ANNEX C: Categories of Change and Individual Precursor Circumstances Affecting The International Aviation System

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CATEGORY:

Aircraft (A/C)		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	**Comments on Aircraft Category**	oni
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
AC1	Introduction of new aircraft types		X	X	X	X	X	X	X	X	X		ongoing	application for certification and/or aircraft projects in advanced developmental stages	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 exploiting novel ideas to redesign the airplane. http://aero.stanford.edu/AA241/intro/futureac.html	**1**
AC2	Introduction of Very Large Aircraft (>600 passengers)		X	X	X	X	X	X	X	X	X		2005	application for certification	Although the basic airworthiness standards should ideally be the same for VLA, wake turbulence considerations and separation standards, inability of ground infrastructure to manage large numbers of passengers, emergency evacuation, and a variety of other potentially new considerations should be addressed for this new class of aircraft.	**2**
AC3	Rapid growth in use of advanced regional jets		X	X	X	X	X	X	X	X	X		2000-2010	firm orders for new aircraft	**Many Regional Jets are all new, not derivatives, where past experience may be more applicable to derivative equipment selection, design solutions and its validation and certification. At the same time Regional Jet manufacturers also delegate much of the design responsibility to partnering companies and equipment manufacturers. This dual development may well result in inadequate transfer of expertise and/or inadequate interface management. Finally, lessons learned from past Regional Jet manufacturers may not be sufficiently covered by FAR's and JAR's.**.	**3**
AC4	Introduction of new design concepts for general aviation aircraft		X	X	X		X	X	X	X	X		2005-2008	application for certification of experimental aircraft	Affordable flight systems that allow near-all-weather flying for light GA airplanes, intuitive cockpit display technologies that provide improved situational awareness and weather/traffic/terrain information to the pilot, and guidelines and certification standards for these technologies may be required in the future. Guidelines and certifications standards may need to be developed for these aircraft in addition to supplementary pilot training requirements which may include uniques aspects of operation at higher Mach numbers. http://www.nasatech.com/NEWS/OCT99/agate_top.html	**4**
AC5	Introduction of new runway independent aircraft concepts		X	X	X	X	X	X	X	X	X		2003-2007	application for certification	Operation of Runway-Independent Aircraft (tilt-wing, tilt-rotor, VSTOL, airships, wing-in-ground-effect) may have significant effects on safety and capacity, airspace operations, and ATC systems	**5**
AC6	Introduction of second-generation supersonic transport aircraft		X	X	X	X	X	X	X	X	X		2007-2012	studies by industry consortia	Technical feasibility, environmental, regulatory and certification studies for Supersonic Business Jets (SBJ) and follow-on projects may result in product launch decisions by aircraft manufacturers	**6**
AC7	Introduction of hypersonic aircraft		X	X	X	X	X	X	X	X	X	X	2015-2020	aircraft projects in advanced developmental stages	This class of vehicles may be used as hypersonic transports and satellite launch vehicles.	**7**
AC8	Introduction of fly-by-light, power-by-wire aircraft		X	X	X			X	X				2005-2008	monitor results of technology sutdies in this area	FBL/PBW technologies provide lightweight, highly reliable, highly electromagnetically immune fiber optic control systems and all-electric secondary power systems for advanced subsonic civil transport aircraft. Installing these technologies on aircraft may lower initial acquisition and direct operating costs, reduce weight, and increase aircraft performance and reliability. Specific fuel consumption may also be reduced as a result of lower aircraft weight and improved thrust specific fuel consumption obtained by eliminating engine bleed air.	**8**

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		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
AC9	Trend toward aircraft designs featuring reduced static stability		X	X	X	X		X	X				ongoing	establishment of certification criteria	Desire to improve performance and increase fuel economy is pushing designers in this direction.	9
AC10	Increasing variation of sophistication of hardware and software within an individual aircraft type		X	X	X		X	X	X				1990 & ongoing	consequences of introduction of advanced aircraft into fleet mix, airline data	Different software versions running on FMS of different airplanes may create difficulty for pilots to use them safely and effectively. "A large number of reports is related to the fact that different versions are simultaneously running on the FMS which sometimes makes it difficult for pilots to communicate their intentions to the system as they are not sure about the required data entry format." (Sarter, 1991, p. 1308)	10
AC11	Increasingly heterogeneous aircraft with widely-varying equipment and capabilities		X	X	X	X	X	X	X	X	X		ongoing	consequences of introduction of advanced aircraft into fleet mix, airline data	Not all aircraft may have the same level of equipage in future "Free Flight" environments. This could lead to multiple modes of conflict resolution (e.g. air-air, air-ground) and to problems in maintaining situation awareness when there are significant gaps in knowledge about other aircraft (e.g. flight path intent information may be lacking, or even knowledge that other aircraft exist).	11
AC12	Increasing lack of standardization in cockpit controls, displays, and automated systems interfaces among aircraft		X	X	X		X	X	X				ongoing	manufacturer data	Standardization may freeze technology progress and innovation as well as result in generalization of features that are not optimized or could have contributed to accidents or incidents.	12
AC13	Increasing reliance on flight deck automation		X	X	X		X	X	X				ongoing	airline experience with B757/767 & A310 aircraft	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 anomalous component performance.	13
AC14	Increasing reliance on automated vehicle health management systems		X	X	X	X	X	X					1978 & ongoing	airline experience with B777 & A320 aircraft, contents of operations/maintenance manuals	Future vehicle health systems may be based on continuously updated vehicle state matrices derived from networks of multiple sensors. The sensor network outputs may be processed by advanced software models incorporating the functional characteristics of the vehicle.	14
AC15	New structural concepts including adaptive or "smart" components and/or composites		X	X	X		X	X					2010	experimental programs	Composites, 'self-testing' structures, and other novel materials and structures concepts may require new attitudes, approaches, and flexibility within regulatory authorities.	15
AC16	Unification of CAO and loss of influence of rules of the art not incorporated in the CAO												ongoing			

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		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
AC17	Increasing reliance on active flight controls		X	X	X		X	X	X	X			2003-1010	monitoring of Boeing & Airbus initiatives	Functional interfaces between pilot-in-the-loop/autopilots and fly-by-wire-flight controls may produce unforeseen benefits and problems.	16
AC18	Improvements in flight data recording and cockpit surveillance systems		X	X	X		X	X	X				ongoing	monitoring of NTSB/FAA initiatives, notice of proposed rule-making	Simultaneous recording of flight data, cockpit video and audio data may permit location and replay of key flight events, encouraging more crew interaction during debriefing, analysis, reflection and self-discovery. These technologies may offer additional insights to airline FOQA staff or accident investigation teams.	17
AC19	New higher energy propulsion and control systems		X	X	X	X	X	X	X	X	X		2005 - 2010	propulsion and control systems manufacturer data	Advanced systems such as prop-fans and hydrogen-fueled aircraft and high-pressure hydraulic systems may be used in future aircraft. Increasing reliance on automation will increasingly remove the operator from immediate control of the power of a system.	18
AC20	Implementation of advanced synthetic-vision technologies		X	X	X	X	X	X	X	X			2002-2007	monitoring technology development programs for business, commercial & military aircraft	With more widespread use of synthetic vision aids, aircraft may encounter a greater exposure to adverse conditions (e.g., icing, wind shear, etc.) associated with bad visibility. The rest of the aviation safety infrastructure must keep pace with synthetic vision advances (i.e., unsafe conditions may be created by virtue of the fact that aircraft may be able to fly when they previously would have been grounded due to poor visibility). Pilots may be more prone to Plan Continuation Errors as they increasingly rely on synthetic vision technologies.	19
AC21	Implementation of advanced supplementary cockpit weather information systems		X	X	X	X	X	X	X	X	X		2005	monitoring technology development programs for business, commercial & military aircraft	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.	20
AC22	Increasing use of cockpit warning and alert systems		X	X	X		X	X	X	X			ongoing	airline experience with B757/767, A310 & F100 aircraft	Advanced digital audio and warning systems in aircraft cockpit may change crew workload and situational awareness.	21
AC23	Increasing pressure for outsourcing of maintenance/modifications of aircraft		X	X			X	X					1990 & ongoing	emerging regulations & airline experience with B727F STC & AD	There has been a shift from the established practice of major airlines doing their own aircraft maintenance towards contracting out these activities and the expansion of third party maintenance services. The development of international alliances also encourages re-organisation of airline maintenance to take advantage of synergies within an alliance. Maintenance providers are aware of this phenomenon and are working with authorities to propose rules covering this.	22
AC24	Increasing need for maintenance of complex integrated aircraft		X	X	X		X	X	X				ongoing	emerging regulations & airline experience with B747 at Stanstead	Maintenance of these complex vehicles may require greater care and verification once completed as well as coordination of maintenance actions with the flight crew.	23

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		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE			
AC25	Increasing instances of installation of un-approved parts on aircraft		X	X	X	X	X	X			X		1999 & ongoing	airline/authority data	This has been an issue in the past and may be an increasing problem in the future.	24
AC26	Aging avionics, powerplants, electrical and mechanical systems, and structures		X	X	X		X	X	X		X		ongoing	accident/incident reports, anecdotal, airline/authority & aircraft manufacturer data	New approaches may be required to guarantee aircraft structural integrity. Aging mechanical systems aboard aircraft may become a critical safety issue. This issue has a number of implications (not only for structural integrity) due to extended aircraft lifetime. Structural and system aging problems are already being addressed by regulatory authorities. ASTRAC events may also provide insight into this phenomenon. Reconfiguration of aging passenger aircraft as freighters may prolong their useful operational life but introduce unforeseen operational and safety considerations.	25
AC27	Increasing demands on aircraft systems for support of next-generation personal, in-flight entertainment and business systems		X		X	X	X	X					2000	trend analysis for existing and future aircraft types	Power requirements, wiring requirements, and effects of internal and external high-energy radiated fields emitted from these systems may place increasing demands on aircraft systems and maintenance.	26

Maintenance, Repair & Overhaul (MRO)		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Maintenance, Repair & Overhaul Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
MRO1	Decreasing numbers of qualified maintenance personnel	X		X	X		X	X		X			2000	data from authorities and aeronautical organizations	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 maintenance in service. "Hard-timing" of aircraft becomes a possibility with its economic penalties. NEED COMMENTS	**28**
MRO2	Decreasing maintenance expertise	X		X	X	X	X	X			X		ongoing	data from authorities and aeronautical organizations	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.	**29**
MRO3	Increasing importance and implementation of Maintenance Resource Management techniques	**x**		**x**	**x**		**x**	**x**					ongoing	data from authorities and aeronautical organizations	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.	
MRO5	Increased use of automation for fault detection, diagnosis, resolution, and tracking	X		X	X	X	X	X	X	X	X		1978 & ongoing	aviation technology providers, authority & airline data	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.	**31**
MRO6	Increasing quantity of available maintenance data	X		X	X		X	X					1978 & ongoing	airline 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	**32**

Operations (OPS)		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Operations Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
OP1	Increasing centralized control of user operations	X	X		X	X	X	X	X		X		ongoing	new international standards, international airline alliances	International coordination of operations and management of fleet operations may be required in the future.	33
OP2	Increased requirement for performance validation and self-checks in complex systems	X	X		X		X	X	X	X			2003	contents of ops/flight manuals	The possible lack of resources for Independent Verification and Validation (IV&V) of increasingly complex critical software/hardware systems may introduce possible safety hazards.	34
OP3	Increasing complexity of regional jets	X	X		X		X	X	X				2005	contents of type certificates, comparison of technical characteristics	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.	35
OP4	Increasing operation of aircraft at lower altitude and/or in adverse weather conditions	X	X		X	X	X	X	X		X		ongoing	ATC data	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.	36
OP5	Discrepancies in pace and approach in development and implementation of airborne vs. ground-based technology systems	X	X		X		X	X	X	X	X		1990 & ongoing	comparisons of demand vs. capacity, change in number and severity of ATC delays	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.	37
OP6	Increasing use of uninhabited aircraft for observation, atmospheric sensing, data communications, and possible cargo transportation	X	X		X		X	X	X	X	X	X	2005	demand for certification criteria for unihabited aircraft, applications for LUA approvals	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.	38
OP7	Increase in numbers of operational airships	X	X		X	X	X	X	X	X	X	X	2001	data from authorities and aeronautical organizations	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.	39

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OP8	Growth in the operations of freighter aircraft with increasingly variable cargo characteristics	X	X		X		X	X	X	X	X		ongoing	data from authorities and aeronautical organizations	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.	40
OP9	Increased numbers of high-speed, low-level flight operations	X	X		X		X	X	X	X	X		ongoing	ATC data	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	41
OP10	Additional ETOPS flights	X	X		X	X	X	X	X		X		ongoing	data from authorities	Economic pressures may result in Extended Range Twin-Engine Operations with increasingly longer time limits.	42
OP11	Very long-range operations	X	X		X	X	X	X	X	X			2002	manufacturer and authorities data	Flights greater than 7000 N.M may become increasingly more frequent.	43
OP12	Movement away from hub-and-spoke operations concepts toward alternate operational models	X	X		X	X	X	X	X	X	X		ongoing		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.	70

The Crew (CREW)		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Crew Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
C1	Introduction of new technologies with unforeseen human factors aspects	X	X	X		X	X	X	X		X		2003	human factors community, manufacturer representatives, application for certification for new equipment	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 that the pilot has seldom or never previously encountered. The latent flaw in the display, or primary flight control system may go undet	44
C2	Increasing level of information inequality in shared decision-making contexts	X	X	X			X	X	X				ongoing	qualitative comparisons between existing and proposed technologies	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.	45
C3	Increasing amount of information available to flight crew	X	X	X		X	X	X	X				2005	airline and pilots' association data	There may be an increased requirement for terrain, weather, and traffic situation awareness. However, since most aircraft may not have three displays, presentation of these data may be likely be hosted on a single display, and this brings a host of potential errors due to lack of effective information integration/monitoring. Too many modes of operation may be available leading to loss of awareness of the system status leading to mode confusion and distraction. "The gigantic scale of [seagoing] vessels creates an abstract environment in which crews are far removed from direct experience of the sea's unforgiving qualities and potentially hostile environment. Heavy automation undermines much of the old-fashioned vigilance and induces engineers to lose their occupational instincts. Qualities that in earlier days of shipping were an invaluable safety factor." from 'Supership' by Neal Mostert	46
C4	Introduction of artificial intelligence	X	X	X		X	X	X	X	X	X	X	2010	application for certification	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.	47
C5	Gap between skills, abilities, and attitude toward technology and automation of future crew members and the past design philosophies used in development of present aircraft	X		X			X	X	X				2000 & ngoing	manufacturere, airline, and pilots' association data	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.	48

	The Crew (CREW)	MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Crew Category	
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C6	Shift in responsibility for collision avoidance from ATC to crew	X		4			2	3	4	1		X	2005	new regulations and self-separation procedures	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	49
C7	Obsolescence of current training methodologies for operation of advanced aircraft			X			X	X	X	X			2000	flight training school & aircrew performance data	Current check-and-training systems developed to maintain flight standards on earlier generation aircraft may not necessarily cover all issues relevant to operation of advanced aircraft. There may be an increasing need to develop error tolerant crew procedures and implement new crew resource management training enabling co-pilots to switch from "assist" to "prevent" mode in critical situations. With the introduction of new aircraft capable of very long haul flights there may be very few landings are made by one pilot in a given period (say one month) with possible adverse safety consequences. Fidelity of simulator envirionment to actual operational environment may be inadequate for many flight regimes.	50
C8	Decreasing level of average pilot airmanship	X	X	X		X	X	X	X	X			ongoing	flight training school & airline data	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	51
C9	Greater reliance on civilian-trained crews			X			X	X	X	X			ongoing	authority & aeronautical organization data	Primarily a U.S. phenomenon, and probably not an issue for Europe and other international regions.	52
C11	Unresolved cultural aspects of Crew Resource Management (CRM)	X	X	X			X	X	X				ongoing	accident/incident database	In certain cultures, the problem of over-acceptance of pilot authority may also be a problem.	54
C12	Increased instances of mixed crew flights.			X			X	X	X	X	X		ongoing	airline & pilots' association data	Language, culture, and gender issues.	55
C13	Possible requirement for psychological screening of flight crews			X			X	X	X	X			2005	proposed new regulations	Need to identify preventive measures in the event of pilot suicide.	56
C14	Possible economic, operational, and safety requirement to achieve best crew mix			X			X	X	X	X	X		ongoing	proposed new regulations	Some studies show that Crew Resource Management works best in mixed, male-female crews because of subtle differences in decision making approaches between the two genders. Screening of flight crews for psychological compatibility/stability may be demanded in the future in certain regions	57
C15	Increasing life expectancy for crew members			X			X	X	X	X	X		ongoing	airline, medical & pilots' association data	Need to reconcile the complex issues raised by the fact that pilots and cabin attendants are living longer and maintaining skills and proficiencies into later years.	58
C16	Introduction of new prescription and over-the-counter medications			X		X	X	X	X	X	X		ongoing	medical association data	Need to identify unknown primary and secondary interaction effects of new and existing medications on flight crew performance.	59
C17	Changing working environment for cabin crew	X		X		X	X	X	X	X			ongoing	airline & flight attendants' association data	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.	60

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		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE			
C18	Increasing radiation exposure	x		x				x	x		x		ongoing	airline, medical & pilots' association data	Single four-hour stratospheric flight provides radiation dosage equivalent to a chest x-ray.

The Passenger (PASS)		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Passenger Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
P1	Trend toward increasingly aggressive/assertive behavior	X		X	X		X	X	X	X	X		1998 & ongoing	airline data	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. http://www.detnews.com/menu/stories/48198.htm	61
P2	Introduction of unique psychological, medical and security passenger considerations for new aircraft types	X	X	X	X		X	X	X	X	X		ongoing	manufacturer studies	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.	62
P3	Increasing public pressure for improved cabin environment	X	X	X	X		X	X		X	X		ongoing	airline data	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 priviledges.	63
P4	Introduction of additional passenger amenities	X	X	X	X		X	X		X	X		ongoing	airline data	Sleeper berths, entertainment and communication systems, rest/exercise areas, etc.	64
P5	Introduction of supplementary passenger protection and restraint systems	X	X	X	X		X	X					2005	availablilty of technology, proposed regulations	Passenger airbags, smoke hoods, etc.	65
P6	Increasing number of elderly passengers	X		X	X		X	X		X	X		ongoing	airline & transportation survey data	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?	66
P7	Increasing use of personal electronic devices	X	X	X	X		X	X			X		ongoing	airline data, cabin crew observations	Potential problem of future computers or devices with send/receive wireless communications capability that may almost never be switched off.	67

The "Organization" (ORG)		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Organization Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
OR1	Increasing economic incentives to outsource organization activities		X	X	X	X		X			X		ongoing	airline data	Maintenance, training, reservations services, etc.	**68**
OR2	Introduction of "virtual oganization" operations concepts	X	X	X	X	X		X	X	X	X		ongoing	airline & authority data	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.	**69**
OR3	Shift away from clear lines of authority and command toward dilution of responsibilities within airlines		X	X	X			X	X	X	X		ongoing	airline data	In a rapidly changing environment an understanding of organizational trends is required to facilitate the choice of more effective management solutions which may involve complicated interactions among people, materials, and financial arrangements.	**71**
OR4	Emergence of low-cost organization/airlines	X	X	X	X	X		X	X	X	X		ongoing	airline & authority data	Cut price airlines in the US and Europe, built primarily on the leisure market, are beginning to make 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. http://www.airwise.com/features/airlines/lowcost.html	**72**
OR5	Increasing corporate and individual liability with each successive accident	X	X	X	X	X		X			X		ongoing	new legislation or judicial precedents	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.	**73**
OR6	Increasing privatization of government services such as ATM and airports	X	X	X	X	X		X	X	X	X		ongoing	authority data & proposed regulations	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. http://www.rppi.org/opeds/tcontrol.html	**74**

The "Authority" (AUTH)		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Authority Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
AU1	International standardization of requirements and procedures	X	X	X	X	X	X		X	X	X	X	ongoing	emerging regulations	Failure to adopt consistent standards and conventions in the face of globalization and centralization within and across organizational/international boundaries may create future problems.	75
AU2	Increasing delegation of responsibility from the authority to the organization	X	X	X	X		X		X	X			ongoing	emerging regulations	New approaches to certification and transfer of responsibilities to cognizant international organizations may take place in the future.	76
AU3	Emergence of new regulatory philosophies and safety/risk management systems	X	X	X	X		X		X	X	X	X	ongoing	emerging regulations	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	77
AU4	Possible privatization of government ATC systems and airports			X	X	X	X		X	X			ongoing	authority data & prposed regulations	When private contractors manage individual towers, upgrades will be at their discretion. In the patchwork of private employers, there's no guarantee that critical systems will be compatible, which could cause serious problems when controllers transfer control of aircraft from one section of airspace to another. http://home.natca.org/natca/mediaandpublicrelations/nbba8_99.html	78

Air Navigation System (ANS)		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Air Navigation System Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
ANS1	Emergence of new concepts for airspace management	X	X	X	X	X	X	X		X	X	X	2005	proposed regulations & legislation, revised equipment requirements	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.	79
ANS2	Increasing number of aviation operations	X		X	X	X	X	X		X	X		ongoing	ATM data & ATM 2000 strategy	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	80
ANS3	Increase in air traffic flow management (ATFM) technology development activities		1	X	X	X	X	X		X	X		ongoing	ATC data	In response to technological developments and user concerns, ATFM will probably move toward partial decentralization. http://www.informs.org/Conf/WA96/TALKS/SE15.1.html	81
ANS4	Increasing requirement for centralized control of ATM	X		X	X	X	X	X		X	X		ongoing	proposed regulations & legislation, revised equipment requirements	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.	82
ANS5	Decreased separation standards	X	X	X	X		X	X		X	X		ongoing	proposed regulations	Between runways, between aircraft, between landing operations, RVSM reductions?	83
ANS6	Increasing operations of low-technology aircraft in ATM environments featuring advanced capabilities	X	X	X	X		X	X		X	X		ongoing	ATM data, capacity limited by lowest level of fit, propsed technical standards	Although opinion polls demonstrate that the public has confidence in the safety of the 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 systesm 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	84
ANS7	Introduction of new technologies with unforeseen human factors aspects	**x**		**x**	**x**		**x**	**x**						human factors community, manufacturer representatives	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.	
ANS8	Increasing level of information inequality in shared decision-making contexts	X	X	X			X	X					ongoing	qualitative comparisons between existing and proposed technologies	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 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.	
ANS9	Increasing amount of information available to ATM personnel	X	X	X		X	X	X					2005	ATM and controllers' association data	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.	

Air Navigation System (ANS)		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Air Navigation System Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
ANS10	Decreasing ATM equipment design and operational expertise	x		x	x			x		x			ongoing	ATM data, certification criteria, proposed technical standards	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 modernization. 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.	
ANS11	Gap between skills, abilities, and attitude toward technology and automation of future air traffic controllers and the past design philosophies used in development of present ATM systems	X		X			X	X					2000 & ngoing	manufacturere, ATM, and controllers' association data	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.	
ANS12	Increasing variation of sophistication of hardware and software within the ANS system		X	X	X		X	X					1990 & ongoing	introduction of advanced ANS hardware and software systems	The proliferation of new software and technology systems may complicate maintenance, drive up costs, preclude software reuse, and increase training requirements and the potential for human error. These systems may be characterized by a lack of a unifying technical architecture as well as different or incompatible communication protocols/data formats, and user interfaces.	
ANS13	Increasing need for maintenance of complex, integrated ANS systems		X	X	X		X	X					ongoing	ATM data & ATM 2000 strategy	Maintenance of next-generation ground-based hardware and software systems may require greater care and verification once completed.	
ANS14	Decreasing maintenance expertise required for state-of-the-art ANS systems	X		X	X	X	X	X			X		ongoing	data from authorities and aeronautical organizations	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.	
ANS15	Increasing reliance on out-dated equipment	X	X	X	X		X	X		X	X		ongoing	maintenance data	Within such a large and complex system we can assume that equipment will wear out or become outdated, and that the the problem may be compounded by slow or incompetent response by both government and private sectors. However, on what basis does the travelling public care that a controller's radar display does not contain the processing power of a personal computer (which may not need)? And why is it perceived as a system shortcoming that backup flight information is still written out on strips of paper?	85
ANS16	Increasing reliance on satellite-based systems for CNS functions	X	X	X	X	X	X	X		X			2005	ATM data, certification criteria, proposed technical standards	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. http://www.cas.honeywell.com/ats/products/cns.html **The much more accurate positioning of aircraft in the airway 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**	86
ANS17	Increasing dependence on secure data links for performing ATM/CNS functions	X		X	X		X	X		X			2005	ATM data, certification criteria, proposed technical standards	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. http://www.arinc.com/About/Press_Releases/05-14-99.html	87
ANS18	Increasing use of ATM warning and alert systems		X	X	X		X	X		X			ongoing	introduction of advanced ANS hardware and software systems	Advanced digital audio and warning systems in ATM environments may change controller workload and situational awareness.	

Air Navigation System (ANS)		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Air Navigation System Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
ANS19	Increasingly complex interactions among highly-automated ground-based and flight-deck systems	X	X	X	X	X	X	X		X			2005	ATC data, certification criteria, proposed technical standards	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 overall systems performance.	**88**
ANS20	Introduction of artificial intelligence	X	X	X	X	X	X	X		X			2010	ATC & manufacturer data, application for certification, propsed technical standards	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.	**89**
ANS21	Discrepancies in the pace and direction of development of ground vs. in-flight CNS systems	X	X	X	X		X	X		X			ongoing	ATC & manufacturer data, air/ground conflict resolution data	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.	**90**
ANS22	Evolution of Flight Management System databases	X	X	X	X		X	X		X			ongoing	manufacturer and authority data	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	**91**
ANS23	Increased requirement for coordination with military flight operations			X	X		X	X		X		X	2005	propsed regulations & data from authorities	Situations in the U.S. and in Europe may be quite different. A critical issue may be detection and avoidance of low-observable military aircraft by civilian ATM systems.	**92**

Airport (AP)		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Airport Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
AP1	Increased demands on airport and community infrastructure due to increased traffic	X		X	X	X	X	X	X		X		ongoing	authority data	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.	**93**
AP2	Introduction of new surface traffic flow management technologies	X		X	X	X	X	X	X		X		2005	data from aviation research organizations	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.	**94**
AP3	Changing characteristics of airport surfaces	X		X	X		X	X	X		X		ongoing	authority data & proposed new technical standards	New materials/compositions may be developed for runway, taxiway, and overrun surfaces in addition to improved runway surface friction management techniques.	**95**
AP4	Trend toward siting of runways adjacent to bodies of water	X		X	X		X	X			X		ongoing	authority data & proposed new airport projects	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. http://birdstrike.org/risk/birdrisk.htm	**96**
AP5	Increasing requirements for improved security	X	X	X	X	X	X	X			X		ongoing	authority data & proposed new security regulations	Screening of ground personnel, baggage, etc.	**97**
AP6	Increasing intensity of aviation operations at smaller, outlying airports			**x**	**x**		**x**	**x**	**x**		**x**		ongoing	authority data & proposed new regulations	Additional operations at airports which have had patterns of low utilization may create unanticipated issues related to local noise and atmospheric pollution as well as local land use.	
AP7	Increasing airport modifications required to permit operation of new aircraft types			**x**	**x**	**x**	**x**	**x**	**x**		**x**		ongoing	authority data & proposed new aircraft	Future aircraft such as Very Large Aircraft may require longer runways, provision for increased turning radii, and alternative approaches to passenger and baggage handling. Vehicles such as tilt-rotors may require fundamentally different terminal design especially if these vehicles are permitted to use rooftop landing areas.	

	The "Environment" (ENV) or "Aviation Context"	MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE: A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE	ONSET TIMEFRAME	VALIDATION TOOL	Comments on Environment Category	
E1	Increased pressure to improve aviation system throughput and flight safety	X	X	X	X	X	X	X	X	X		X	ongoing	media, ground delay measures	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.	98
E2	Increased use of linked, intermodal transportation systems	x	x	x	x	x	x	x	x	x					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	
E3	Change in public perceptions of aviation safety/liability and changes in judicial and legislative attitudes.	X	X	X	X	X	X	X	X	X		X	ongoing	media, political activity	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. An ancillary effect may be pressure to adopt politically expedient but inappropriate safety interventions.	99
E4	Reduction in public funding for ATM/CNS services			X	X	X	X	X	X	X			ongoing		May not become an issue.	100
E5	Increased pressure to assess user fees within U.S. aviation system to recover costs of operation of privatized entities			X	X	X	X	X	X	X			ongoing	FAA	A user fees system comparable to those constructed in Europe and Canada may affect aviation businesses and the safety of operations in American skies. Fees for common services such as landings, approaches, weather reports, flight plans, and certification, may provide a disincentive not to utilize those measures to ensure safe operations.	101
E6	Obsolescense of hardware and software systems in use both on the ground and in the air as well as space-based systems.	x	x	x	x		x	x	x	x		x	ongoing		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.	
E7	Reduction of the market share of specialized hardware and software products utilized by aviation	x	x	x	x			x	x	x			ongoing		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 industry may have a more difficult time obtaining the necessary componentry at favorable prices.	
E8	Increasing use of Commercial Off The Shelf (COTS) products in aviation	x	x	x	x		x	x	x	x			ongoing		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.	
E9	Rapid pace of software and technology development	x	x	x	x		x	x	x	x			ongoing		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.	
E10	Proliferation of hardware and software tools to monitor performance of aviation system	X	X	X	X	X	X	X	X				ongoing		Increased need to monitor incident and accident precursor trends and identify non-standard performance.	102

	The "Environment" (ENV) or "Aviation Context"	MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Environment Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
E11	Increasingly stringent noise constraints	X	X	X	X	X	X	X	X	X			ongoing	media, regulations, ICAO rule changes & proposed new	Aircraft noise and emissions concerns may become the most important strategic obstacles for future development of air transport. Local community restrictions on airport noise may restrict ground-test run-ups of engines following repair or maintenance with possible adverse effects on safety.	**103**
E12	Increasingly stringent emissions constraints	X	X	X	X	X	X	X	X	X			ongoing	media, regulations, ICAO rule changes & proposed new	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.	**104**
E13	Change in fuel composition	X	X	X	X	X	X	X	X	X			2005	oil company data, propsed new standards	Global environmental and safety concerns may require use of alternative fuels to address emisions and volatility concerns.	**105**
E14	Increasing requirement for harmonization of cultural diversity among operators of aviation system	X	X	X	X	X	X	X	X	X			ongoing	policies of international bodies	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.	**106**
E15	Increased economic globalization	X	X	X	X	X	X	X	X	X		X	ongoing	media, signs of conflicting regulatory requirements, economic statistics	International air transport is a world system and continuing air transportataion 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.	**107**
E16	Increasing trend toward mergers and corporate consolidations	X	X	X	X	X	X	X	X	X		X	ongoing	media, economic & related statistics	Shareholder pressures to improve profit margins may force adoption of new, consolidated corporate structures.	**108**
E17	Changing labor/management relations	X	X	X	X		X	X	X	X		X	ongoing	media, data from national aeronautic authorities/organizations	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.	**109**
E18	Increasingly rapid and widespread distribution of information	X	X	X	X	X	X	X	X	X			ongoing	media	Free-flowing information may increase vulnerability of information technology systems and require adoption of new data protection strategies.	**110**
E19	Selective denial of CNS accuracy by governments	**x**		**x**	**x**		**x**	**x**	**x**	**x**				government policy	Failure of the governmental entities to announce activation of Selective Availability may compromise safety for a broad range of aviation operations.	
E20	Increased vulnerability of data links to security breaches or data transmission failures	X	X	X	X		X	X	X	X		X	ongoing	manufacturer data	Increased likelihood of jamming resulting in loss of RF signals used for critical CNS functions and FADEC operation	**111**

The "Environment" (ENV) or "Aviation Context"		MATRIX OF AFFECTED CATEGORIES OF AREAS OF CHANGE											ONSET TIMEFRAME	VALIDATION TOOL	Comments on Environment Category	
		A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE				
E21	Increased likelihood of hostile acts against air- and ground-based elements of the aviation system	X	X	X	X	X	X	X	X	X		X	ongoing	media & government sources	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. Vulnerability to jamming and high-energy radiated fields may become an issue in the future.	112
E22	Revolutionary scientific advances	X	X	X	X	X	X	X	X	X		X	ongoing	consensus from scientific groups, research reports	Full-surface laminar flow, MEMS flow control technologies, adaptive flight surfaces, all-composite aircraft, ground-to-air power transmission, etc.	113
E23	Decreasing commitment to basic research and technology development in both government and private sectors	x	x	x	x		x	x	x	x			ongoing		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	
E24	Effect of "political opportunism" on aviation	x	x	x	x		x	x	x	x			ongoing	policies of individual states and international bodies	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.	
E25	Reduction in public funding for safety research	x	x	x	x	x	x	x	x	x				government and safety institute data	It is estimated that the funding for aviation safety related research has been cut by half in the past ten years.	
E26	Potential disruption resulting from unstable capital markets		x	x			x						ongoing	financial sector data	Volatility of hi-tech and particularly e-stocks have defied all the conventional wisdom about price/earnings ratios. The aviation industry is highly dependent upon the products from the technology sector.	
E27	Impact of characteristics of the software industry	x	x	x	x		x	x	x	x			ongoing		Rapid turn-over of technologies with little long-term product support.	
E28	Increasing criminal liability leading to protective measures against an efficient safety system	x	x	x	x		x	x	x	x			ongoing	legislatative action	Reduced pace of research in order not to uncover possible defects, hiding accountabilities, etc.	
E29	Decreasing aircraft design and operational expertise		X	X	X	X	X	X	X				1985 & ongoing	data from authorites and aeronautical organizations, ATR72/Roselawn & SF340/Schipol events	The knowledge of why aircraft are designed as such, how key maintenance is to be performed, and and why the operational rules are as they are is being lost due to long product design cycle times and extended product life. Unforeseen uses of the product (such as operation at higher load factors) 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 design tools such as Computer-Aided Design must be used with care since in most cases these tools have narrow functionality (such as structural design) and do not model the full physics of the systems being modelled. Artificial intelligence may be useful for providing design data bases containing previously successful design details and principles.	27
E30	Economic pressures to reduce the authority of the pilot in command vis a vis dispatch		X	X			X	X	X	X			ongoing	airline & pilots' association data	Economic pressure by airline operators to strive for maximum economy by reduction of fuel loads below what pilot wants to accommodate changes in flight path due to weather or for diversion to alternate airports. This may be more of an issue in some parts of the world than in others.	53

	The "Environment" (ENV) or "Aviation Context"	A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE	ONSET TIMEFRAME	VALIDATION TOOL	Comments on Environment Category	
E31	Changing cultural awareness of safety and roles of safety assurance personnel within user community	X		X	X	X	X	X	X	X			ongoing	accident/incident reports	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 value which will provide the underlying logic directing all members'	30

	Space Operations (S)	A/C	MRO	OPS	CREW	PASS	ORG	AUTH	ANS	AP	ENV	SPACE	TIMEFRAME	TOOL	Comments on Space Category	
S1	Introduction of new space vehicles	X	X	X	X	X	X	X	X	X	X		2010	NASA, FAA, JAA	The operational characteristics of future space vehicles may require operators of wing-borne vehicles to adopt different ATM approaches.	114
S2	Development of standards and certification for space vehicles	X	X	X	X	X	X	X	X	X	X		ongoing	NASA, FAA, JAA	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.	115
S3	Increasing frequency of commercial and government space vehicle traffic			X	X	X	X	X	X	X	X		2005	NASA, FAA, JAA	Rapid, routine clearances for penetration of flight levels (typically utilized by commercial aircraft) may be rquired by expendable launch vehicles, re-usable launch vehicles, and commercial space operations. Wing-borne space vehicles may require re-entry trajectories that can be predicted accurately even in emergency situations. These procedures will need to be coordinated with destination and alternate airports. In addition, special operational procedures may be required for penetration of restricted airspace in both normal and abnormal situations.	116
S4	Introduction of space tourism and accompanying safety/reliability considerations	X	X	X	X	X	X	X	X	X	X		2010	NASA, FAA, JAA	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 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. http://www.gwu.edu/~spctour/market.html	117