hoc procedures.
- In some cases regulators allow its use under temporary conditions, e.g. FMS for PRNAV in the TMA under TGL 10.

The human tendency is to minimize complexity and workload. The FAST recommendations aim to ensure correct functioning at all times since these systems may sometimes be the last line of defense.

Databases:

Use of databases has evolved into many aerospace applications, both on board as well as on the ground. Typical examples are databases in FMS, but also in EGPWS, TCAS, AFCAS, EICAS/ECAM/MFDS, ATC systems, etc. Use of databases is currently only in its infancy, with an exponential increase just around the corner, if only for CNS/ATM use. The same is even true for interactions where the integrated AGS will also call for an exponential increase.

Database integrity, i.e. "end-to-end aeronautical data integrity" starts at the beginning, e.g., two DME's (4 nm apart) were given the same identifier and then processed through the system into the FMS. Other issues: how is certification maintained after incremental uploads?
Examples: 1. Where an Authority upon checking an EGPWS in a simulator could not find the highest obstacle (>100M) next to the airfield because it was not in the database. 2. Lookup table upon A/C go-around looks at wrong engine thrust table 3. One operator regularly comparing a 28-day FMS revision cycles with the previous edition using software tools finding numerous errors.

Data base errors/malfunctions may lead in part to loss of situational awareness, or misleading and/or incorrect information or just a plain overload of the human being. This being the case where the right information is given at the right time, but is simply either not processed or incorrectly processed due to this situation.

Sabotage and cyber attack:

Use of computer software has evolved into many aerospace applications, both on board as well as on the ground. The connections of S/W with the "outside world" are through a) Loading in the shop: Initial Program Load on the chip/EPROM, b) physical on board S/W loading by means of floppy or cable and c) logical, through a data link or wireless network. Today, the threat of cyber terrorism against aircraft is minimal. But when looking into the future airspace paradigm, see Theme I, with many aircraft and ground systems in a multi-agent distributed air ground [AGS] system, *ever more critical information* will be transmitted via data link, this is considered a serious threat.

FUTURE MEDIUM [5 -10 years]:

Theme I: The integrated Air-Ground-Space system **Score**

13. CNS/ATM: Based on previous research and rule making, use required safety targets and safety analysis to develop and design components of the air/ground/space (AGS) system and enable total system safety assessment across organisational boundaries.	23.8
18. MANUFACTURERS: Based on previous research and rule making, use required safety targets and safety analysis to develop and design components of the air/ground/space (AGS) system and enable total system safety assessment across organisational boundaries.	23.8
10. REGULATORS: Based upon previous research, adopt and implement standards for certification and operation defining safety targets and safety analysis at the total system level for present and future air/ground/space (AGS) systems and enable total system safety assessment across organisational boundaries.	19.0
11. REGULATORS: Combine ATM safety regulations and Aircraft safety regulations in order to achieve a total system approach.	19.0
14. CNS/ATM: Develop appropriate procedures for abnormal and emergency situations, in particular failure conditions involving multiple alerts from various sources (for example, one alert from ground system and one from airborne system)	15.2

15. <u>ALL</u>: Work with the rest of the aviation community to develop processes that will establish and maintain historical documentation containing the requirements, design details and assumptions that were made during initial design and any subsequent changes to the system (documentation should answer Know How, Know Why, Know Where). This process should include the establishment of reporting requirements and preservation of in-service feedback.	15.2
16. <u>RESEARCH COMMUNITY</u>: Work with the rest of the Aviation Community (including Regulators) to establish and evaluate safety targets and safety analysis at the present and future air/ground/space (AGS) system level, e.g., interaction both normal and abnormal conditions and security infringements, etc.	15.2
12. <u>REGULATORS</u>: Review and if necessary improve as appropriate todays certification process to ensure adequate resolution of existing interface of the total system.	14.3

Justification:

By the year 2020, we expect Aircraft, Air Traffic Control Centres, Airline Operation Centres, and Satellites to be the nodes of an integrated Air Ground Space System (AGS) that will operate during all phases of flight (gate-to-gate) and communicate through data-link.

The airspace system will undergo significant changes (e.g. free routing/free flight; new airspace classification; development of 4 Dimensional trajectories) that will change the way the different actors or "stakeholders" will operate, individually and globally, co-ordinate their activities, and co-operate.

The progressive development of such a "distributed multi-agent system" in which artificial agents e.g. a computer or network of computers), automation, computers, data-bases and even Artificial Intelligence will play an important role is a response to the challenges posed to the future civil aviation. That is: increased airspace capacity, better respect to the environment (in a "sustainable growth" approach), and improved safety.

The various changes that will affect the aviation system are therefore oriented towards improved performance and safety. But this future global Air-Ground-Space system will also give rise to a series of Hazards, which require attention today. FAST has tried to identify those hazards and the above recommendations have been formulated, in order to prevent, control, or manage them in a proactive way.

Because so many organisations are and will be involved in the development of this AGS system, it is imperative, that a *system* safety assessment can be performed. Not only within ones own organisation, but more importantly also across organisational boundaries. As a result, safety standards and targets should be open and in full view of all involved.

<u>Theme IV: Absence of Human Agent</u> **<u>Score</u>**

17. <u>EDUCATION AND TRAINING</u>: Training programs should emphasize pattern recognition and skill-based procedures to cope with time critical situations, rather than relying on knowledge based analysis. (CAST Intervention 487)	8.2
19. <u>OPERATORS</u>: Require training/standardization programs, which teach situation awareness. (The knowledge and understanding of the relevant elements of the pilot surroundings, including aircraft systems, and the pilots intentions) (CAST Intervention 147)	8.2

Justification for these recommendations will follow under the next time frame Future Long, because these fall under Theme IV: Absence of Human Agent

FUTURE LONG [> 10 years]:

Theme IV: Absence of Human Agent **Score**

20. RESEARCH COMMUNITY: Develop sensor and data management technology that detects unique and un-planned-for problems that replicates human sensory capability	19.2
21. RESEARCH COMMUNITY: Develop data sensing, data merging, data filtering, data analysis and diagnostic techniques (Artificial Intelligence, expert systems – in particular neural nets)	19.2
22 RESEARCH COMMUNITY: Develop compensation technology that replaces pilot and cabin crew reasoning and problem-solving abilities especially for those unique situations that require novel and immediate responses by ground or automatic systems	15.3
23. MANUFACTURERS: Develop data sensing, data merging, data filtering, data analysis and diagnostic techniques (Artificial Intelligence, expert systems – in particular neural nets) for supporting software and equipment	19.2
24. MANUFACTURERS: Work with the rest of the aviation community to develop processes that will establish and maintain historical documentation containing the requirements, design details and assumptions that were made during initial design and any subsequent changes to the system (documentation should answer Know How, Know Why, Know Where). This process should include the establishment of reporting requirements and preservation of in-service feedback	12.3
25. REGULATORS: Develop new regulatory measures dealing with issues of absence of human agents aboard aircraft (as well as absence of human agents in Supervisory Command and Control (SCC) facilities)	15.3
26. CNS/ATM/SCC: Devise methods to keep SCC advised of current aircraft performance capabilities that would normally be evaluated and communicated by flight crew and devise methods to intervene and correct anomalies.	12.3
27 EDUCATION AND TRAINING: Use education and training requirements as a cornerstone of the design process and use training as a source of feedback to the design process.	11.4

Justification:

Despite the low probability of operational fully automatic flights within the next 20 years, FAST decided to investigate this possibility as an extreme case of automation permitting:

- to highlight tendencies valid for automated manned flights (e.g. situation awareness)
- To highlight that in a silent cockpit of a plane, crew awareness of phenomena maybe poor and new detection technologies may be necessary in the near future.

Detection technologies for unexpected problems will be developed if un-crewed passenger carrying airplanes are to be built. If these technologies are not developed, then those airplanes will not be built. Therefore, the recommendations under this Theme IV strive to have systems and technologies to accurately detect, or solve, an unexpected safety-related hazard on a so-equipped airplane.

There are several required technologies that could contribute to the technical solutions of these detectors. Improved aural (hearing), olfactory (smell), tactile (feel), and visual sensors could be part of the technology. Nano-sensors and "smart" sensors that do not broadcast information unless the information is deemed significant could provide a network of basic sensors, which if properly interpreted, could sense a problem. Networking technologies will also play a part; wireless detection and transmission to the decision-making computer will be a key for manufacturing purposes. The "decision-making computer" must also "ping" remote sensors if problems are expected and no information is flowing to it from the sensors.

The *biggest technology hurdles* however are data merging, diagnostic, interpretation, decision-making and problem solving. Sensor information from many good sources is useless, unless it can be interpreted regarding what the unexpected problem is. For instance, a flight crewmember could walk to the aft cabin while in flight, see a mist trailing the right wing, and determine that a fuel leak probably exists. Having a similar (at least functionally) sensing and deduction capability will be necessary for decision-making and subsequent problem solving (When a problem is rightly detected and interpreted, appropriate recovery measures still need to planned and executed). This may require substantial application of diagnostic, decision-making, planning and action and capabilities, most of them being addressed by Artificial Intelligence (AI).

Even if these very challenging technologies are developed, the burden of proof for its acceptability will be "that a FAF airplane will need to be at least as good as a piloted aircraft". One serious concern will be that this may lead to a regulatory overkill due to the many uncertainties around FAF, a typical example from the past being automatic landing. Under autoland conditions, unrealistically harsh conditions need to be simulated, for instance under crosswind limits, leading to manual landings when crosswind exceeds the simulated limit of e.g. 25 knots. Flight testing has shown that the automatics under these conditions would have made a perfect landing, while the manual landings in excess of 25 kts crosswind have shown in several cases to end up in significant mishaps.

All automation topics, but especially FAF and also the integrated AGS, identify computer software safety and security issues, either as inherent hazards or as hazards generated by interactions. Artificial Intelligence and rapid pace of software and technology development were identified as two of these interactions.
In particular the following issues were raised:
1) What the system learns is not predictable and may not be shared with subsequent operators;
2) Certification issues with Artificial Intelligence (e.g. neural nets, fuzzy logic), etc.

Increasingly autonomous military airplanes will be introduced along with long endurance communication and civil surveillance platforms for detecting fires, security threats and the like. Twenty years from now, it is possible that there will be fairly autonomous cargo carrying airplanes flying, and passenger airplanes may be being designed at that time. So, the transition to FAF will not occur at once. It will have a phased introduction, starting with single pilot operated aircraft, which will necessitate substantial Human Factors research to integrate the pilot with its "semi-autonomous" aircraft. This research may also have significant spin off for today's man-machine interfaces.

Design assumptions Documentation: a novel defense:

Two recommendations, i.e. 15 & 24 appear under two themes; that is Theme I: The integrated AGS and Theme IV Absence of Human Agent. They are repeated below because their justification may not be immediately clear from the justification given above.

15.ALL: Work with the rest of the aviation community to develop processes that will establish and maintain historical documentation containing the requirements, design details and assumptions that were made during initial design and any subsequent changes to the system (documentation should answer Know How, Know Why, Know Where). This process should include the establishment of reporting requirements and preservation of in-service feedback.	15.2

24. MANUFACTURERS: Work with the rest of the aviation community to develop processes that will establish and maintain historical documentation containing the requirements, design details and assumptions that were made during initial design and any subsequent changes to the system (documentation should answer Know How, Know Why, Know Where). This process should include the establishment of reporting requirements and preservation of in-service feedback	12.3

Justification:

Throughout the FAST process, we have found that, not only for the AGS system or fully automatic flight, but also for many contemporary aircraft, or ground ATC and Space systems now in production and operation, it is foreseen that they will be longer in production & operation than ever before. This will require a novel defense.

Since the life span of e.g. aircraft type certificates is known to be much longer than originally projected (B737 version span as an example) this will especially be true for Fully Automatic Flight and any intermediate aircraft, if only because of the ever increasing development cost of these aircraft. This will naturally drive manufacturers to do derivatives as one continuing process. The same will be true for the Ground [ATC] and Space "nodes" of the future AGS system.

To combat these special issues, where the operators, designers, regulators, researchers, etc. may have left the industry, long before the last derivative enters operation and hence essential information will be lost, the above novel recommendations/defences needs to be implemented.

It should be noted that these last issues are key to many accidents and one of the the origins of FAST, since in many accidents (60-70% according to a Boeing study) the environment proved to be different from what was assumed during the design.

Finally, for a detailed list of all prioritised recommendations, see Appendix 16.

Final remark:

FAST believes the above recommendations make sense, provide direction and are of sufficiently high abstraction level that world wide safety teams can further develop these into practical interventions. This is important, because it was always the FAST intention to highlight items, not to do the work that so many safety organisations day in day out do.

1.8 Proposed actions:

The following tasks are proposed, **as an immediate follow-up** of this report:

Task 1:
Issue the report and get broader concurrence within the JAA & upcoming EASA system, in particular of Sectorial Teams

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Task 2:
Provide the future hazards, prioritised recommendations and background information to CAST.

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Task 3:
Cooperate to develop joint EU & US safety enhancements.

Task 4:

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Have FAST start the study of the next Area of Change, “Emergence of new concepts for airspace management” in early 2004. This requires support from EUROCONTROL, in particular the nomination of a Co-chair. Since this Area of Changes is interrelated to the one studied, the methodology would be validated, particularly relative to the Master Hazard’s list and Master Recommendation list. If this would not be possible take the next one in the list: Introduction of new technologies with unforeseen human factors aspects (C-1) or Proliferation of heterogeneous aircraft with widely-varying equipment and capabilities (AC-11)

Task 5:
Enable the continuation of FAST during 2004, this requires further exploration in particular relative to resources and general strategy. Tasks envisioned are:
Review the list of Area's of change as compiled 4 years ago to update it as necessary, ref paragraph 8.2.
Review the methodology as outlined in chapter 7.8

Task 6:
Create a data-base of Future Hazards and of associated recommendations: this should be initially populated by those identified for “increased reliance on Flight Deck Automation”. This data-base should contain all hazards and recommendations

1.9 FAST long term plans will be defined around the end of 2004 when the above actions will have been completed or nearing completion

1.10 Conclusions:

From the FAST work done so far it can be concluded that:
1. The FAST process works
2. FAST has developed a methodology to address future hazards.
3. FAST has identified a middle route that is Heterogeneous INCIDENT & OPERATIONAL DATA that should bridge the gap between CAST/historic approach & FAST/Prospective approach.
4. A set of 27 recommendations have been provided for implementation by world wide acting aviation safety teams.
5. There is a set of proposed actions including 5 tasks for the next JSSI steering group meeting.

EXECUTIVE SUMMARY PART II: Methodology and Areas of Change

1.11 Summary of the basic methodology:

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The overall process consists of six major elements:

1. Identification of Areas of Change (AoC) affecting the aviation system either from within or from external sources
2. Prioritization and selection of highest priority AoC's for subsequent analysis
3. a) Identification of potential hazards arising from the inherent characteristics of the target AoC as well as potential hazards arising from interaction of the target AoC domain with other AoC's that may not be obvious
   b) Formulation of target recommendations for action that are transmitted to cognizant safety organizations, authorities, and manufacturers
4. Assemble and update a Master Hazards List
5. Assemble and update a Master Recommendations List
6. Continuous monitoring of the aviation system for purposes of updating the AoC's, hazards list, and recommendations via an appropriate feedback mechanism.

A graphic depiction of the overall process is provided in Figure 1.

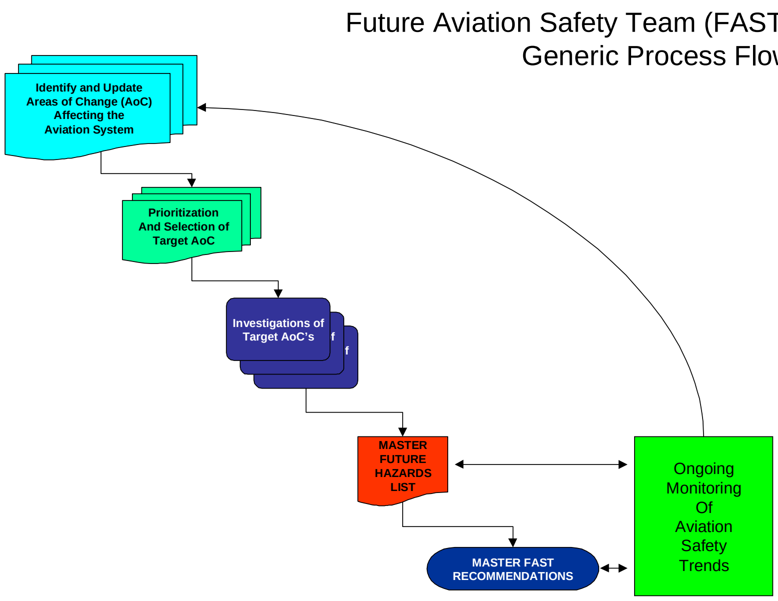

Figure 1,

A fundamental assumption underlying FAST is that it is not possible to accurately predict future hazards based on retrospective analysis of past accident data. Because of this, FAST developed a prospective analysis approach to identifying probable future hazards to the aviation system. This process is based on developing methods to uncover latent and overt emerging hazards arising from relevant changes *internal* and *external* to the Aviation System.

The reality faced by the aviation system is that change is simultaneously occurring in many domains. The generic FAST methodology provides a framework for prioritization and selection of significant Areas of Change, resulting hazards, and recommendations for further study. The methodology will help subsequent analysis teams efficiently identify the highest priority future hazards and recommendations. The FAST process can be used to identify past, current, and future conditions that may manifest themselves as future hazards.

In addition to a set of results applicable to the initial AoC selected for study, FAST has produced a generic methodology that may be applicable to other areas of aviation safety. This generic process may have value for other technology domains involving hazardous activities with potential for serious adverse consequences. The generic FAST process shown in the figure below is slightly different that what was actually used. The recommended generic FAST process incorporates lessons learned and refinements from the analysis of the initial AoC.

Unique systematic strengths of the proposed generic FAST process:

- Interaction-analysis methodology: The FAST process contains a strong, intentional emphasis on a systems approach to uncovering unique hazards arising from interactions of multiple Areas of Change. As the aviation world becomes more complex, interrelated, and interdependent, unintended adverse consequences will likely arise from the interplay of technology, organizational, economic, and environmental domains. The interaction-analysis aspect of the FAST methodology assures that regardless of the composition of a team focused on a particular area of change, unanticipated hazards resulting from complex interactions will likely be uncovered.
- Diversity in composition: FAST began its work with a group of generalists from government and industry sectors encompassing a wide variety of experience including line pilots, regulators, manufacturers, and researchers. This group developed the original AoC list and performed the analysis of the initial AoC, and this same team is now evolving into the current FAST Core Group. The Core Group maintains and updates the Master Hazards and Recommendations Lists. The FAST process should ideally be performed by multi-disciplinary teams, consisting of: generalists, technology domain experts, and safety-methodology specialists. Round-table discussions that occur during execution of the FAST process as a result of the different points of view of the team members will help prevent bias toward a particular position. These teams will develop an appropriate set of analysis methods to enable identification of hazards and recommendations for their target AoC. Tools used by these teams in their hazards analyses may include exploration and development of scenarios, concepts of operation, formal brainstorming methods, prioritization methods such as the Analytical Hierarchy Process (see Appendix 4 for details), etc.

In order to evaluate the reasonableness of the findings, a final step consists of periodic internal review of the results for a target AoC by the FAST Core Group and the use of external resources. External resources may include scientific literature and reports, safety publications, stakeholder assessments based on industry and government forecasts, current aviation accident, incident, and operational trends, comparison with other safety initiatives (e.g. CAST, JSSI, etc.), direct surveys of affected constituencies, and expert opinion.

1.12 Area's of Change:

FAST developed and prioritized the list of 157 Areas of Change to arrive at the following top 20 list: (between brackets is the coding used in Appendix 3):

1. Increasing reliance on flight deck automation (AC-13)
2. Emergence of new concepts for airspace management (ANS-1)
3. Introduction of new technologies with unforeseen human factors aspects (C-1)
4. Proliferation of heterogeneous aircraft with widely-varying equipment and capabilities (AC-11)
5. Discrepancies in pace and approach in development and implementation of airborne vs. ground-based technology systems (OP-5)
6. Increasing number of aviation operations (ANS-2)
7. Introduction of new technologies with unforeseen human factors aspects (ANS-7)
8. Variation of sophistication of hardware and software within an individual aircraft type (AC-10)
9. Ageing avionics, powerplants, electrical and mechanical systems, and structures. (AC-26)
10. Decreasing numbers of qualified maintenance personnel (MRO-1)
11. Decreased separation standards (ANS-5)
12. Increasing pressure for outsourcing of maintenance/modifications of aircraft (AC-23)
13. Increasing lack of standardization in cockpit controls, displays, and automated systems interfaces among aircraft (AC-12)
14. Shift in responsibilities for collision avoidance from ATC to crew (C-6)
15. Increasing level of information inequality in shared decision-making contexts (C-2)
16. Increasing Reliance on active flight controls (AC-17)
17. Increasing numbers of aircraft operations at lower altitude and/or in adverse weather conditions (OP-4)
18. Increasing need for maintenance of complex integrated aircraft (AC-24)
19. Discrepancies in the pace and direction of development of ground vs. in-flight CNS systems (ANS-21)
20. Decreasing maintenance expertise (MRO-2)

For details see Paragraph 4.

This Top-20 AoC's can be grouped into the following four major trends:

1. Introduction of new air, ground, and satellite-based automated systems.
2. Increased heterogeneity of: aircraft types & flight capabilities, equipage & software, airspace utilization approaches, and development directions & timelines for airborne, ground, and space-based aviation support systems.
3. Increase in absolute numbers of aviation operations and corresponding reduction in safety margins as a result of: increased demand decreased separation and more frequent operation in or near adverse weather conditions.
4. Ensuring adequate maintenance of air- and ground-based systems in an environment of increased outsourcing of work, increased complexity of hardware, firmware & software, and a shortage of qualified maintenance personnel.

1.13 Process for the Analysis of Areas of Change :

"Increasing reliance on flight deck automation" was the Area of Change selected to develop the generic methodology and initial FAST recommendations. A graphic depiction of this process is provided in Figure 2.

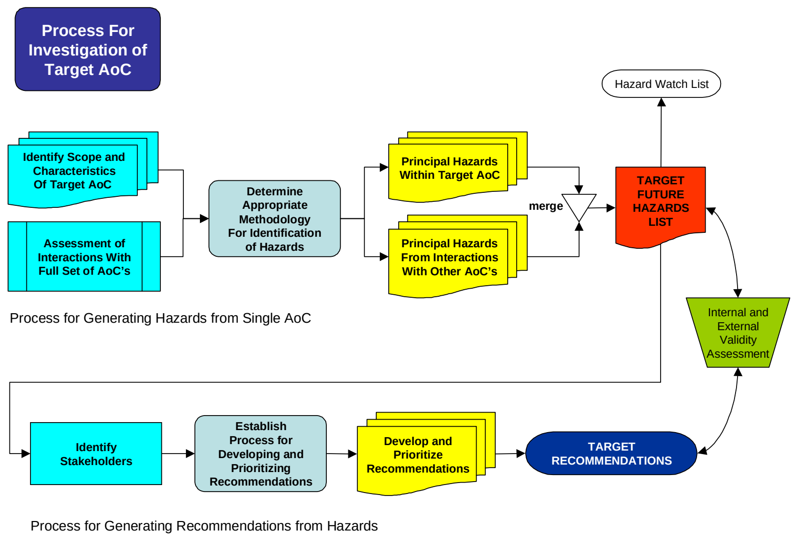

Figure 2.

After the selection of an Area of Change to study is made, an appropriate methodology for the identification of hazards must be determined. In this case, since cockpit automation can be linked to ATA airplane classification codes, the ATA codes were uses to select the significant interactions. The following areas were selected using the process described in Paragraph 5.3.1:

1. CRM issues arising from "automation"
2. Flight management systems
3. Situational awareness display
4. CNS-ATM (Free Flight)
5. Fully automated flight
6. Navigation using terrain following recognition

An important aspect of the generic FAST methodology is to look at all the interactions of the selected Area of Change (AoC) with the other areas of change. This process and the results can be found in paragraph 5.5.

The process flow used to analyze AC13 differs slightly from the Generic process.
A graphical depiction of the recommended process is presented in Figure 3.

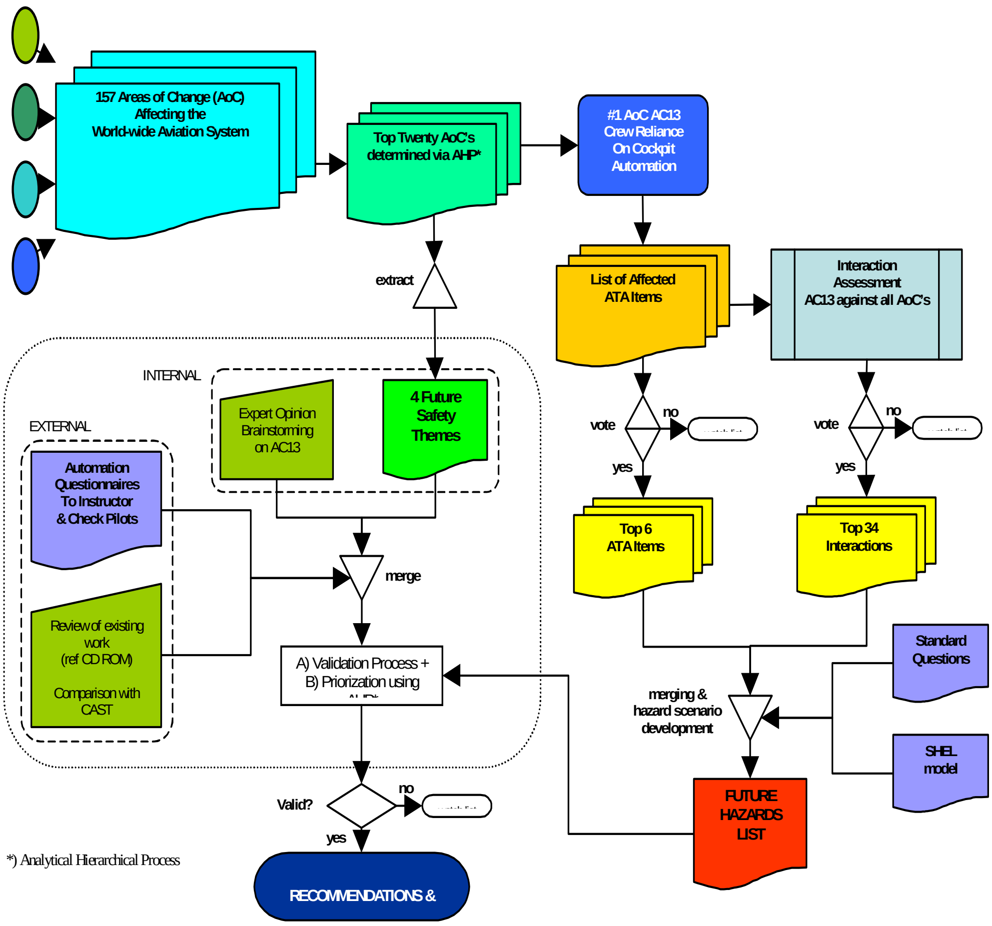

Figure 3.