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Abstract

This study was conducted to identify existing work, material, practices and standards related to aviation safety minima and Target level Of Safety, which are being commonly used by the aviation community.

The ultimate objective of this study is to provide for a factual set of information in a summarised form, useful to refer to when developing an ATM Risk Model through which the relationship of ATM to the risk of aircraft accidents and incidents could be established and which would permit the setting of ATM minimum acceptable levels of safety (or safety minima for ATM) in a total aviation context.

Keywords

SAFETY REGULATION	SAFETY MINIMA	HAZARD	RISK
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DOCUMENT APPROVAL

The following table identifies all management authorities who have successively approved the present issue of this document.

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The following table records the complete history of the successive editions of the present document.

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0.02	19/11/99	Draft Issue- Taking into consideration comments received from: ❑ Swedish CAA ❑ French DGAC/CENA ❑ SRU staff	Sections 1.1.1, 3.3.2, 3.3.3 and 4.2
0.03	26/11/99	Draft Issue- Taking into account comments from head of SRU. Circulated for review and comments to SRC.	Sections 1.1.3, 1.3.11.4.23.1.7, 3.1.83.1.10, 3.1.12, 3.2, 3.3.2, 4.2
0.04	10/10/00	Draft issue- Updates to make the document current. Added information about proposed amendments to ICAO Annex 11 and PANS RAC. Added sections on JAA AMJ 25-11. Added a section on practices in Australia.	Addition of new sections 3.1.4 till 3.1.7 3.1.18 and 3.1.20/3.1.21
1.0	20/12/00	Incorporates comments received from SRC. Released Issue	Editorial modification in sections 1.1.4 and 2.1.7. Addition of reference to ESARR 4 SRC POL DOC 1 in foot notes.

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EXECUTIVE SUMMARY

1. EUROCONTROL have set up a Safety Regulation Commission (SRC), supported by the Safety Regulation Unit (SRU), who is responsible for the development of harmonised EUROCONTROL safety regulatory objectives and requirements for the Air Traffic Management (ATM) System. The SRC has identified a number of tasks to be undertaken as a priority, two of them being related to the development of, on one hand, **safety minima in ATM**[1] and, on the other hand, **a risk classification scheme** to support the setting of safety requirements for modifications of existing elements of the overall ATM System[2].

2. The SRU has undertaken some research activities to contribute to the establishment of a framework for the regulation of ATM in Europe. As part of the framework, this study was conducted to identify existing work, material, practices and standards related to aviation safety minima and Target level Of Safety, which are being commonly used by the aviation community.

3. The ultimate objective of this study is to provide for a factual set of information in a summarised form, which will be useful to refer to when developing an ATM Risk Model through which the relationship of ATM to the risk of aircraft accidents and incidents could be established and which would permit the setting of ATM minimum acceptable levels of safety in a total aviation context.

4. Current and future Work in that area consists in deriving a substantiated framework for ATM safety minima and for risk classification to support the setting of Safety Requirements for the provision of new, or modification of existing, elements of the overall ATM System. It is intended that this be achieved through the following:

   a) Establishment of an ATM Severity Classification Scheme;

   b) Establishment of appropriate Probability Criteria, quantitative, to establish the unacceptable/tolerable risk boundary in ATM;

   c) Establishment of guidance material for the implementation of a risk assessment and mitigation process in ATM, as well as to apportion risks in ATM .

   It is intended that this work gives full consideration to the work on-going within the EUROCONTROL Agency Safety Group and relies upon a representation of the different perspectives taken of ATM in the consideration of collision avoidance safety measures (e.g. maintaining separation between aircraft, between aircraft and the ground, and between aircraft and objects).

[1] Including airborne and ground elements.(Refer to SRC POLICY Doc 1)
[2] Including the CNS **elements considered as the enabling techniques/infrastructure.** (Refer to ESARR 4)

1. INTRODUCTION

1.1 Background

1.1.1 EUROCONTROL have set up, under the revised convention, a Safety Regulation Commission (SRC), who is responsible for the development of harmonised safety regulatory objectives and requirements for the Air Traffic Management (ATM) System, which will be implemented and enforced by the EUROCONTROL member states. The SRC is supported by the Safety Regulation Unit (SRU). The SRC will develop objectives for the safety regulation of ATM, prepare harmonised safety regulatory requirements and standards, develop harmonised processes for approval and oversight of ATM and finally monitor the application and uniform implementation by the member states of the safety regulatory requirements.

1.1.2 The SRU has undertaken research activities to contribute to the establishment of a framework for the safety regulation of ATM within the ECAC area. As part of this framework, it is intended that SRC establishes a model of ATM, through which the relationship of ATM[3] to the risk of an aircraft accident/incident can be defined. Indeed, the SRC has identified a number of tasks which need to be addressed as a priority, two of them being related to the development of, on one hand, **safety minima in ATM** and, on the other hand, **a risk classification scheme[4]** to support the setting of safety requirements for modifications of existing elements of the overall ATM System[5].

1.1.3 Given the current and anticipated future increase in the volume of air traffic over the next decade, concern has been raised that simply maintaining the current accident rate (in terms of flight hour) will lead to an unacceptable increase in the number of incidents and accidents, with likely detrimental consequences on civil air transport. It is therefore considered essential to achieve a decrease in the overall accident rate sufficient to offset the effect of rising traffic levels. This may require all contributors to the overall aviation risk, including ATM, to decrease their absolute contribution, noting that the absolute contribution may only be maintained in the short term. This desire is reflected in the safety objective in the EUROCONTROL Air traffic Management Strategy for 2000+, which states “that the number of ATM induced accidents and risk bearing incidents do not increase and, where possible, decrease”.

[3] Including its supporting infrastructures Communication/Navigation/Surveillance.
[4] Refer to ESARR 4 “Risk assessment and mitigation in ATM”;
[5] The Current SRC/RTF definition of ATM does not include the CNS part. However, the TLS/Safety Minima to be considered by the SRC is not restricted to the human and procedures elements of the ATM system but should also include the supporting techniques and infrastructure being considered under CNS.

1.1.4 In order to achieve this, it has been necessary to understand the contribution of ATM to aircraft accidents/incidents, such that appropriate safety objectives and requirements can be set and monitored. Some useful information can be found in the EUROCONTROL SRC study report '*Aircraft Accidents/Incidents and ATM contribution*'[6] which relies on a review and analysis of historical data. In addition, it is intended that safety trends, key risk areas and ATM involvement in accidents and incidents be more consistently monitored in the future, when the EUROCONTROL Safety Regulatory Requirement '*Reporting and Assessment of Safety Occurrences in ATM*'' (ESSAR2) with related EUROCONTROL Agency standards and Guidance Material are implemented across the ECAC region.

1.1.5 Given that the aviation community has been using specific ATM models and related safety minima and/or Target levels Of Safety for some time, it has been necessary to understand, for each existing TLS or Safety Minimum, the rationale and assumption behind its development, as well as its scope, to better anticipate any limitation in applicability that SRC ought to be aware of when setting safety minima objectives in ATM.

1.1.6 Such information can be found in this report:- '*Air Traffic Management-Safety Minima Study/Review of existing material'*. The ultimate objective of this study is to provide for a factual set of information in a summarised form, which is considered as useful reference when developing an ATM Risk Model through which the relationship of ATM to the risk of aircraft accidents and incidents could be established and which would permit the setting of minimum acceptable levels of ATM safety (safety minima) in a total aviation context.

1.1.7 The expectation is that an ATM Risk Model[7] will facilitate the derivation of appropriate Safety Requirements for those parts of the ATM System (encompassing equipment, people and procedures) that are subject to change, whether by modification to existing systems, or by the introduction of new parts to the system. These Safety Requirements can then be developed and applied to European projects, such as ARTAS, EFDP, GNSS, RVSM and 8.33kHz, responsible for implementing the changes as well as to other national developments.

[6] SRC DOC 2- Ed. 1.0
[7] Consistent with ESARR 4 "Risk assessment and Mitigation in ATM".

1.2 Objective of the Study

1.2.1 The objective of this Study was to review and summarise existing models, practices and standards setting Target level of safety for ATM and/or ATM safety Minima. The set of factual information of this study is intended to support the establishment of a substantiated framework for ATM safety minima and for risk classification to support the setting of Safety Requirements for the provision of new, or modification of existing, elements of the overall ATM System[8].

1.2.2 The review of existing standards was to enable identification of any limitation in the scope, or rationales/assumptions in the development of existing safety minima/TLS in order to support SRC in the setting of Safety Minima in ATM[9] and in the development of a Risk/Hazard Classification Scheme in ATM.

1.3 Scope of the Study

1.3.1 The scope of the study encompasses the complete ATM System**, including equipment, people and procedures** (i.e. the CNS/ATM system), that supports the safe and expeditious management of civil air traffic Gate to Gate. In this context, ATM is intended to prevent the following basic accident[10] types leading to the loss of one or more aircraft and/or multiple (fatal) injury to occupants:-

a) collision between aircraft in flight or moving on the ground

b) collision between aircraft and the ground

c) impact between aircraft and other avoidable airborne object (e.g. missile, birds)

d) impact between aircraft and other avoidable ground based object (e.g. vehicle, physical structure)

e) loss of control/catastrophic degradation of aircraft ability to fly resulting from an avoidable external influence such as:

- severe meteorological conditions (e.g. wind shear, turbulence, storms)
- wake vortex or jet wash

1.3.2 It should be noted that this interpretation of an accident encompasses the ICAO definition of accident (see Appendix B), although expanding upon the basic concept established[11].

[8] Refer to ESARR 4 “Risk Assessment and Mitigation in ATM”
[9] Refer to SRC Policy DOC 1 “ECAC safety Minima for ATM”
[10] Refer to the ICAO definition of accident in Annex 13
[11] A risk assessment and mitigation process needs to anticipate the severity of effects of identified hazards taking into account the worst case scenario.

1.3.3 The functions or elements that make up the ATM System are varied, although fundamentally consisting of:-

- the provision of current aircraft and environmental information to a Controller such that he can manage the air traffic situation;
- a means of communication between Controllers and Pilots; and
- the means for Pilots to comply with control instructions.

1.3.4 A more specific breakdown of the ATM System can be viewed in terms of the basic functions required to facilitate the control and management of Air Traffic. A description of these functions is provided in Volume 1 of the document "Overall CNS/TM Architecture for EATCHIP" with further description of the identified function blocks provided in its Volume 2 Annex A.

1.3.5 Finally, it is stressed that the scope of this study is to provide a set of baseline information to ultimately support for the derivation of ATM Safety Minima for use by the ATM Community and more specifically the SRC, when developing harmonised regulatory views on the acceptability of changes to the ATM system.

1.4 Limitations

1.4.1 The immediate scope of the study is ECAC airspace, although this is likely to be applicable to much of the rest of the world, where Air Traffic Control using ground based infrastructure is employed.

1.4.2 The focus of this study is ATM applied to General Air Traffic (GAT). It is however noted that Military operations (Operational Air Traffic: OAT) influence ATM provided to GAT through their interaction with civil flights, but operations involving only OAT or only OAT and services provided by military organisations are not encompassed.

1.4.3 The study considers the existing material and standards, and seeks to take account of known current developments and best practices. It is noted that the study output will need to be reviewed and updated as necessary in the light of future developments.

1.4.4 The study does not consider all national models, standards or practices as they were not all available to SRU. It is noted that the study output will need to be reviewed and updated as necessary in the light of future knowledge and/or developments.

2. APPROACH

2.1 Methodology

2.1.1 This study relies significantly on the results of a Contract Study managed by SRU, with support from the Agency/SQS and from the DFS (Germany).

2.1.2 The initial activity undertaken for this study was to gather data and references pertinent to the study objectives, in particular related to the use of and derivation of Aviation or ATM risk targets (or TLS), and collision risk modelling. A variety of mechanisms were utilised to support this activity as follows:

a) Search through the Contractor library of safety publications, documents and papers, in particular those specifically related to ATM;

b) Use of specific papers and documents collated by the SRU;

c) Key word search of general publications held at the UK CAA Library;

d) Topic and word based searches of the World Wide Web.

2.1.3 The results of this data gathering activity is presented in a Bibliography, which provides a reference to the material and also gives a brief summary of the information therein, as pertinent to this study. The Bibliography has been circulated to interested parties, including the SRC, for comment and to identify any additional material of note for consideration by the study. Limited feedback was provided, as a result of which a limited number of additional items were encompassed by the study.

2.1.4 Following the initial search and collation of reference material, some further publications and papers were gathered from various parties. Reference to this additional material was then incorporated into a final Bibliography, which is presented in Appendix A to this Report.

2.1.5 Review of the material, and meetings with appropriate experts has provided the source for the historical review of the establishment of safety/risk targets for aviation in general and certain aspects of air traffic operations, in particular related to general collision risk.

2.1.6 A Working Draft of the report has been circulated within EUROCONTROL (Agency/SQS and AMN) as well as to the national organisations which were mentioned in the report, namely France (DGAC/STNA), UK (NATS) and Sweden (LFV). Comments received were duly taken into account before a revised Draft was circulated to SRC (Ed. 0.03).

2.1.7 Additional information was collected from the JAA, CASA and ICAO. This led to the production of a revised version of SRC DOC 1 (Ed.0.04), submitted to SRC for comments.

2.2 Presentation of Study Results

2.2.1 Section 3: “Aviation & Air Traffic Management Target Levels of Safety” summarises the processes employed in the past or current best practices to derive TLS, apply risk assessment and considers the units of measure that are employed.

2.2.2 Section 4 “On Going and Future Work: ATM Risk Model” summarises probable orientations in the Future Work which remains to be completed to set safety minima in ATM and to develop a related risk model.

2.2.3 Section 5 provides for the list of References used in this study.

2.2.4 Annex A provides a General Bibliography.

2.2.5 Annex B provides a definition of Terminology.

2.2.6 It should be noted that within this Report, quantitative results are expressed using standard UK numeric notation, in other words using ‘,’ as thousands delimiter and ‘.’ as delimiter for decimals. In addition, from a terminology perspective, this study has used ‘Target Level of Safety’ in referring to the Aviation domain, while ‘Safety Minima’ is used in the ATM domain.

3. AVIATION AND ATM TARGET LEVEL OF SAFETY

3.1 Existing TLS Derivation Processes

3.1.1 The setting of a Target Level of Safety (TLS) for aviation as a whole has historically been driven by the desire by airworthiness authorities to place quantified targets upon the contribution made by aircraft systems to aircraft accidents. In Europe, the setting of such targets has been undertaken by the Joint Aviation Authorities (JAA), and elaborated in the Joint Aviation Requirements (JAR-25 'Large Aeroplanes', i.e. greater than 5,700 kg Certified Take Off Weight, paragraph 1309).

3.1.2 The Advisory Material Joint (AMJ) associated with JAR 25.1309, identifies that historical evidence (in practice 1960's accident data) demonstrated the accident rate attributable to 'operational and airframe-related causes' to be of the order of 1 per million (10^6) flight hours. Furthermore it is identified that about 10 percent of the total can be attributed to failure conditions caused by the aeroplane's systems. This results in the design requirement for new designs such that the probability of a serious accident from all aircraft system Failure Conditions be not greater than 1 per ten million flight hours, or 1×10^{-7} per flight hour. The remaining 90% relate to other operational aspects, which include ATM along with other factors such as flight crew error, unavoidable meteorological conditions and aircraft maintenance.

3.1.3 Based upon this derived figure, and a working assumption that there are around 100 potential Failure Conditions that would prevent 'continued safe flight and landing', and assuming an equal apportionment of the overall target, the upper risk limit, or maximum probability of occurrence, for each Failure Condition would be 1×10^{-9} per flight hour. In terms of JAR-25.1309, this then establishes the lower limit for the 'Extremely Improbable' probability classification, associated with the Catastrophic category of effect. It is notable that these targets, despite being established in the 1960's are still current in the latest updates to the JAR 25, although there has been some debate over the continued applicability of the 100 Failure Conditions assumption, given the increased systematic complexity, hence potential for new Failure Conditions, of modern large aeroplane design.

3.1.4 JAA AMJ 25-11 includes a section which contains "General Certification Requirements". These considerations mostly relate to the display of some flight and navigation data in the cockpit. At least two functions dealt with in JAA AMJ 25.11 have a direct relationship with the Air Traffic Management System:-

- display of communication data; and
- display of navigation data**.**

Safety requirements are specified in this JAA document, based on the criticality of the data being displayed, assessed using AMJ 25.1309. Those requirements address both the loss of information and the display of hazardous misleading information.

These requirements were derived based on AMJ 1309 material and their essential objective is to ensure that the crew can operate safely the aircraft (“Flight Operations” perspective). No consideration is given to the effect of related hazards on the ability to provide safe Air Traffic Management in the airspace(s) (or classes of airspace) and associated environment(s) of operations where the aircraft will fly, hence to the potential target level of safety applicable to that airspace (or aerodrome).

3.1.5 AMJ 25-11 does not propose any rational for those requirements but does recognise that these safety requirements "may depend on the type of navigation system installed (on board and on ground installations) and the flight phase". JAA AMJ 25-11 does not assume anything else with regard to the ground communication and navigation performance, nor to any other characteristics of the environment(s) of operations envisaged. It however states that "previous certifications have shown that, in the traditional ATC environment, this level of safety has been achieved by simultaneous display of raw radio equipment data in addition to any multi-sensor commuted data".

3.1.6 AMJ 25.11 is currently being harmonised with AC 25.11 (FAA/JAA Avionics Systems Harmonisation Working Group). One of the issues is obviously the criticality of the displayed information and the link to ATM.

3.1.7 JAA Headquarters have undertook to document any ATM related assumption made during these criticality assessments as well as to re-assess if current AMJ 25-11 requirements are stringent enough to meet the quantitative safety objectives contained in ESARR 4 (EUROCONTROL Safety regulatory requirement: Risk Assessment and Mitigation in ATM’)[12].

[12] With rationale developed in SRC POLICY Doc 1.

3.1.8 The overall aviation and aircraft Failure Condition targets derived from the JAR have been used as the basis for TLSs applied to various risk classification schemes intended for use in the ATM environment. In particular, it has uniquely been applied as the TLS for the UK NATS 'Pilot Interpreted' and French CENA 'Airborne Components' risk classification scheme, i.e. those elements of ATM that directly impact upon aircraft operations. In addition, the TLS adopted by the Swedish ATM Safety Regulatory Authority , as proposed in their risk classification scheme, has overtly attempted to adapt the JAR 25.1309 targets to the ATM environment. These schemes could be proposed to be applied to the complete ATM System, encompassing equipment, people and procedures, and this approach is stressed by the NATS and Swedish schemes. It should be highlighted that they differ in that sense with the JAA scheme which is only related to **aircraft design** requirements, encompassing ONLY the aircraft equipment (hardware and software) for a certain category of aircraft.

3.1.9 The Swedish concept makes the ATM system safety objective comparable to the requirements for aircraft system in the JAR 25.1309, namely the probability for a 'catastrophe' (or serious accident) due to all failures of aircraft systems is less than 1×10^{-7} per flight hour. It is then assumed that a single control sector, or ATS unit, is on average responsible for 10 aircraft at any one time, and thus the concept arises that the probability of a catastrophe initiated by ATM in a single sector (or ATS unit) is less than 1×10^{-6} per 'operative' hour[13]. Corresponding higher probabilities are then allowed for less severe consequences. It is then identified that where a number of failure conditions can lead to the same consequence, the individual goal per failure condition will be proportionately more stringent. For example, should 10 failure conditions potentially lead to a 'catastrophe' then the individual failure condition goal would be 1×10^{-7} per 'working' hour.

3.1.10 Other approaches to deriving an ATM related TLS have been applied to Collision Risk Models (CRMs) which consider the ultimate loss of separation minima. A number of methodologies have been considered for determining the TLS based upon the consideration of accident statistics from aviation and other transport or public risk sectors. For example, various methods were considered by the ICAO Review of the General Concepts of Separation Panel (RGCSP), before finally deciding on use of a methodology based upon the estimation of the rate of fatal accidents involving jet aircraft; methods used include:

a) comparison of air transport with surface public transport

b) establishment of upper and lower limits on air transport risk as a proportion of whole population mortality rates due to all causes

c) comparison of Aircrew occupational air transport risk to other occupational risks experienced in other transport and public utilities.

3.1.11 The methodology finally selected by the RGCSP and since applied to other CRMs has been described in various papers over the years, although much of the original information has been derived from the ICAO Circular 120. An extensive summary of previous work performed on deriving a TLS for en-route collision risk is provided by a RGCSP Working Group paper written in 1995 (Réf: RGCSP/WG-A/WP8). Appendix A to this Report provides a bibliography of references identified during this study, including those relating to the topic of aviation and ATM Target Levels of Safety.

3.1.12 The method based on the consideration of the rate of fatal accidents involving jet aircraft was initially developed by the ICAO North Atlantic Systems Planning Group (NATSPG) during 1966 to 1968. The original NATSPG method and numerical data employed were as follows:

[13] Based on the assumption that 1) there is an equivalence between aircraft TLS expressed in terms of 'per flying hour' and ATC TLS, expressed in terms of 'per working hours' and 2) each aircraft is exposed to an equivalent level of risk.

a) Calculate the rate of fatal accidents for jet aircraft, per flight hour, for a chosen historical sample period. The total number of fatal accidents involving jet aircraft on scheduled air services from all causes was used for the original sample chosen to be from 1959 through 1966.

Based on a final figure of 36 fatal accidents and an estimate of 15.5 million flight hours, this gave rise to an estimated fatal accident rate from all causes of 2.34×10^{-6}.

b) Assign a proportion of the overall accident rate to collisions. A proportion was set at 1 in 10, i.e. a factor of 0.1, for accidents due to collisions, but the basis for assumptions is not evident or recorded. It is noted that an assumption was made that one collision equated to two fatal accidents. Thus the estimated rate of fatal accidents due to collision was assessed to be 2.3×10^{-7}.

c) Apply an improvement factor. To turn an estimated historical accident rate into a future target, it was considered that 'systems planing' should aim at improving the historic safety record. As such, an improvement factor was applied to the historic rate, which was initially chosen to be between 2 and 5 over a time period of 5 years. Thus a TLS in the range 12×10^{-8} to 4.6×10^{-8} fatal accident per flight hour due to collision arose.

d) Apportion the overall TLS to three flight dimensions. As the aim of the original process was to establish TLS for loss of lateral separation, i.e. to support the determination of North Atlantic Track separation minima, the overall TLS was divided into the three components of flight, Lateral, Longitudinal and Vertical. To achieve this it was assumed that the risk be apportioned equally between the three dimensions, thus giving rise to a TLS for collision due to loss of lateral separation, from all causes, in the range 4×10^{-8} to 1.5×10^{-8} fatal accidents per flight hour. However, here again, the basis or rationale for assumptions is not evident.

3.1.13 The basic method described above has been utilised over the past thirty years to derive revised TLS for North Atlantic and En-route airspace, and more recently for in the implementation of (for NAT), and planning for (en-route) reduced vertical separation. For each iteration, it has been necessary to change the base accident statistic to apply to the time frame and flight phase in question, and consider the appropriateness of the proportions and factors applied. A further enhancement has more recently been applied to establish targets into the 1980's. The modification has been to extrapolate the estimated accident rate due to collision into the future based on extrapolating forward the historic trends in aviation accident rates. This process removes the need to apply a discrete improvement factor in defining the TLS, as in step c. above.

3.1.14 It is noted that historically, the derived TLS and supporting models have fundamentally been derived for a specific subset of operations such as Oceanic and En-route, where the complexity of route structures is relatively low, largely based on parallel tracks and procedural control only is provided. These simple structures facilitate the modelling of aircraft track keeping ability within defined criteria, and with respect to target probabilities, utilising readily available historic data. The purpose of these models has been to establish the suitability of an aircraft (of any type), with a given avionics fit and performance capability, to fly in a given airspace and achieve a tolerable level of safety, as defined by the TLS.

3.1.15 A number of proposed and recommended TLS have been stated for adoption for developments to be implemented beyond the year 2000. Many of these are described in the RGCSP Working Group paper, and over-viewed in the more recent documentation listed in Appendix A. In general these proposals and recommendations for fatal accident risk, from all causes, fall into the range 2.5×10^{-9} to 10×10^{-9}, with a bias towards 5×10^{-9} per dimension, as indicated in Attachment B to the latest version of ICAO Annex 11.

3.1.16 In addition to the RGCSP methodology described above, other ICAO Panels have developed Collision Risk Models, with associated Target Levels of Safety, in particular the All Weather Operations Panel (AWOP) and Obstacle Clearance Panel (OCP). Whereas the RGCSP have considered the probability of accident, or collision risk, in the Oceanic and En-route environment, the AWOP and OCP have principally addressed the safety of aircraft during the Approach and Landing phases, with the OCP also concerned about missed approach paths below the Obstacle Clearance Altitude/Height (OCA/H).

3.1.17 The process of derivation of a TLS for all weather operations has most recently been documented in the report of the All-Weather Operations Panel (AWOP) 15th Meeting. The basis for the TLS is accident (Hull Loss) and operational statistics derived for the world-wide Commercial Jet fleet, excluding Turbo-prop aircraft. The statistics identify average Hull Loss risks per mission (i.e. average flight, assumed to last 1.5 Hours) due to Final Approach and Landing to be 51×10^{-8} and 27×10^{-8}, respectively, compared to a overall Hull Loss per mission of 1.87×10^{-6}. An overall safety target is then postulated (TLS) at 10^{-7} per flight hour, or 1.5×10^{-7} per mission, representing an improvement on the current achievement. This overall TLS is then apportioned across all the flight phases, very broadly following the proportion of Hull Loss accidents occurring within each flight phrase. It is notable that within this apportionment, different units of measure are assigned to different flight phases, with the Oceanic and En-route portion assigned the unit 'per flight hour', while Descent, Approach and Landing, and Take-off and Climb assigned the unit 'per mission'. The final conclusion of this process has been to allocate an equal TLS of 1×10^{-8} per mission for hull losses to each of the final Approach and Landing phases.

3.1.18 As noted above the OCP considers similar phases of flight to the AWOP, and addresses the risk of collision of aircraft with obstacles such as buildings, trees, mountains and holding aeroplanes that are either laterally off the path or vertically beneath the path of an approach/landing, or approach/missed approach. For the approach phase, safety has been expressed in terms of the number of accidents for a given number of approaches performed. Utilising historic accident data, a target has been defined, so as to ensure that future systems provide similar or greater level of safety. The current target has been set at no greater than one accident in ten million approaches, a risk per approach of 1×10^{-7}.

3.1.19 ICAO is currently consulting States on proposed amendments to ICAO Annex 11 and PANS RAC to include requirements and recommendations with regard to Safety Management. Specific proposed amendments relate to the development of target safety levels for airspace and aerodromes as well as with the assessment of risks when contemplating changes to the ATM System. It can be considered that current SRC work in these areas will provide a harmonised European approach to the implementation of the ICAO requirements and recommendations.

3.1.20 The above approaches are consolidated and summarised in the table overleaf to facilitate comparison.

3.1.21 The institutional arrangements after the split of the Civil Aviation Authority into the Civil Aviation Safety Authority Australia and Airservices Australia have been such that the primary responsibility for establishing TLS-Safety Minima type standards and associated methodologies was left with Airservices Australia. The current CASA top-level regulatory requirements that are closely related to the topic of TLS-Safety Minima, can be summarised [14] very briefly as requiring AA:

a) To establish, document and maintain a Safety Management System based on risk management principles and addressing, among other things, the safety objectives applied, the methods for achieving target levels of safety, measurement and trend analysis.

b) Define, document and maintain a change management process which, among other things, describes the current baseline configuration, detailing the known function/performance configuration of the system, equipment or procedure as approved prior to the proposed change; identifies the impact of change on the existing system configuration; describes the Risk Control/Mitigation process for eliminating or reducing risk factors and details approval authorities who are linked to the identified safety accountabilities.

[14] The full set of requirements can be found in Attachment A to *Safety Regulation of Airservices Australia and Aerodrome Rescue and Fire Fighting Service Providers - Final Draft Regulatory Arrangements and Standards,* Civil Aviation Safety Authority, April 1996.

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Guidelines applicable to meeting the above summarised requirements have been developed[15]. With the potential introduction of competition in years to come, CASA is slowly becoming more involved with the responsibility for establishing TLS-Safety Minima type standards and associated methodologies. CASA work in this area includes:-

a) *Overview of the Airspace Risk Model (ARM),* Robert Phillips, CASA, 29 June 2000
b) *Acceptable Risk Criteria (especially with respect to midair collisions in terminal areas),* by Robert Phillips and Warren Jones, CASA, version 6 January 2000
c) *The Airspace Risk Model (ARM) MBZ/CTAF Analysis*, Robert Phillips, CASA, March 1999
d) *The Safety Value of Human Life,* Robert Phillips and Warren Jones, CASA, version 3, 7 May 1999

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- *Guidelines for the preparation of Safety Cases,* Civil Aviation Safety Authority Australia, CASA/AA MOU.AIRWAYS-1(0) February 1998.
- *Software and its use in Safety Critical Systems*, Civil Aviation Safety Authority Australia, CASA/AA MOU.AIRWAYS-2(0) July 1999.
- *Manual on Airspace Planning Methodology for the Determination of Separation Minima*, Appendix 10, ICAO, Doc 9689-AN/953 First Edition - 1998.

Source (last updated)	Scope of TLS	TLS	Causal factors addressed	Phase of Flight	Risk to aircraft	Applicability	Source of data
JAR 25.1309 / AMJ25.1309-1 (1994)	Failure conditions of individual aircraft systems	10^{-9} per flight hour per aircraft system failure condition	Failure of aircraft systems	All	Hull Loss	Large aeroplanes >5700 kg CTOW. May be applied to small aeroplanes >10 passenger seats	'Historical evidence', i.e. Accident data from 1960's, and that 10% due to aircraft systems, and assuming that 100 failure conditions exist.
AMJ 25.11	Display of specific data	Acceptable probabilities of specific failure conditions related to the display of data (10^{-5} or 10^{-7} per flight hour)	Loss of information and display of misleading data-navigation and communication-	All	Hull Loss	Large aeroplanes >5700 kg CTOW. May be applied to small aeroplanes >10 passenger seats	Historical evidence', i.e. Accident data from 1960's, and that 10% due to aircraft systems, and assuming that 100 failure conditions exist. Assumption of a "standard" ATC environment.
NATSPG (1992)	Collision Risk	$4x10^{-8}$ to $1.5x10^{-8}$ fatal accidents per flight hour per dimension	All Causes	Oceanic (North Atlantic)	Fatal Collision	Not limited. Applicable to any aircraft to determine suitability for given operation- Parallel Tracks/Low density/Procedural operations	Fatal accidents involving Jet Aircraft on scheduled airlines 1959 – 1966, 10% due to collision (arbitrary), improvement factor of between 2 & 5 applied, equally divided to three dimensions.

Source (last updated)	Scope of TLS	TLS	Causal factors addressed	Phase of Flight	Risk to aircraft	Applicability	Source of data
RVSM (1992)	Collision Risk	2.5×10^{-9} per flight hour in vertical dimension	Aircraft Systems (affecting height keeping performance) i.e. excluding ATC and Pilot errors	Oceanic & Subsequently En-route	Fatal Accident from loss of procedural vertical separation	Not limited. Applicable to any aircraft to determine suitability for given operation Parallel Tracks/Low density/Procedural operations	US civil aircraft fatal accident data
RGCSP (1995)	Collision Risk for period 2000 to 2010	5×10^{-9} per flight hour per dimension	All Causes	En-route	Fatal Accident	Not limited. Applicable to any aircraft to determine suitability for given operation Parallel Tracks/Low density/Procedural operations	Fatal accidents involving Jet Aircraft on scheduled Air Services. Trend curve into future.
AWOP (1994)	Aircraft Accident	10^{-7} per flight hour 1.5×10^{-7} per mission	All Causes	All	Hull Loss	Not limited. Applicable to any aircraft to determine suitability for given operation	Worldwide commercial jet fleet accident data 1959 – 1990, for aircraft heavier than 60000lbs (excluding turbo-prop) factored for improvement.

Source (last updated)	Scope of TLS	TLS	Causal factors addressed	Phase of Flight	Risk to aircraft	Applicability	Source of data
	Aircraft Accident	10^{-8} per mission	All Causes	Approach & Landing	Hull Loss	Not limited. Applicable to any aircraft to determine suitability for given operation	Apportionment of the “All phases of flight” figure.
OCP (1980)	Collision with Obstacles	10^{-7} per approach	Collision with obstacles due to aircraft that are laterally off-path or beneath approach path	Approach & Landing	Accident (collision with obstacles)	Not limited. Applicable to any aircraft to determine suitability for given operation	Historical accident data factored for improvement.

3.2 TLS Units of Measure

3.2.1 Aviation Units of Measure

3.2.1.2 The units of measure generally applied to aviation risk are aircraft flight hours. The historical determination of this unit of measure took due consideration of, but discarded, other measures related to calendar time, number of aircraft movements and distance flown. The use of calendar time was discounted on the basis that this was not easily related to individual aircraft, being dependent upon traffic levels. The number of aircraft movements, the distance flown, and the aircraft flight hours are all closely related but the interrelation is dependent upon assumptions regarding average flight time per movement and average speed per flight.

3.2.1.3 It has therefore been determined that the most appropriate units of measure in the aviation arena for en-route phases of flight are ‘per flight hour’, and for the take-off, approach and landing phases of flight are ‘per movement’

3.2.2 ATM Units of Measure

3.2.2.1 The units of measure generally applied to risk to aviation due to Landing Systems (such as ILS) are ‘per approach’ or ‘per Movement’.

3.2.2.2 Very few Air Traffic Service providers have a formal safety management environment explicitly addressing risk, and hence formally derived units of measure. Within Europe, the various natonal approaches are summarised within the EATCHIP Safety Assessment Methodology (SAM). The overall approach taken by the last published EATCHIP SAM was to present qualitative probability levels (e.g. Unlikely to occur throughout the lifetime of the system) against failure impacts upon individual aircraft or upon sectors for ATC, noting that this is presented only as guidance within the document.

3.2.2.3 The EATCHIP Safety Assessment Methodology summarises the approaches taken for NATS and the ATNP. The NATS units of measure are ‘per flight hour’ for Pilot interpreted systems[16] and ‘per sector per hour’ for ATC interpreted systems[17]. The ATNP units of measure are ‘per flight hour’ for aircraft failures and ‘per year’ for failures of ground elements. It is anticipated that the ATNP model be replaced by the outcome of the joint EUROCAE WG53/RTCA SC189 group (due by end 2000), which is tentatively being co-ordinated with EUROCONTROL.

3.2.2.4 More recently, further approaches have been adopted by the French DGAC/CENA and the Swedish ATM Safety Regulatory Authority. For CENA, the units of measure are ‘per flight hour’ for airborne components of ANS, and are ‘per operational hour’ for ground components of the Air Navigation System.

[16] Pilot interpreted systems are those that can directly influence the aircraft e.g. ILS
[17] ATC interpreted systems are those that influence the Air Traffic Service provision e.g. Surveillance

Another level of granularity in the units used in CENA is also the ATCO working position, which is considered to be handling to a relatively constant number of aircraft[18]. The Swedish units of measure are 'per operative hour per sector/ATS unit' (assuming a small ATS unit equates to a single sector).

3.2.2.5 The states applying a measure of 'per sector per hour' implicitly acknowledge that the risk to aircraft of ATM failures is dependent upon the combination of the following:

- The phase of flight e.g. en-route, TMA, Oceanic (approach & landing, where differentiated, tend to be 'per approach' or 'per Movement');
- The density of aircraft in the airspace;
- The complexity of traffic flows in the airspace;
- The volume of airspace covered by an Air Traffic Service Unit (for ATM failures that may affect a whole unit).

Other factors may need to be considered such as the diversity of aircraft equipage or the level of automation in ATM.

3.2.2.6 The concept of using an ATC Sector-based approach addresses some of the above issues. In general, and using (of necessity) a somewhat theoretical approach, the following principles are applied across the states:

- The greater the density of aircraft, the smaller the sector (Note: this statement may need to be revisited to account for the route structure in place in the sector);
- The more complex the traffic flows, the less traffic that is handled by a sector.

Generally, a new sector will be opened when the sector capacity is seen as being superseded by traffic demand.

3.2.2.7 It may be considered that the above principles are generally self-regulating. It should be noted that no formal link has yet been established between the size of a sector and the density and complexity of traffic, rather it is a subjective assessment of Controller workload based largely upon simulations (and backed up by operational experience). However, even if there is no world-wide accepted method for defining and detecting sector capacity, it may be considered that this does not detract from the fundamental principles that are generally applied.

3.2.2.8 Another advantage of utilising a Sector based approach is that it relates directly to the ATC unit of control and is consequently well understood both in the ATC and Aircrew environments.

[18] This eases the process by which constraints on system design are being derived.

3.3 Limitations of existing standards/practices

3.3.1 Current TLS vary a lot in terms of scope. Related applicability to the setting of safety minima and to the safety assessment of changes to the ATM system is therefore limited. Assumptions and related limitations (E.g., Route structure, assumed aircraft density, type, assumed phases of flight, etc..) related to each specific TLS are not always clear or well understood by the whole aviation community. There is a need to adopt a total aviation system perspective, top down, which would be complementary to existing practices while still enabling them to be put in context.

3.3.2 There are a number of differences in the respective scope of TLS/Safety Minima as applicable to aircraft and to the ATM system. It is essential to explain and understand the specifics of the aircraft TLS, (refer to FAR/JAR 25 for the design of aircraft), in order to understand the need for TLS/Safety Minima for Air Traffic Management[19].

3.3.3 A failure in an aircraft can directly and immediately lead to a catastrophic situation. This may not be the situation when a failure originates in the ATM system. Conversely, some common mode of ATM failures might, under certain circumstances, increase the likelihood of ‘catastrophic’ failures potentially impacting many aircraft at the same time. (For example, communication or surveillance blackouts in specific environments). These modes of failure might become more frequent as technology integrates and diversity principles are ‘forgotten’.

3.3.4 The setting of safety minima in ATM should not be restricted to the human and procedural elements of the CNS/ATM system but also include the infrastructure. Therefore, the area to be addressed by the SRC should be ATM/CNS, the provision of ATM services being supported by the CNS infrastructure.

3.3.5 A detailed review of ATM safety shows that there are a number of perspectives that can, and are taken on the matter. The most obvious examples being the ‘risk’ perspective embodied within the assessment of air proximity hazards (Airprox), and the ‘distance’ based perspective related to separation minima standards. Others may include the ability to recover from a hazardous situation. To enable an all-encompassing view of ATM safety to be taken, it is considered necessary to establish a logical, consolidated framework. Perhaps this could be achieved by, having a previously agreed *accident/incident causation model* used to analyse system’s behaviour.

[19] ATM defined in accordance to the SRC/RTF definition : « ATM is the aggregation of ground based (comprising variously ATS, ASM, ATFM) and airborne functions required to ensure the safe and efficient movement of aircraft during all appropriate phases of operations. »

3.3.6 The discussion presented in this section of the Report has mainly considered the Target Level of Safety (TLS) against a single event, namely aircraft accident. It is notable that very few events result in accidents, whereas incidents of lesser severity (but which still carry a risk of collision) are relatively more frequent. In order to facilitate the control of all potential risks that could contribute to an accident, it may be necessary to have some means of ranking the relative importance of effects against some form of ‘safety measure’.

3.3.7 A fundamental concept that still needs consideration concerns the relationship between Aircraft Flight Hours and ATM System Sector Hours. Historically, this relationship has been subject to a degree of confusion as evidenced by differing approaches taken by individual states, which is itself symptomatic of the various and potentially limited rationales supporting the current stances.
This relationship between Aircraft Flight Hours and ATM System Sector Hours will also need to account for the definition of ATM, including both airborne and ground-based functions.

4. ON GOING AND FUTURE WORK: ATM RISK MODEL

4.1 The main objective of on going and future work in the ATM risk assessment and mitigation area is to derive a substantiated framework for ECAC Safety minima and for risk classification to support the setting of Safety Objectives in ATM and the setting of Safety Requirements for the provision of new, or modification of existing, elements of the overall ATM System.

4.2 The setting of minima in ATM should also include the CNS elements, even though CNS is a supporting element to ATM. Indeed, the enabling infrastructure can be unserviceable without an increase of the risk to aircraft if there is an acceptable contingency planning[20].

4.3 SRC is finalising the development of a EUROCONTROL Safety Regulatory Requirements ESARR 4 (‘Risk Assessment and Mitigation in ATM’) which will be complemented by a Guidance Material to ATM Safety Regulator. Complementary work is taking place in the Agency Safety Group, in relation to the safety assessment of the ground element of the ATM system, where proposed methods by which risk in ATM can be assessed and controlled is being developed according to a phased approach.

4.4 Consideration is also given to the safety objectives reflected in the EUROCONTROL ATM 2000+ strategy, approved by MATSE in January 2000, to develop an SRC Policy Document specifying the tolerable ECAC safety minima for ATM (SRC POL DOC 1:- “*ECAC Safety Minima for ATM*”).

4.5 Most of the ATM risk models may consider the units of measure of the safety minima in ATM from a qualitative perspective. However, SRC 7 recognised that quantitative probabilities are also likely to be necessary for expressing safety minima. It is anticipated that a method be provided to enable States to derive national quantitative objectives, in a manner that ensure that aircraft flying in the ECAC airspace are being provided with an equivalent level of safety **wherever they fly**.

4.6 A method to implement ESARR 4 and to apportion risk needs to be developed as guidance material to ESARR 4 and related SRC POLICY DOC 1.

[20] The planning must be such that it is easy to reduce the capacity in a sector to a level where the ATM still can handle the traffic in a safe manner, as a controlled degradation of the system.

5. REFERENCES

No.	Title	Version
1	EUROCONTROL Revised Convention. Brussels, 27 June 1997.	September 1997 Edition
2	JAR 25.1309: Joint Aviation Requirements, Large Aeroplanes. Subpart F, Paragraph 1309 'Equipment, Systems and Installations'. AMJ 25-11:	Change 14, 27/05/1994 Ch 14 (Amend. 93/1, Eff. 8.3.93)
3	AMJ 25-11: General Certification Requirements	Ch 14 (Amend. 93/1, Eff. 8.3.93)
3	RTCA SC-189/Eurocae PUB 22: CNS/ATM Safety Assessment.	Revision PostPUB9 September 2000
4	Boeing Airplane Safety Engineering (B-210B): Statistical Summary of Commercial Jet Aircraft Accidents. World Wide Operations 1959 - 1994	Airplane Safety Bulletin March 1995
5	Working Paper SRC4.15: Aviation Safety Goals for Air Traffic Management (ATM) in Sweden established by Aviation Safety Department.	11/03/1999
6	RGCSP/WG-A/WP8: Review of the General Concept of Separation Panel (RGCSP): Working Group A – A Review of Work on Deriving a Target Level of Safety (TLS) for En-route Collision Risk. I G Parker.	Dated 01/05/1995.
7	ICAO Circular 120 AN/89/2: Methodology for the Derivation of Separation Minima Applied to the Spacing Between Parallel Tracks in ATS Route Structures.	1976
8	ICAO All-Weather Operations Panel: Report on the 15th Meeting, 26 September – 12 October 1994	AWOP/15-WP/718
9	SAF.ET1.ST03.1000-MAN-01-00: EATCHIP Safety Assessment Methodology.	Issue 0.4, November 1996
10	ASE.ET1.ST02-ADD-01-00: Overall CNS/ATM Architecture for EATCHIP.	Edition 1.0, 18/08/97
11	ICAO Doc. 7300: Convention on International Civil Aviation – Annex 11: Air traffic Services.	12th Edition - July 1998
12	ICAO proposed amendments to Annex 11 and PANS RAC	2000
13	EUROCONTROL: Air Traffic Management Strategy for 2000+.	November 1998
14	SRC DOC 2	Draft October 2000

APPENDIX A

ATM Safety Minima Study
General Bibliography

Title	Reference	Application
RTCA SC-189/Eurocae WG-53 Position Paper; CNS/ATM Safety Assessment	PUB22, September 2000	Identifies a model for Safety Assessment of CNS/ATM services supported by data communications and crossing 'institutional' boundaries. Identifies Operational Safety Assessment Hazard Classification Matrix applicable to Operations, Occupants, Aircrew and Service Provider.
EATCHIP Safety Policy	SAF.ET1.ST01.1 000-POL-01-00, November 1995	Principal safety objective is to minimise the air navigation contribution to the risk of an aircraft accident as far as reasonably practicable. Principles for Safety Achievement: Wherever practicable, quantitative safety levels should be derived and maintained for all systems; All new systems and changes to operational systems should be assessed for their safety significance and system functions should be classified according to their safety criticality.
EATCHIP Safety Policy : Implementation Guidance Material	SAF.ET1.ST01.1 000-GUI-01-00, 15 July 1997	Provides amplification of EATCHIP Safety Policy and Principles. Describes need for, and processes and activities to implement Safety Management, including of establishment of safety targets and risk criteria.
EATCHIP Safety Assessment Methodology	SAF.ET1.ST03.1 000-MAN-01-00, Edition 1.0 April 2000	Part I introduces concept of FHA, severity of a failure condition and use of risk classification scheme. Part IV Annex C provides preliminary guidance material on safety planning.
NATS Safety Management Manual	CAA Doc 529, 2nd Edition	Provides in SP401 an example of a Risk Classification Scheme as applied in practice by NATS. Defines severity, probability and risk tolerability criteria for both ATC and Pilot Interpreted systems. Provides TLS for Pilot Interpreted systems based upon the JAR 25.1309 criteria for Failure Conditions affecting flight. Effective TLS for ATC Systems set at 10^{-7} for Hazard Severity Category 1, but no rationale provided for values given.

Title	Reference	Application
Risk Assessment of Approach Landing and Information Systems	CAA Doc 675	Provides Failure Mode Effects Tables for Approach Aids, Landing Aids and Airport Information, from Pilot and ATC perspective. Provides basic rationale for establishment of Safety Targets, in line with JAR 25.1309 criteria. Subsequently proceeds to assigns Severity and hence establishes TLS for each Failure Mode in isolation.
G R Profit, Systematic Safety Management in the Air Traffic Services	Euromoney Publications, ISBN 1 85564 470 3	Provides example of Risk Classification Scheme based on original NATS Safety Management Manual in Chapter 4. In addition chapter 4 introduces an illustrative derivation of an ATM / Aviation Risk budget and thence associated TLS.
ICAO; Methodology for the Derivation of Separation Minima Applied to the Spacing between Parallel Tracks in ATS Route Structures	Circular 120 – AN/89/2, 1976	Section 3, identifies the limitations, or assumptions, of the CRM. Section 7 provides a summary of work to derive and proposals for numerical TLS to be used in assessing separation values. NB. Much of the data provided was then used in CAA Paper 77002. Provides statistical data used to derive target safety levels. Comes down to proposed TLS for accidents due to loss of lateral separation of 0.2×10^{-7}.
P Brooker, Target Levels of Safety for Controlled Airspace	CAA Paper 77002, February 1977	Describes the derivation of numerical TLS for Mid Air Collision in aircraft route structures. Considers unit of measurement and choice of a target for total risk from all causes. Comes down to proposed TLS for accidents due to loss of lateral separation of 0.2×10^{-7}.
E H Davies; Review of the Target Level of Safety for NAT MNPS Airspace	CAA CS Report 9301 – Issue 2, August 1993	Continues story from CAA Paper 77002. Describes the derivation of numerical TLS for NAT and En-route aircraft. Considers unit of measurement and choice of a target for total risk from all causes. Section 5, comes down to proposed general TLS for next 10 years for accidents due to loss of separation of 5×10^{-9} for each dimension. For NAT system proposal is 1×10^{-8} for the horizontal plane as a whole.

Title	Reference	Application
A Review of Work on Deriving a Target Level of Safety for En-route Collision Risk	RGCSP/WG-A/WP/8, 1st May 1995.	Reviews previous work on the derivation of TLS, primarily in the NAT region. Proposes TLS of 5 x 10^{-9} fatal accidents per flight hour per dimension for the period 2000 to 2010.
A Concept for Establishing Improved Oceanic Separation Standards Based on Equipment Certification	MP97W0000068, November 1993	4 dimensional model encompasses waypoint crossings. Considers Accuracy & Continuity, Intent Integrity, System Integrity, and Recovery Procedures to determine if sufficient separation is maintained. Proposes TLS for the Air Navigation & Control System of 10^{-7}.
ICAO Manual on use of Collision Risk Model for ILS Operations	ICAO Doc 9274 – AN/904, 1980	Provides overview of, and describes practical use of Obstacle Clearance CRM Model. Identifies in Chapter 1 (section 1.3) a Target Level of Safety of 1 x 10^{-7} per approach.
R D Hunter, The Development of Obstacle Clearance Criteria for ILS Operations at Civil Airports	CAA Paper 80009, 1980	Linked to ICAO Doc 9274. Provides overview of Obstacle Clearance CRM Model. Identifies in section 4.2 risk budget of one accident in 10 million approaches (a TLS of 1 x 10^{-7} per approach)
EATCHIP Safety Improvement Subgroup (SISG), Development of Safety Indicators	EAT/SISG WP/4	Introduces SMITF and concept of Safety Indicators and their practical usage. Appendix 3 identifies potential indicators and associated metrics, together with causal factors, covering ATC and engineering.
DNV, Hazard Analysis of Route Separation Standards	C4501_1 Rev 3	Provides Hazard Identification of mechanisms and scenarios that could lead to lateral deviations. The frequency of the scenarios is determined from incident and general reliability data. Likelihood and effectiveness of ATC intervention is determined and overall collision risk estimates derived. Source of general causal and dependent failure concepts and information derived from practical data.

Title	Reference	Application
Air Traffic Management Strategy for 2000+	EUROCONTROL Paper, November 1998, No specific reference.	Provides strategy and goal information for EUROCONTROL. Introduces SRC/SRU (V1 4.2.2; V2 2.2.2, 9.2.3.7); Objective that ATM induced accidents and serious incidents do not increase (V1 5.2.1); Safety Nets assist in reducing risk of aircraft collisions (V1 6.4.3); Total Aviation systems safety approach for all European Airspace (V2 3.1); Forecast Traffic Statistics (V2 3.7.1); Safety Objectives (V2 4.2); Changes required to Safety Management (V2 6.3.1); Future ATC (V2 7.3); Improvement Steps (V2 8.2 et seq.)
EATCHIP Operational Concept Document	FCO.ET1.ST07.DEL01, Edition 1.1, 4 Jan 1999. Released Issue.	Identifies a variety of concepts and strategies for EUROCONTROL. Introduces Separation Assurance (4.7); “Improving safety levels in the face of increasing traffic demand” (6.3 + Footnote 17); Airspace Management & ATFM V’s ATS roles in supporting Safety (6.9); Concept of Safety ‘Levels’ in terms of separation time (Annex A, 1.3; App 8, 3); Future ATM enabler concept (App 9)
ICAO Manual on Implementation of a 300m (1,000ft) Vertical Separation Minimum between FL290 and FL410.	ICAO Doc 9574, 1st edition, 1992.	Identifies in Section 1.1 Collision Risk due to loss of vertical separation caused by technical systems to be less than 2.5×10^{-9} per flight hour. Further identifies in paragraph 2.1.3 the proportion of height keeping errors, derived from modelling, to ensure overall TLS.
Convention on International Civil Aviation – Annex 11: Air Traffic Services	ICAO Doc 7300	Identifies the objectives and features of Air Traffic Services for different airspace classifications, including airspace, system and procedural requirements. Attachment B proposes that when determining parallel track or ATS route spacing, and where ‘fatal accidents per flight hour’ is considered to be an appropriate metric, then risk of accident (TLS) should be less than 5×10^{-9} per flight hour for each dimension for systems implemented after the year 2000. Where ‘fatal accidents per flight hour’ is not considered an appropriate metric, justifiable alternate metrics and methods of assessment should be established.

Title	Reference	Application
Proposed amendments to Annex 11 and PANS RAC		Proposes to add some requirements and recommendations with regard to:- - the setting of TLS for national airspace and aerodromes; - the implementation of safety management system; and - the implementation of safety assessment of proposed changes to the ATS system.
ICAO All-Weather Operations Panel, 15th Meeting 26/09/94 – 12/10/94	AWOP/15-WP/718	Report on the proceedings of 15th meeting of the AWOP. Includes in chapter 2 of Annex B to Agenda Item 3 a paper on the concept and application of RNP, in particular an apportionment of RNP incident risk from an accident TLS of 10^{-8} for the approach and landing phase. In addition, Attachment B of Annex B to Agenda item 3 identifies the background to the derivation of the Target Level of Safety for the 'tunnel concept', namely apportionment from historic hull loss data derived from the Boeing Statistical Summary of Commercial Jet Aircraft Accidents 1959 – 1990.
ICAO All-Weather Operations Panel, 16th Meeting 23/06/97 – 04/07/97	AWOP/15-WP/756	Report on proceedings of 16th meeting of the AWOP. Provides, as Table 2-1 within Appendix B to Agenda Item 1, proposed Target Levels of Safety for different severity effects ranging from Catastrophic (multiple deaths) through to Minor (discomfort/slight increased workload), targets ranging from 10^{-9} through 10^{-3}. Also identifies RNP continuity and integrity criteria, and their apportionment to aircraft and ground based navigation systems, for Cat I, II and III operations. Introduces requirement for A-SMGCS not to introduce an additional (new) global risk of a fatal accident in 10^{7} flights.
Joint Aircraft Requirements JAR25 – Large Aeroplanes: Advisory Material Joint System Design & Analysis AMJ 25.1309		AMJ25.1309 presents the rationale for the setting of JAA/JAR TLS such that an aircraft TLS of 10^{-7} per flight hour is met through individual system contributions of 10^{-9} per flight hour on the assumption that there are about 100 potential failure conditions in an aeroplane. Provides the relationship between probability and severity of failure condition.

Title	Reference	Application
Joint Aircraft Requirements JAR25 – Large Aeroplanes: Advisory Material Joint System Design & Analysis AMJ 25.1309	AMJ 25.1309-1 Proposed Revision	Reiterates TLS rationale identified above. Similarly, provides relationship between probability and severity, in line with earlier version. Change proposal reveals significant change to requirement to undertake detailed Safety Analysis, namely this is now only required for Hazardous and Catastrophic Failure Conditions as determined by the functional Hazard Assessment. Minor and Major Failure Conditions now have more 'relaxed' safety analysis goals.
Joint Aircraft Requirements JAR25 – Large Aeroplanes: Advisory Material Joint AMJ 25.11	AMJ 25-11	Includes requirements for loss of information and display of misleading and hazardous data to the pilot.
Aviation Safety Goals for Air Traffic Management (ATM) in Sweden established by the Aviation Safety Department	WP SRC4.15, 11 March 1999	Proposes Severity Categories and probabilities (per operative hour per sector) largely based upon AMJ to JAR 25.1309: Identifies severity categories viewed from parallel perspectives (e.g. effect on occupants, crew and separation distances). Safety goals related to a sector, with Catastrophe at 10^{-6}, Very Serious Incident at 10^{-4}, Serious Incident at 10^{-2}, and Minor Occurrence at 1 per Op Hr.
RTCA SC-189/Eurocae WG-53 Position Paper, PUB 22	P-PUB-22 September 2000	Proposes guidelines to help in capture the characteristics of any CNS/ATM operational environment, using Air Ground Data Comms. A template 'matrix', with descriptive guidance, is provided characterising the environment in terms of Airspace (configuration and traffic), and CNS/ATM Infrastructure, functional, operational and performance characteristics.
Boeing, Statistical Summary of Commercial Jet Aircraft Accidents. World-wide Operations 1959 - 1994	Airplane Safety Engineering (B-210B), March 1995	Provides definition of Accident. Based on this definition, provides comprehensive analysis of aircraft accidents in terms of rates of occurrence, primary causes, aircraft types and flight phase. Data is provided for US and/or Non-US commercial operators. Provides a basis to distinguish between Airport/ATC and other Primary accident causes, against flight phase.

Title	Reference	Application
CAA, Global Fatal Accident Review, 1980 – 1996	CAP 681, March 1998	Summarises an analysis of 621 global fatal accidents to Jet and Turboprop aircraft. Provides comprehensive analysis of aircraft accidents in terms of rates of occurrence, operators regions, geographical location, primary causes, aircraft types and origin, and flight phase. Provides an identification of primary accident causes and consequences. In addition identifies (in Appendix) ATC/Ground Aids as a Primal Causal Group for 10 out of 589 fatal accidents.
AIRCRAFT ACCIDENTS/INCIDENTS and ATM CONTRIBUTION: *Review and Analysis of Historical Data*	EUROCONTROL Study Report SRC DOC-002 Working Draft Ed 0.04	Provides an analysis of the number and causal factors of aircraft accidents and incidents. Considers ATM in general, assessing a number of accident and incident data sources for causal factors covering Human Factors, Equipment and Procedures. Provides summary of statistics and data.
EATCHIP Safety Improvement Sub Group (SISG) – Slide on Subjective list of Areas of Safety Concern	Informal Review of SISG Concerns	0 Identifies 21 'areas of safety concern', against an undefined rating of concern (from 1 to 8 units). Most 'significant' concern relates to RT Phraseology, followed by Level Busts and IFR/VFR Mix. 1 Background to slide needed to properly interpret.
Slide from AIRSYS ATM, Systems Safety Assessment Process: Background	AIRSYS ATM Presentation 12/1/99	2 Identifies contribution to ATM risk from Human, Procedural and Equipment elements to be 75%, 21% and 4% respectively.
SRC Inputs to Performance Review Commission (PRC)	SRC/INTERFACE / PRC/113/MB	3 Provides input to PRC from the SRC for the 'safety section' of Key Performance Indicators (KPI). Identifies pyramid view of accidents, incidents and related occurrences, and describes the current SRC approach to safety performance measures at top level. Defines proposed breakdown for indicators into Accidents, Serious and other Incidents, sub-divided into Air-Air, Air-Ground, Ground-Ground and other occurrences.

Title	Reference		Application
SRC Initial Report on Available Safety Data and Causal Factors to PRC	SRC\INTERFACE \ PRC-PRU\ 1999	4	Provides indication of current level of supporting data for KPI, as described in paper reference SRC/INTERFACE/PRC/113/MB. Accidents/Fatalities world wide and for ECAC area, from 1990 through 1998, are identified, together with current total of reported Airprox. Initial summary of causal factors also provided, with a broad indication of relative weighting for the major factors.
The Probabilistic Approach to Safety – Success or Failure	Proceedings of Institution of Mechanical Engineers, Volume 209 (Pg. 177)	5	Describes the derivation of JAR 25.1309 TLS for aircraft systems. Explores the implementation of Safety Assessment resulting from the requirements, and the success of the approach in terms of accident rates and causal factors.
		6	Concludes that ‘the use of numeric probabilities has proven to be of no great benefit’ to the system designer, but considers that the structured approach mandated has probably contributed to the improvements in airworthiness related accidents.
Overall CNS/ATM Architecture for EATCHIP, Volume 1	ASE.ET1.ST02-ADD-01-00	7	Provides a generic description of the architecture of the overall CNS/ATM system serving the ECAC area. It is intended to form a consistent basis within EATCHIP for the definition and specification of the CNS/ATM environment and implementation into the future. Two presentations are provided, a Functional Architecture and an Organisational Architecture view.
		8	Needs to be considered as a potential source of information defining the ATM system to be considered by the Safety Minima study.

APPENDIX B

Definition of Terminology

The following definitions relate to terminology or concepts used in the study. The definitions have been extracted from ICAO and EUROCONTROL documentation, including ICAO SARPS and EUROCONTROL ATM 2000+.

Accident [ICAO Annex 13]	An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which: a) a person is fatally or seriously injured as a result of - being in the aircraft, or - direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or - direct exposure to jet blast, or b) the aircraft sustains damage or structural failure which: - adversely affects the structural strength, performance or flight characteristics of the aircraft, and - would normally require major repair or replacement of the affected component c) the aircraft is missing or is completely inaccessible.
Air Traffic Management [EUROCONTROL ATM Strategy for 2000+]	The process that encompasses: Airspace Organisation and Management – the structure, division and categorisation of airspace, and the rules which apply; Flow and Capacity Management – managing the dynamic balance between capacity and demand; En-route[, Oceanic] and Terminal Air Traffic Control – the monitoring and separation of aircraft, traffic sequencing, and management of capacity and flexibility for en-route[, oceanic] and terminal airspace; Airport Air Traffic Control – air-side traffic management, separation and sequencing of traffic on the airport and on final approach and departure, and other airport issues, including environmental impacts.
Air Traffic Management [EUROCONTROL SRC/RTF]	ATM is the aggregation of ground based (comprising variously ATS, ASM, ATFM) and airborne functions required to ensure the safe and efficient movement of aircraft during all appropriate phases of operations.
Air Traffic Management System	The System (i.e. the combination of equipment, people and procedures) organised to execute the process of Air Traffic Management, as previously defined.
Air Traffic Service [ICAO Annex 11]	A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service).

Aircraft Proximity [ICAO PANS-RAC]	A situation in which, in the opinion of a Pilot or air traffic services personnel, the distance between aircraft as well as their relative positions and speed have been such that the safety of the aircraft involved may have been compromised. An aircraft proximity is classified as follows: *Risk of collision*. The risk classification of an aircraft proximity in which serious risk of collision has existed. *Safety not assured.* The risk classification of an aircraft proximity in which the safety of the aircraft may have been compromised. *No risk of collision.* The risk classification of an aircraft proximity in which no risk of collision has existed. *Risk not determined*. The risk classification of an aircraft proximity in which insufficient information was available to determine the risk involved, or inconclusive or conflicting evidence precluded such determination.
Aircraft [ICAO Annex 11]	Any machine that can derive support in the atmosphere from the reaction of the air other than the reactions of the air against the earth's surface
AIRPROX [ICAO PANS-RAC]	The code word used in an air traffic incident report to designate aircraft proximity.
Incident [ICAO Annex 13]	An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation.
Meteorological Information [ICAO PANS-RAC]	Meteorological report, analysis, forecast, and any other statement relating to existing or expected meteorological conditions.
NOTAM [ICAO Annex 11]	A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.
Serious Incident [ICAO Annex 13]	An incident involving circumstances indicating that an accident nearly occurred.
System [EATCHIP ANS SAM]	A combination of inter-related system elements (equipment, people and procedures) arranged to perform a specific function.

GLOSSARY

8.33KHz	Project to implement 8.33KHz separation for Air Ground VHF radio channels.
ACAS	Airborne Collision Avoidance System
ADS	Automatic Dependent Surveillance
A/G	Air / Ground
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service
ALARP	As Low As Reasonably Practicable
AMAN	Arrivals Manager
AMJ	Advisory Material Joint
ARTAS	Advanced Radar Tracker and Server
ASE	ATM System Engineering
ASM	Air Space Management
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATNP	Aeronautical Telecommunications Network Panel
ATS	Air Traffic Service
ATSU	Air Traffic Services Unit
AWOP	All Weather Operations Panel
CAA	Civil Aviation Authority
CASA	Civil Aviation Safety Authority- Australia
CENA	Centre d’Etudes de la Navigation Aérienne
CFIT	Controlled Flight Into Terrain
CFMU	Central Flow Management Unit
CNS	Communication, Navigation and Surveillance
CPDLC	Computer – Pilot Data Link Communication

CRM	Collision Risk Model
DFS	Deutsche Flugsicherung
DMAN	Departure Manager
DME	Distance Measuring Equipment
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme
EATMP	European Air Traffic Management Programme (follow on from EATCHIP)
ECAC	European Civil Aviation Conference
eFDP	European Flight Data Processor
EGNOS	European Geostationary Navigation Overlay System
FDP	Flight Data Processing
FMP	Flight Management Position
GAT	General Air traffic
G/G	Ground / Ground
GMR	Ground Movement Radar
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HMI	Human Machine Interface
ICAO	International Civil Aviation Organisation
IFPS	Initial Flight plan Processing System
ILS	Instrument Landing System
IRS	Inertial Reference System
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirement
KPI	Key Performance Indicator
MALS	Minimum Acceptable Level of Safety
MATS	Manual of Air Traffic Services
MET	Meteorological Information
MLS	Microwave Landing System
MSAW	Minimum Safe Altitude Warning
MTCD	Medium Term Conflict Detection
NATS	National Air Traffic Services (UK ATC Provider)
NATSPG	North Atlantic Systems Planning Group
NOTAM	Notice to Airmen
OCA/H	Obstacle Clearance Altitude/Height
OCP	Obstacle Clearance Panel

OAT	Operational Air Traffic
RGSCP	Review of the General Separation Concepts Panel
RNAV	Area Navigation
RNP	Required Navigation Performance
RTCA	Radio Technical Commission for Aeronautics
RVR	Runway Visual Range
RVSM	Reduced Vertical Separation Minima
SAM	Safety Assessment Methodology
SID	Standard Instrument Departure
SOP	Standard Operating Procedures
SRC	Safety Regulation Commission
SRU	Safety Regulation Unit
SSR	Secondary Surveillance Radar
STAR	Standard (Terminal) Arrival Route
STCA	Short Term Conflict Alert
TLS	Target Level of Safety
TMA	Terminal Control / Manoeuvring Area
UAV	Unmanned Airborne Vehicle
UHF	Ultra High Frequency
VHF	Very High Frequency
VOR	VHF Omnidirectional Radio-Range
WG	Working Group