International Civil Aviation Organization
South American Regional Office
Workshop/Seminar for the assessment of system risks prior to RNAV-5 Implementation and SAM Region ATS Routes Network Optimisation - Regional Project RLA/06/901
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Agenda Item 1 Analysis of general aspects on safety management system

(Presented by the Secretariat)

Summary

This working paper presents information on aspects related to safety as established in ICAO SARPs and associated documents, such as PANS/ATM (Doc 4444), Doc 9613, the SMM Manual (Doc 9689), as well as implementation projects related to RNAV5 and SAM Region ATS routes network optimisation.

References:

- ICAO Annex 11
- Doc 4444, PANS/ATM
- Doc 9859, Safety Management Manual (SMM)
- Doc 9689, Manual on Airspace Planning Methodology for the Determination of Separation Minima
- Doc 9613, Performance-based Navigation (PBN) Manual
- Short term RNAV5 implementation programmes and SAM Region ATS routes network optimisation

ICAO Strategic objectives

Strategic Objective A *Safety*
Strategic Objective D *Efficiency*

1 Background

1.1 ICAO SARPs on safety are shown in Annexes 1, 6, Parts I and III; 8, 11; 13 and 14. These Annexes deal with the activities of recognised training organisations, international aircraft users, and maintenance organisations, recognised organisations responsible for the type design or aircraft manufacturers, air traffic services providers and certificated aerodromes. In case of Annex 1, the SARPs on safety management are exclusively limited to recognised training organisations that are exposed to safety risks during the provision of services.

1.2 The SARPs on safety management are addressed to two specific groups: States and Services Providers. The term “service provider” refers to all organisations that provide an aviation service. The term comprises recognised training organisations that are exposed to safety risk, while providing services, aircraft users, and recognised maintenance organisations, organisations responsible for the design or aircraft manufacturers, air traffic services providers and certificated aerodromes, as required.

1.3 ICAO SARPs on safety management refer to three types of specific and well defined requirements:

a) Requirements related to the State Safety Programme (SSP), including the acceptable level of safety (ALoS) of an SSP;

b) Requirements related to safety management systems (SMS), including the effectiveness of an SMS safety; and

c) Requirements related to the responsibility and rendering of expenses of the administration with respect to safety management during the provision of services.

1.4 With regard to safety management, ICAO SARPs, introduce the notion of acceptable level of safety (ALoS), as a way to express the minimum degree of safety established by the State and must be assured by a SSP, and the notion of safety effectiveness as a way to measure the safety effectiveness of a service provider and its SMS.

2 Analysis

2.1 Annex 11, para.2.27.5, *Safety Management*, established that any significant safety-related change to the ATS system related to safety, including the implementation of a reduced separation minimum or a new procedure shall only be affected after the safety assessment has demonstrated that an acceptable level of safety will be met and users have been consulted. When appropriate, the responsible authority shall ensure that adequate provision is made for post-implementation monitoring to verify that the defined level of safety continues to be met.

2.2 When, due to the nature of the change the acceptable level of safety can be expressed in quantitative terms, the safety assessment may rely on operational judgment.

2.3 On the other hand, Document PANS/ATM (Doc 4444), in Chapter 2, Safety Management, in item 2.6, *Safety Assessments* para. 2.6.1, *Need for safety assessments*, establishes that:

2.4 A safety assessment shall be carried out in respect of proposals for significant airspace reorganizations, or significant changes in the provision of ATS procedures applicable to an airspace or an aerodrome, and for the introduction of new equipment, systems or facilities, such as:

a) reduced separation minimum to be applied within an airspace or at an aerodrome;

b) a new operating procedure, including departure and arrival procedures, to be applied within an airspace or at an aerodrome;

c) a reorganization of the ATS route structure;

d) a resectorization of an airspace;

e) physical changes to the layout of runways and/or taxiways at an aerodrome; and

f) Implementation of new communications, surveillance or other safety-significant systems and equipment, including those providing new functionality and/or capabilities.

Note 1. A reduced separation minimum may refer to the reduction of a horizontal separation minimum, including a minimum based on required navigation performance (RNP), a reduced vertical separation minimum of 300 m (1000 ft) between FL 290 and FL 410 inclusive (RVSM), the reduction of a radar separation or a wake turbulence separation minimum or reduction of minima between landing and/or departing aircraft.

Note 2. When, due to the nature of the change, the acceptable level of safety cannot be expressed in quantitative terms, the safety assessments may rely on operational judgement.

2.5 Proposals shall be implemented only when the assessment has shown that an acceptable level of safety will be met.

2.6 On the other hand, Doc 9613, Performance-based Implementation Manual, in analysing Process 3 for implementation, establishes that the first step of this process is the formulation of a safety plan for the PBN implementation and leads to the application of the methodology of the Safety Management Manual (SMM). It also indicates that, depending on the nature of the implementation, this could be a State or regional safety plan as in our Region. Part A, Chapter 3, *Considerations on Safety Assessment* of Doc 9613, is inserted as **Appendix A** to this working paper.

Safety assessment of PBN project for en-route operations

2.7 In view of the above, PBN project for en-route operations in the SAM Region, evaluated some aspects related to the development of a plan for performance measuring including gas emissions, safety, efficiency, etc.

2.8 As per the analysis carried out by the SAMIG Group, the airspace safety assessment methodology may be quantitative or qualitative. An example of quantitative method is the safety assessment applied to RVSM implementation and post implementation. These quantitative methods are based in the Collision Risk Model (CRM) and require the hiring of experts in specific areas, such as Statistics and Mathematics. Safety assessment for the application of en-route PBN application would be justified only in case of great changes in the airspace, such as a complete routes network restructuring in a significant airspace volume. Examples of Collision Risk Models used in the safety analysis are shown in Doc 9689, *Manual on airspace planning methodology for the determination of separation minima*.

2.9 For the implementation of isolated routes, or as in the case of RNAV5 implementation in the South American Region airspace, the SAMIG agreed that a qualitative evaluation would be more appropriate, based in the operational judgment. This decision was adopted in view that the ATS routes structure is not expected to be modified, but only the definition of RNAV5 specification in RNAV routes already implemented in the Region. Then, this type of assessment must be documented through a safety case, based on the SMS methodology. An example of systematised use of this methodology is doc 9859 – ICAO Safety Management Manual, and Doc CAP 760 (Guidance on the conduct of Hazard Identification, risk Assessment and the Production of Safety Cases), from United Kingdom. This latter document may be found in the following website: **http://www.caa.co.uk/docs/33/cap760.pdf**.

2.10 Another matter considered by the SAMIG Implementation Group for the future is that will be necessary to make an estimate of the "route spacing" based in specific characteristics of a precise airspace, such as passing frequency, air traffic volume, lateral deviations, etc. This method is based on quantitative methods, using CRM. As previously mentioned, in this first phase the routes spacing applied in the region is not expected to change.

Prepare a preliminary assessment on safety in the airspace

2.11 Preliminary safety assessment shall be finalised a year before the implementation, this will ensure the necessary conditions for the beginning of the pre-operational phase for a one-year period.

Prepare a final assessment on safety in the airspace

2.12 The final safety assessment is normally carried out one year after implementation, which will ensure the operational phase of one route or routes network.

SAM Region ATS routes network optimisation project safety assessment

2.13 SAMIG concluded that in the same way as for RNAV5, when analysing the ATS routes network optimisation programme, it would be necessary to establish a safety assessment methodology within the study of Phase 1, Implementation of Version 01 this project, in function of the magnitude of the proposed changes. The study was revised by the SAM/IG/4 Meeting and concluded that a safety assessment would be carried out jointly with the RNAV5 implementation project, reason for which projects, RNAV5 and ATS routes network will be evaluated jointly.

Conclusions

2.14 As it may be noticed, ICAO SARPs on safety management are shown in Annexes 1; 6, Parts I and III; 8, 11, 13 and 14.

2.15 Annex 11, para. 2.27.5. "*Safety Management*" establishes that any significant change will only become applicable after an assessment has proven that it will meet the target level of safety and that users have been consulted, but at the same time indicates that, when, in view of changes, the target safety level may not be expressed in quantitative terms, safety assessment shall depend on an operational judgment.

2.16 Document PANS/ATM (Doc 4444), in Chapter 2, Safety Management, in item 2.6, Safety Assessments, para. 2.6.1, need for safety assessments provides the main guidelines to carry out a safety assessment in a system and reaffirms that, when due to changes the acceptable level of safety may not be expressed in quantitative terms, safety may depend on an operational judgment.

2.17 In addition to the above, the systematic focus of safety implies among others, that each element of the ATM system wherever applied (aircraft, ground, airspace, etc), will be subject to a specific analysis of safety, as a particular element and as a component of the integrated system of a greater nature. Implementation of any system element will be subject to appropriate processes of safety assurance.

2.18 When a change in a system implies a deviation regarding operational boundaries currently approved, management of the change must be evaluated and carried out in order to ensure that these changes will not adversely affect the system.

2.19 In view of the above, both in the RNAV5 implementation programme and the ATS routes network optimisation programme, it was concluded that due to the nature of the changes to be produced with both implementations, safety assessment will be carried out through a safety case, based on SMS, as shown in ICAO Doc 9859, Safety Management Manual (SMM).

2.20 The assessment of hazards that the implementation of both programmes could face, shall determine how do the different ATM system components contribute to safety management, which are the deficiencies to be corrected, and will give us a more solid idea of the current and future situation in the safety field, and will let us clearly define de risk mitigation measures for each one of the hazards identified. A monitoring programme of implementation will also help us to identify whether the necessary mitigating measures to be implemented respond to the safety objective expected and shall enable introduction of improvements into the system.

3 Suggested action

3.1 The meeting is invited to:

a) Take note of the information provided in this working paper;

b) Provide the comments deemed pertinent upon the proposals presented in this document; and

c) Agree to carry out a safety assessment through a safety case based on the SMS methodology contained in Doc 9859, Safety Management Manual (SMM).

APPENDIX A

Part A, Chapter 3 Safety Assessment Considerations - Doc 9613

Chapter 3

SAFETY ASSESSMENT CONSIDERATIONS

3.1 SAFETY ASSESSMENT CONSIDERATIONS

3.1.1 Introduction

3.1.1.1 Parts B and C of this volume contain navigation specifications which are applied in an airspace concept. When applying a navigation specification, a number of safety considerations have to be assessed.

3.1.1.2 Planners should consult these key reference documents:

— *Safety Management Manual (SMM)* (Doc 9859), Chapter 13, provides guidance on performing safety assessments.

— *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689), provides information on quantifying the effect separation minima have on air traffic safety.

— *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168), Volume II, provides design criteria for ATS routes and procedures.

— *Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905), provides design criteria for RNP AR procedures.

— *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM) (Doc 4444), provides separation minima.

3.1.1.3 The following provides an overview of some of the performance characteristics that need to be considered in the safety assessment. Table II-A-3-1 providing cross-references to safety assessment references for the navigation specifications in Parts B and C of this volume concludes the section on safety assessment.

3.2 AIRCRAFT PERFORMANCE

3.2.1 *Normal performance:* Lateral accuracy is addressed in the individual navigation specifications in Parts B and C of this volume. Lateral accuracy is expressed in terms of a nautical mile value on either side of a desired track centreline. The aircraft is expected to be within that lateral value of the desired track centreline for 95 per cent of the time. Longitudinal accuracy is also defined as the accuracy of distance reporting or the fix location.

3.2.2 *Non-normal errors:* Navigation specifications in Part B of this volume do not define aircraft performance in cases of non-normal errors. Non-normal errors include RNAV system failures, as well as “blunder” type errors such as selection of the wrong route. Navigation specifications in Part C of this volume address some non-normal errors through the on-board performance monitoring and alerting requirements, including aircraft and signal-in-space failure conditions. Blunder errors are not included in the on-board performance monitoring and alerting requirements, and must be handled through crew procedure and training, detection through surveillance or additional separation.

3.3 SYSTEM FAILURES

3.3.1 The safety assessment must consider aircraft that have single navigation systems, where allowed in the particular navigation specification. Potential mitigations are identified by considering the nature of the aircraft system failure, availability of alternate means of navigation and the available CNS ATM environment.

3.3.2 In a surveillance environment, one aircraft with a failure of navigation capability could normally be handled successfully by ATC. Where there is no surveillance, it is necessary to consider two situations: 1) the complete failure of the RNAV system; and 2) the potential that an aircraft's navigation system has an unreported position error. In either case, mitigations will need to be identified and incorporated into the operating procedures in order to implement the navigation application.

3.3.3 Potential mitigations will depend upon the ATM environment. For example, in the case of complete navigation system failure on an aircraft, where the navigation application is implemented in a low-traffic environment, with no intent for future implementation of closely spaced tracks, autonomous navigation capability (inertial or dead reckoning) may provide sufficient reversion. In cases where there is a plan to implement closely spaced routes, a potential mitigation could be to increase aircraft separation to enable safe operation in a procedural environment. In a non-surveillance environment, RNP navigation specifications address the issue of unreported position errors through the requirements for on-board performance monitoring and alerting.

3.4 INFRASTRUCTURE

3.4.1 Failure of navigation aid (navaid) environment

3.4.1.1 The impact of failure of the navaid environment depends upon the navaids being employed for the operation. For most ground-based navaids, the number of aircraft using a given aid is normally small. Depending on the number of navaids available, the loss of a single VOR or DME facility may not result in the loss of position fixing capability. The navaid infrastructure environment and the degree of redundancy of navaids will need to be specifically studied. Inertial navigation capability should also be considered for mitigation of a sparsely populated ground-based navaid infrastructure.

3.4.1.2 When GNSS is planned to be the main or sole positioning source, consideration needs to be given to the impact of loss of navigation capability, not to just a single aircraft, but to a predetermined population of aircraft in a specified airspace. *Global Navigation Satellite System (GNSS) Manual* (Doc 9849) provides guidance when GNSS is planned to be used. Where ATS surveillance is proposed as the mitigation, consideration has to be given to the acceptability of the resulting ATC workload, in the event of a possibly near-simultaneous loss of navigation capability by a number of aircraft. The likelihood of GNSS outage should be considered in the evaluation.

3.4.1.3 If it is considered that the likelihood of an outage is unacceptable and the ATC workload would not be acceptable, and therefore that reliance only on ATS surveillance is an unacceptable mitigation solution, another mitigation could be an aircraft requirement for carriage of an alternative navigation capability. An example could be the requirement for the carriage of an inertial navigation capability. Other potential mitigations, depending on the navigation specification being implemented, could be a requirement for the availability of an alternative terrestrial navaid input to the RNAV system position solution.

3.4.2 ATS surveillance and communication

3.4.2.1 Along with considering the aircraft performance requirements of the navigation specification planned for implementation, and the available navaid infrastructure (both for primary and reversionary navigation capability), the

contributions of ATS surveillance and communications to achieve the TLS for a desired route spacing, must be considered. ATS surveillance and communications can be examined to determine what mitigation to navigation errors they can be expected to provide.

3.4.2.2 The availability of ATS surveillance along the route is a major element in determining if the desired route spacing for the planned navigation implementation (i.e. the navigation application) will support the TLS. The amount of redundancy in the ATS surveillance capability must also be considered.

3.4.2.3 With the exception of navigation specifications implemented in oceanic or continental remote airspace, where HF, SATCOM and/or CPDLC can be encountered, the ATS communications requirement is VHF voice. In some States, UHF voice to support military operations is also available. In addition to accounting for the availability of communications, the reception strength of the communications (strong or weak signal) should be considered.

3.4.2.4 The effectiveness of ATC intervention in the event of an aircraft not following the route centreline must be considered. In particular, controller workload in a busy environment can delay ATC recognition of unacceptable route centreline deviation beyond the point where the TLS is maintained.

Table II-A-3-1. Navigation specification safety assessment references

Navigation specification	*Safety assessment references*	*Notes*
RNAV 10 *Note.— Retains designation of RNP 10 in implementation.*	1) *Regional Supplementary Procedures* (Doc 7030) 2) *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689) 3) *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM) (Doc 4444)	
RNAV 5	EUROCONTROL B-RNAV route spacing study European Region Area Navigation (RNAV) Guidance Material (ICAO EUR Doc 001, RNAV/5)	
RNAV 2	To be developed.	
RNAV 1	EUROCONTROL safety assessment of P-RNAV route spacing and aircraft separation	
RNP 4	1) *Regional Supplementary Procedures* (Doc 7030) 2) *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689) 3) *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM) (Doc 4444)	
RNP 2	To be developed.	Navigation specification in development.

Navigation specification	*Safety assessment references*	*Notes*
Basic-RNP 1	*Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168), Volume II	
Advanced-RNP 1	To be developed.	Navigation specification in development.
RNP APCH	*Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168), Volume II	
RNP AR APCH	*Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual* (Doc 9905)	