EUROPEAN ORGANISATION
FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

SINGLE EUROPEAN SKY
(SES) REGULATIONS

ENCLOSURE 2

DRAFT ADVISORY MATERIAL FOR

THE ESTABLISHMENT OF A RISK CLASSIFICATION SCHEME FOR THE DESIGN OF THE AIR TRAFFIC MANAGEMENT (ATM) FUNCTIONAL SYSTEM

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Edition 0.6

DOCUMENT CHANGE RECORD

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

Edition No.	Date	Reason for Change	Pages Affected
0.1	26-Nov-07	New document submitted to review group (former Annex 1 of justification material).	All
0.2	23-Jan-08	Revised document after review.	All
0.3	11-Jun-08	Revised document after formal consultation	All
0.4	29-Jul-08	Revised document after internal SRU review	All
0.5	20-Aug-08	Revised document after last comments received from States	All
06	10-sep-08	Revised document after comment received during the working session (28 august 08)	all

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EXECUTIVE SUMMARY

EUROCONTROL has been requested to support the European Commission (EC) in developing appropriate regulatory material for a Risk Classification Scheme (RCS) for the design of the ATM functional system. A Mandate formalising this request (the RCS Mandate) was accepted by EUROCONTROL in April 2006.

In response to the Mandate, EUROCONTROL has developed a draft Implementing Rule in consultation with stakeholders and technical experts to lay down the requirements for the definition and implementation of a common set of safety targets at European level and its apportionment in RCS at States' level.

The purpose of this document is to present non-binding advisory material which should help the EU States to implement the European RCS. The non binding documentation is divided into two parts. The part A of the document presents the material which could be considered as the basis for a Community Specification (CS) and therefore become a means of compliance to the proposed draft rule. The part B of the document presents the material which should be considered as guidance to assist the States in the implementation of their RCS.

This document establishes a common set of safety targets at European level, identifying *inter alia* their values for each severity class of risk at European level. The process for their calculation, together with the underlying rationale, is also presented. In addition the document proposes an approach for the apportionment by the States of the Common set of safety targets.

Using the existing data available at EUROCONTROL (i.e. ESARR 2 Annual Summary Template), the statistical analysis shows the limitations in term of confidence, uncertainties and variability to support the calculation of a common set of safety targets. Due to those limitations, only the safety target for severity 1 is considered as binding. The other safety targets are not binding but should provide a baseline for the implementation of the common set of safety target in RCS at State level. Further development of data reporting systems at European level will be required to support inclusion of the targets within the Implementing Rule itself.

The document also deals with the complex subject of apportionment at State level of the European safety targets. With no prejudice of the methodology of apportionment already used at organisation level, the document is providing a generic process in order to ensure an apportionment of the European common set of safety targets at State level. However, the analysis on this subject shows that an universal apportionment applicable to all individual elements of ATM does not exist, as apportionment is dependent on the role of the organisation to which it applies, and as the services provided by this organisation involve various part of the ATM functional system from an organisation to another. States should therefore undertake their own specific apportionment of the single EU common set of safety targets in order to obtain their RCS.

Finally, EC Regulation 2096/2004 allows that *quantitative approach can be complemented by qualitative* arguments for the design of the ATM functional system under the responsibility of the ANSP. The establishment of *quantitative* targets is the objective of this mandate however *qualitative* aspects cannot be ignored and have to be considered with the adequate level of rigor when necessary.

In accordance with existing regulations, ANSPs should develop safety objectives consistently with the values of the European RCS established and apportioned at State's level. The development of safety objectives and the apportionment process at

ANSPs' levels should be consistent with existing standards and recognised best practices. This is not the objective of this present document.

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1. INTRODUCTION

EUROCONTROL has been requested to support the European Commission (EC) in developing appropriate regulatory material for a Risk Classification Scheme (RCS) for the design of the ATM functional system. A Mandate formalising this request (the RCS Mandate) was accepted by EUROCONTROL in April 2006. The material produced in response to this Mandate will include a draft Implementing Rule (IR) *"Establishing a Risk Classification Scheme for the Design of the ATM Functional System"* and associated advisory material.

An RCS is an approach used within the safety assessment and mitigation process for ATM functional system to classify the risk and to determine required Safety Targets as thresholds not to be exceeded when designing such a system. In an RCS, in order to represent the classification of the level of risk, a table is used to associate the severity of the effect of each hazard arising in the ATM functional system with the rate of occurrence of all risks having a given severity. The combination of these two is called a Safety Target.

2. CURRENT REGULATORY SITUATION

The CR's have been the basis for the transposition of ESARR 4 requirements into Community law, but do not include quantified safety targets, as these could not yet be considered sufficiently mature for inclusion into legislation. However, the need to complete the RCS was identified and specified in Recital 16 of the CR's, which specified that "EU Member States and the EC, acting together with EUROCONTROL, should complete and update those values".

Commission Regulation (EC) No. 2096/2005 (Common Requirements or CR's) contains a severity classification scheme for the identification of the effects of ATM related hazards on the safety of aircraft.

EUROCONTROL Safety Regulatory Requirement No. 4 ‘Risk Assessment and Mitigation in ATM’ (ESARR 4) contains an RCS with a maximum tolerable rate for ATM directly contributing to accidents in the ECAC region. In the ESARR 4 scheme, a *quantified* maximum tolerable rate has been established for severity class 1 occurrences - the most severe - those leading to an accident. Maximum tolerable rates for severity classes 2 (serious incidents) to 5 (no impact on safety) have still to be developed.

3. PURPOSE, STRUCTURE AND AUDIENCE OF THE DOCUMENT

3.1 purpose

The purpose of this document is to present non-binding advisory material which defined a RCS at European level. This document is supporting the draft implementing rule dealing with the RCS for the design of ATM functional system and should help the EU States to implement their RCS on the basis of a common set of safety targets defined at European level. On one hand it provides the material which could be considered as being the basis of a further standard, like a Community Specification. On the other hand, it develops the rationale justifying the values and the methodology proposed for the apportionment of the safety target for accidents. This material includes:

- A common set of safety target values and their justification for severities 1 to 4 (no target will be set for severity 5).
- In the case of severity 1 (accidents), the safety target value corresponds to the term “highly improbable” of the RCS implementing rule.
- The set of all RCS values are called “common set of safety targets”, as defined in the RCS implementing rule.
- The rationale which has been developed in order to justify the values of the safety targets.
- Finally, the document proposes an approach for the apportionment of the European RCS which can be used the EU States to implement the European values taking into account the characteristics of their traffic and/or organisation.

3.2 Structure

The document consists of two types of materials presented in two parts.

- The material (part A of this document) which could be considered as the basis of a Community Specification (CS) which and therefore become a means of compliance to the proposed draft rule. The part Aaddresses:
    - Quantitative aspect of the design of ATM functional system : Common set of Safety Targets
    - Safety target for Accidents
    - Other safety targets
    - Apportionment Process
    - Qualitative aspects in safety assessment and mitigation process
- The material (part B of this document) which should be considered as being guidance, to assist the States in the implementation of their RCS.
    - Justification of the values of the common set of safety targets
    - Data Base
      Uncertainties of historical data vs. future needs
    - Process for establishing safety targets in RCS
    - Apportionment Methodology
      Apportionment Methodology at State level
    - Example of different types of apportionment
    - Constraints applicable to the apportionment process

3.3 Audience

The RCS as proposed in this document is an input to the States to define their national values consistently with the European safety targets.

This document is aiming to support the States’ in the implementation of the RCS. It does not provide an apportionment process and or methodology for the establishment of safety objectives at organisations’ levels[1].

[1] In accordance with existing SES regulation (EC) 2096/2004, ANSP should develop safety objectives related to the design of the ATM functional system consistently with the European RCS established and apportioned at State level. The development of safety objective and the apportionment process at ANSPs’ levels are developed in other specifications or standards as. They should use their own apportionment processes, which should be consistent with the European RCS apportioned at State’s level and under the supervision of the NSAs. Other organisations than the ANSPs, should have similar approach, when it is required by specific implementing rules.

4. PART A: PROPOSED MEAN OF COMPLIANCE WITH THE RULE

4.1 Common set of Safety Targets

The common set of safety targets is a set of 4 values which are associated at European level to severities classes 1, 2, 3, 4. The common set of safety target is the baseline for the implementation of the RCS and its apportionment at State's level.

The establishment of the common set of safety targets and the use of a RCS is independent from the overall performance of safety which is achieved in operation.

The common set of safety targets does not deal neither with accurate design of specific equipments, nor with a specific local implementation of the ATM functional system. They should therefore be apportioned by the State in order to establish the values against which the organisation should design their part of the ATM functional system, including software, procedure and human contribution.

The definition of the common set safety targets in ATM at European level and its implementation by the States are specifically focused on the design of the parts of the further ATM functional system.

Designing such a system against the common set of safety targets should lead to the overall improvement of its safety performances. However the common set of safety targets are mathematically linked neither to the monitoring of the safety levels nor to performance indicators.

The ATM functional system should be designed against the values of the common set of safety targets defined at European level for the year 2020.

The parts of ATM functional system should be designed taking into account the apportioned values of the RCS safety targets.

The use of a RCS for the design is made mandatory by the implementing rule, and the organisation / ANSP should provide evidences that the part of the ATM functional system under its responsibility is designed against those values.

The common set of safety targets at European level is presented in the table below; the common set of safety target should be reviewed every five years.

Severity	*Effect*	*Common set of safety targets (per flight hours)*	*Reference to the RCS Implementing Rule*
1	Accident	10^{-8}	Highly Improbable
2	Serious incident	10^{-5}	
3	Major incident	10^{-4}	
4	Significant incident	10^{-2}	
5	No effect	No target	Not referred in the rule

Common set of safety targets in EU

4.2 Safety target for severity 1: accidents

As required by the RCS implementing rule, the probability that an accident (Severity 1) consequence due to change to the ATM functional system should remain “high improbable” i.e. with a maximum probability of 10^{-8} accident per flight hours.

The safety target used for the design of individual parts of the overall functional system and their combinations must be established such that the overall safety target at national level is met. However, the risk of an accident (severity 1) must remain "highly improbable" whatever the provided services are.

4.3 Other safety targets: severities 2 to 5

The establishment for the values associated to severity 2, 3, 4 are based on the projection of estimates which should be confirmed over time because of the uncertainties and variability of data base.

The common set of safety targets associated to severity 2 to 4 should be considered as a baseline for the implementation of values for severity 2 to 4 of a RCS at State level.

The severity 5 is the severity class which is related to the effects with no safety impact. It should not have quantitative target.

4.4 Establishment of the State’s Risk Classification Scheme

The State should establish a RCS for severity 1 to 5 taking into account:

- The maximum probability of 10^{-8} accident per flight hour establishes the safety target for severity 1 as “highly improbable”.
- The State should implement its RCS using the common set of safety targets associated withseverity 2 to 4 which represents the maximum probabilities for those severities.
- The State should choose safety target for severity 2, 3, 4, but should not propose values greater than the values of the common set of safety targets for severity 2 to 4.

The State should assess the values of the safety targets of his RCS every 5 years.

4.5 Apportionment process

The safety targets should apply to the entire ATM functional system and be taken into consideration when an individual change is made to the ATM functional system. The value of the overall safety target does not apply to individual changes. The values applied to an individual change are the safety objectives calculated by the mechanisms developed by the organisation and / or ANSP in accordance with its safety assessment and mitigation process.

At State level it is highly recommended to use an apportionment consistent with the type of services which are provided over his territory. It is recommended to establish an apportionment which is independent of the implementation of the functions and services.

The apportionment consists in distributing and propagating an overall safety target into different parts of a breakdown structure.

Several apportionments strategies should be possible.

Depending of the apportionment strategy chosen by the State, the safety targets which is distributed within the breakdown structure can be expressed in the unit which is pertinent to the demonstration, for instance per flight hours, per movements, etc…

The values are apportioned amongst different levels of the breakdown structure. Those values should be determined by extrapolating the potential harmful effects of the changes having an impact at each levels of the breakdown structure.

As a minimum, the State should apportion the value for severity 1 to its traffic or/and to its organisations.

The organisation / ANSP should use the apportioned safety targets in order to develop the safety objectives.

Some principles should be applied by the States, to ensure that the apportionment relies on justified criteria to distribute the risk between the different levels of the structure:

- The apportionment process should be supported by an explicit strategy,
- The components of the breakdown structure should be identified explicitly,
- The mechanisms of generation and propagation of the apportioned safety target should be clearly identified and should be reliable and valid,
- The apportionment is independent enough from variable elements and remain valid while the implementation of ATM functional system is evolving,
- The independence between the different parts of the breakdown structure can be assured.
- The criteria to stop the breakdown of the structure should be defined explicitly.

4.6 Qualitative aspects in safety assessment and mitigation process

The objective of the RCS regulation is to establish quantitative safety targets. However the demonstration that quantitative safety targets are met might be limited by uncertainties.

In addition to the quantitative safety arguments, qualitative safety arguments should be considered for the design of the ATM functional system.

It is important that the qualitative estimate of the risk is supported by the conclusions from the largest possible panel of experts.

The reasons of the limitation of the quantitative safety demonstration should be explained in the safety arguments provided by the organisation.

It should be highly recommended to provide evidences, if *qualitative* aspects should be developed, that all safety arguments (qualitative and quantitative) have been included in the design of the functional design.

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5. PART B: JUSTIFICATION OF THE VALUES OF SAFETY TARGET

The regulatory framework should provide clear targets in order to ensure an effective implementation of the safety requirements resulting from the risk assessment and mitigation applied by an organisation / ANSP in relation to ATM functional systems. The organisation / ANSP needs to know the maximum tolerable frequency of accidents and incidents caused by hazards, or any combinations of failures which can cause losses of separation.

This input is essential to determine specific safety objectives applicable to parts of the ATM functional system, notably in the case of changes to this ATM functional system. Thus, it is important to stress that, irrespective of the way the safety targets are apportioned at lower levels, there will still be some rather complex safety allocation process to derive safety objectives. Following the analysis of existing risk, it is essential to determine the level at which a risk becomes unacceptable for society and for the ATM functional system users. The RCS is a representation of this tolerable risk and it is the pivot of the risk allocation process. This section deals with:

- The justification of the values of the common set of safety targets,
- The apportionment methodology,
- The considerations given to quantitative aspects.

5.1 Safety Data to Support RCS establishment

5.1.1 AST Data Base

It exist several data base of occurrences reports in aviation, for instance the ICAO data base. The AST data base has been chosen to be the baseline of the calculation of the common set of safety targets because this data base gives a framework for the reporting ofsafety occurrences at European level. Several types of safety occurrences should be reported and the estimated safety impact of these occurrences is taken into consideration.

In accordance with the requirements forsafety occurrence analysis (ESARR 2), Annual Summary Template (AST) reports are provided each year to the EUROCONTROL (SRU) by ECAC Member States. These contain summary data, as analysed by States, on accidents and incidents and form the basis of the statistics provided in the Annual Safety Reports of the Safety Regulation Commission (SRC). ESARR 2 has been mandatory since 2000, but was also applied voluntarily by States to cover the year 1999.

The levels and quality of reporting has improved year after year and, in particular, the period between 2001 and 2006 gives results of good quality. Even if some variation exists in the levels of reporting, continued work with Member States by EUROCONTROL has ensured that the reported data are now sufficiently homogeneous to support a realistic estimate of orders of magnitude for the safety target for the design of the ATM functional system.

The information provided by this process is proposed as the European baseline to establish the RCS safety targets. The number of occurrences which have been already reported through that process is sufficient to support the statistical analysis for establishing a risk classification scheme at European level.

Having regard to the quantity of safety occurrence data available for the establishment of targets, the table below shows the number of reported occurrences from 1999 to 2006, all categories included:

Accidents (all types)	4,335[2]
Ops Incidents (all types)	101,351
Technical incidents (all types)	40,843

Member States provide the numbers of occurrences related to aircrafts those MTOW is above 2.25 Tons. The occurrences are categorised as follows in the template of the AST:

- General Air Traffic (GAT) operations;
- Fatal accidents;
- Non fatal accidents;
- Accident with direct ATM contribution;
- Accidents with indirect ATM contribution;
- Types of flights (Commercial, general aviation, other);
- Flight rules (VFR/IFR);
- Types of operation (GAT/OAT);
- Phases of flights;
- Classes of airspace,
- Different types of accidents:
    - Mid air collision;
    - CFIT;
    - Ground collisions between aircraft and/or objects;

More specifically, with regard to the calculation of common safety target and in accordance with the draft implementing rule, for each State of the 29 States (27 EU states plus Switzerland and Norway) only a part of this information has been taken into consideration for the calculation of the ALS. The principal focus is placed on:

- General Air Traffic (GAT) operations.
- Accidents with direct and indirect ATM contribution
- Number of safety occurrences classified in accordance with ESARR2

When reporting through AST, States categorise accidents and incidents in terms of their severity, and these reported severities take into account the effects of safety nets in the achieved safety performance represented by the ALS. For the design of new systems and under certain conditions defined in the EUROCONTROL SRC policy on their use, safety nets may now be included in the common set of safety targets for the ATM functional system design. This being the case, it is considered that the severity classifications used in safety reporting (such as in ESARR 2 and consequently in AST) and in ATM functional system design (such as in ESARR 4) are equivalent.

The current AST occurrence reporting system has certain limitations, mainly associated with the software tool which is used to support the AST database. As a result, data-mining capabilities are limited and prevent specific analysis in certain directions. Nevertheless, actions are being taken to remove these limitations through the improvement of this database and to support future data reporting requirements.

[2] *A period up to 2004 includes all types of accidents (including small aircrafts and ultra light) the annual average is 692 accidents per year, the second period consider only the 2.25 ton Maximum TOW.*

Common practices in statistics show that the inability to precisely predict future safety targets is due to two factors: uncertainty and variability. On one hand, the AST reporting as with any empirical approach is subject to uncertainties regarding the data which are reported. On the other hand, the calculation of the safety targets, as any statistical approach, has to deal with random variability.

The uncertainty deals with the limits of the knowledge about the domain being studied. The variability is linked to the randomness of the characteristics of the sample provided by AST data. The lack of statistical techniques means that uncertainty is difficult to measure, but this can be mitigated by gathering more data and improving the characteristics to be sampled. The variability can be estimated.

The determination of common set of safety targets faces both uncertainty and variability factors, and as the need exists to confirm over time the values chosen, uncertainty and variability have to be taken into account in the methodology. A first set of safety targets for all severities is therefore established in a way which can ensure their improvement. This advisory material proposes a methodology in order to progressively reduce uncertainty and variability factors over time.

The concepts of uncertainty and variability, together with their effects on establishment of a common set of safety target, are explained further in Section 5.1.2 and 5.1.3 below.

5.1.2 Uncertainties of Historical Data vs. Future Needs

The AST historical baseline is that provided by Member States since 1999. The uncertainties of the characteristics of the reported data which are needed for the calculation of safety targets depend on the:

(a) reliability of the numbers of occurrences reported per severity class by Member States. In general, the reporting of safety occurrences of severity 1 and 2 (accidents and serious incidents) may be considered more reliable than for severities 3 and 4. With regard to occurrences classified as having no impact on safety, the AST data have not been taken into consideration in the calculation of safety targets due to their lack of reliability. Considering severity 3 and 4, the reporting processes are now supported by specific measures such as automated tools and, together with improved reporting cultures and transparency given by the analysis related to those occurrences, they ensure better confidence in those data;

(b) availability of safety occurrence data from some Member States. The number of reported incidents depends on the level of implementation of safety occurrence reporting by Member States. It has been agreed by the EUROCONTROL Provisional Council (PC) that Member States' efforts in this area should be improved. Gathering more information year after year can reduce uncertainty and several projects have been launched with this objective through the European Safety Programme (ESP) and the PC's Safety Reporting (SAFREP) Task Force. To date, an improvement of data reported has been confirmed in the SRC's 2006 Annual Safety Report, and a revised format of AST is yielding improved information, and therefore improved reliability;

(c) use of automatic safety reporting tools. Some organisations / ANSPs report safety occurrences to the NSA by using specific tools. This increases the level of confidence in the data collection process completeness as it does not rely solely on human reporting

(d) classification of the severity of the occurrences is not yet fully harmonised at European Level. In particular, some overlaps exist in the national classification, especially for severities 2 and 3, and severities 3 and 4. This harmonisation will be reviewed as the maturity of the reporting process improves. However, while differences exist, they are consistent through the overall safety reporting process at EU level and, by applying correction factors, can be assumed not to have any significant impact on the trends.

(e) estimation of ATM contribution. The depth of the analysis of occurrences (incident and accident investigations) can be variable, and therefore the attribution of ATM contribution can be uncertain. Once again, a sampling made in order to estimate the uncertainties will be easily undertaken once the planned improvements in safety occurrence reporting at European level have been implemented.

In practice, therefore, several methods can be put in place to reduce uncertainty. As well as AST process enhancements, improvement in Member States' know-how in occurrence-reporting is taking place, and the sampling of reports, for example through the ECCAIRS data base, can help to estimate the percentage of errors/difference in the classification of occurrences and in the estimation of their ATM contribution.

5.1.3 Taking in account the variability of the ALS

Variability addresses the element of randomness that exists within the reporting process, such as the variation in numbers of occurrences or the variation of their characteristics between one annual data set and another. This variability can be defined more accurately by further data collection, but can never be eliminated.

In order to reduce variability, the calculation of safety targets focused on the six-year period for which robust data exists for both incidents and accidents. The use of descriptive statistics is used to estimate the consistency of the calculated rates. By taking basic statistical indicators, (mean, median, standard deviation), confidence levels have been calculated and are presented and commented in the following sections of the document.

This statistical approach gives information on the confidence and the consistency of the data which are provided to date by Members States. This basic approach will be improved through further statistical development, but requires data to be gathered over a more extended period.

5.1.4 Process Establishing the Common Set of Safety Targets

The generic process for the establishment of a common set of safety targets at European level to be used in States' (or Functional Airspace Block – FAB's) RCS, as applied at the European level, can be summarised by the steps as follows:

- **Step 1: Gathering of Historical Occurrence Data:**
    - Identifying the data needed from AST for the calculation.
- **Step 2: Gathering of Data on Actual Traffic (European)**
- **Step 3: Yearly Rates for Achieved Levels of Safety (ALS):**
    - Deriving, on the basis of the AST, the Achieved Level of Safety (ALS) for accidents having an ATM contribution (severity 1) during the period 1999-2006 for General Air Traffic (GAT);
    - Estimating the ALS for incidents (2001-2006; severities 2 to 4);
    - Limiting the uncertainties of the ALS by focusing on "best reporters";

  - Perceiving the variability of the sample.

- **Step 4: Trends for Traffic Growth and "Reference Year";**
  - Identifying 2020 as being the year of reference for the estimation of the future safety target definition;
  - Projecting the evolution of traffic;
- **Step 5: Estimation of Safety Targets for Severities 1 to 4 (in 2020)**
  - Taking into account future developments and the interpretation of SESAR objectives for safety improvement;
  - Considering the 3-fold improvement factor applied to ALS;
  - Proposing a common set of safety targets taking into account the calculated historical values (including their uncertainties and variability and the improvement factor.
- **Step 6: Periodic Verification of Safety Targets**

As applied at the European level, the steps are explained in more detail in the following paragraphs.

5.1.4.1. Step 1: Gathering Historical Occurrence Data (from AST)

In meeting the need for safety improvement in ATM, the implementation of risk mitigation can be done through any part of the ATM functional system, even when those parts relate solely to the environment of operations, such as airspace design or ATFM. Their respective contribution to ATM safety is already demonstrated.

In addition, for design purposes, it has been agreed that some part of ATM which can indirectly contribute to safety occurrences may have a positive contribution with regard potential mitigation means, therefore this role should be taken into consideration for the design of ATM functional system.

The notion of ATM contribution has to be considered in this context. It is therefore equally necessary to consider the contribution of all parts of the ATM functional system, including those that can only result in an indirect contribution to accidents. Accordingly, in considering the use of AST data to support RCS, the scope of ATM contribution has been extended to include occurrences with both direct and indirect contribution.

An analysis of the historical data reported through the AST shows that the data:

- for **accidents** for the period 1999 to 2006 are considered sufficiently reliable, and are therefore may be used in calculations relating to Severity 1.
- related to **incidents** reported for 1999 and 2000 are not considered reliable enough to be included in the safety targets calculation for incidents. Data used for further calculation of common set of safety targets for severities 2, 3 and 4 are therefore derived from the period 2001-2006 inclusive *(N.B. Accordingly, incident data for 1999 and 2000 have been excluded from the relevant tables which follow).*
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The table below presents the number of occurrences per severity class which have been reported through the AST process.

Severity & Type of Event	1999	2000	2001	2002	2003	2004	2005	2006
S1 accidents	1	8	9	4	1	10	2	5
S2 serious incidents			355	342	412	373	399	353
S3 major incidents			881	865	908	1482	1467	1373
S4 significant incidents			1539	5495	8510	8386	9932	10756

Table 1 - Numbers of occurrences per severity class reported through AST

5.1.4.2. Step 2: Gathering of Data on Actual Traffic (European)

The data from the EUROCONTROL Central Flow Management Unit (CFMU) have been used to calculate the:

- number of movements in the European region (i.e. the 27 EU states plus Norway and Switzerland);
- total flight duration taking into account the average flight duration in Europe (same flights from end to end), which is calculated on the basis of CFMU data to which an additional 18% time has been added for taxi duration to provide an overall gate-to-gate figure.
- VFR flights hour are excluded from this calculation.

5.1.4.3. Step 3: Yearly Rates for Achieved Levels of Safety (ALS)

The ALS has been calculated for GAT accidents with ATM contribution from 1999 to 2006. Table 3 below presents the achieved levels of safety year-by-year during this period for the 29 States identified above.

The AST are then used to calculate the numbers of occurrences for different severities on the basis of the classification made by States in their annual AST reports.

The summary of the Achieved Levels of Safety calculated from AST, for all type of safety occurrence (i.e. accidents, and incidents of different severities) are provided in Table 3 below. These ALS are normalised taking into account the yearly levels of traffic provided by CFMU.

GAT Accidents in EU – ATM Involved	1999	2000	2001	2002	2003	2004	2005	2006
No. of GAT ACCIDENTS Reported in AST	1	8	9	4	1	10	2	5
ALS per Flight Hours 18% taxi	8.18E-08	6.07E-07	6.83E-07	3.11E-07	7.51E-08	7.22E-07	1.39E-08	3.33E-07

Table Table 3: Achieved levels of safety for accidents of all EU states (plus Norway and Switzerland) from 1999 to 2006 for accidents (per movements and per flight hours)

Severity & Type of Event	1999	ALS	2000	ALS	2001	ALS	2002	ALS	2003	ALS	2004	ALS	2005	ALS	2006	ALS
S1 accidents	1	8.18E-08	8	6.07E-07	9	6.83E-07	4	3.11E-07	1	7.51E-08	10	7.22E-07	2	1.39E-08	5	3.33E-07
S2 serious incidents					355	2.69E-05	342	2.66E-05	412	3.09E-05	373	2.69E-07	399	2.77E-05	353	2.35E-06
S3 major incidents					881	6.69E05	865	6.72E-05	908	6.82E-5	1482	1.07E-04	1467	1.02E-05	1373	9.13E-05
S4 significant incidents					1539	1.17E-04	5495	4.27E-04	8510	6.39E-04	8386	6.05E-05	9932	6.91E-04	10756	7.15E-04

Table 4 : European achieved level of safety, 29 EU states, between 1999 and 2006 per flight hours for all severities

5.1.4.3.1 Limitation of the uncertainties of the ALS by focusing on the “best reporters”.

It has been already considered that the number of accidents can be objectively calculated with fewer uncertainties than for other severity classes.

With regard to severity 2(serious incidents),taking into account the existing regulatory framework in Europe, it could be considered that the level of reporting is reliable enough. Therefore the order of magnitude of the ALS for severity 2 can be accepted as a basis for the establishment of the common set of safety targets.

The calculation of the yearly ALS presented in table 3 and 4 of Step 3 above relies on statistics made on the basis of the reports from 29 European States. The calculation relies on ratios which do not take into account the differences between the good reporters and the others.

In order to reduce this uncertainty, it is proposed to focus on the States which meet some criteria in terms of the quality of their AST reporting. Twelve European States have been considered to provide a satisfactory safety reporting with regard to the establishment of a common set of safety targets. They represent 75 % of the number of movements in EU for the year 2006.

In order to select the “best reporters”, the several criteria have been taken into account as follow:

- the State provided systematic safety occurrences reporting from 2001 to 2007,
- the number of reported occurrences of each category are credible, for instance:
    - o the overall number of reported occurrences are credible taking into account the size of the state and its level of traffic,
    - o the State with very few occurrence in the category of *serious incident* and numerous occurrences with *no effect on safety* have been removed,
    - o the number of reported safety occurrences for each severity are consistent from one year to another,
    - o the number of occurrences of the same severity are in the same order of magnitude over years.

Some yearly reported occurrences from the 12 selected States are considered as being not credible enough (important inconsistencies between reported occurrences) and have been removed from the calculation.

Table 5 presents the average of the ALS achieved for severity 3 4 over a 6 years period (from 2001 to 2007) for the chosen 12 States. Considering that the ALS values for severity 1 and 2 reliable enough, they are the same as the ones in table 4.

Severity & Type of Event	Severity 3	Severity 4
Average 12 states 2001 to 2007	2E-6	1E-5

Table 5 : ALS severity 3 and 4 for 12 states.

Despite their consistent order of magnitude, they should not be considered as not being enough reliable due the uncertainties explained in chapter 5.1.2.

More specifically when examining in detail the number of occurrences reported by the 12 best reporters, it is clear that for the entire sample of this period the number of occurrences of severity 3 can be extended from 0 occurrences per year to 433.For occurrence of severity 4 the extension is from 2 to 2507 occurrences. It should be taken into consideration the differences in ALS of two powers of ten for severity 3 and three powers of ten for severity 4. In order to show those differences the table 6 presents the mean and the maximum order of magnitude of reported occurrences. A theoretical value of ALS based on the average of the achieved targets for severities 3 and 4, could be too stringent, taking into account these inconsistencies across Europe.

Severity & Type of Event	Order of magnitude of the calculated ALS	Maximum order of magnitude
S3 major incidents	2E-6	2E-4 (1E-4)
S4 significant incidents	1E-5	1E-2

Table 7: Variations in orders of magnitudes of ALS severity 3 and 4

This wide uncertainty should be integrated in the calculation of the common set of safety targets for severities 3 and 4 as presented in further chapter 5.1.9.2.

5.1.4.3.2. Perceiving the variability of the sample on the basis of the mean of the ALS

For each severity, a safety target value is calculated for each of the six years in the chosen period. So, for each severity, a range of safety target values exists from which the final safety target value may be calculated. Overall, the number of targets gathered for a 6 years sample is low, being six for each severity class. In this case, the median values are more representative, more demanding, and represent a better balance of the statistical distribution than the mean values. The median values are therefore used as the basis for further calculation. Beyond the quality of data reporting, some statistical uncertainties remain due to the low numbers of reports for some categories, such as accidents with ATM contribution. In some cases, there are small statistical aggregates, and for others, no occurrences at all are reported as having an ATM contribution. In cases of very small numbers, a very small increase in occurrence numbers may lead to a significant change in the calculated ALS.

Looking at each severity class, the range of values forms a confidence interval, bounded by confidence limits (these being the values of the lower and upper boundaries of the confidence interval). Confidence intervals are usually calculated, using the standard deviation, to a percentage of 95%.

The width of the confidence interval gives an indication of how uncertain we are about the unknown safety target. A very wide interval may indicate that more data should be collected before a conclusion can be reached about the safety target.

Based upon the range identified, it is then necessary to calculate the statistical mean and median for each range of targets in order to approach the final value to be chosen in each severity class.

Overall, the number of targets gathered for a 6 years sample is low, being six for each severity class. In this case, the median values are more representative, more demanding, and represent a better balance of the statistical distribution than the mean values. The median values are therefore used as the basis for further calculation.

Table 8 and table 9 below present the results of the statistical analysis of AST data for the period 2001-2006.

Descriptive Statistics	Accidents	Serious Incidents	Major Incidents	Significant Incidents
Mean	1.37E-7	9.68E-6	2.98E-5	1.90E-4
Median (50%)	1.16E-7	9.58E-6	2.88E-5	2.21E-4
Standard Deviation	9.93E-8	1.02E-6	5.70E-6	7.94E-5
Sample Variance	9.86E-15	1.03E-12	3.25E-11	6.31E-9
Confidence Level (95%)	1.04E-7	1.07E-6	5.98E-6	8.34E-5

Table 8: Descriptive statistics, level of confidence applied (95% and 70%) to ALS (2001 to 2006)

Range of ALS 2001-2006	Accidents	Serious Incidents	Major Incidents	Significant Incidents
Mean - Confidence Level (95%)	3.31E-8	8.61E-6	2.39E-5	1.07E-4
Mean + Confidence Level (95%)	2.42E-7	1.07E-5	3.58E-5	2.73E-4

Table 9: Level of confidence applied to ALS (2001 to 2006) for severities 1 to 4

all severities, all states

The rates calculated for each severity class for the six year period are considered as four statistical values, and are subject to the uncertainties described previously. Nevertheless, the data analysed reveal conclusions regarding the quality of the results.

Taking the values shown in Table 8, the data analysis shows a good level of consistency and homogeneity. While additional indicators[3] can be used, most are only meaningful in the context of a statistically normal distribution, and this cannot be ensured in this case as the sample under consideration is small, and the distribution unclear.

The values for mean and median are close, inferring that the statistical distribution of the data is nearly symmetrical. The median gives better information of the spread of the data in the distribution. Consequently, it will be chosen to establish the safety target of the basis of the value of the Median.

The Standard Deviation (SD) is a small value for each severity class, reflecting a low spread of the data, and serving a good consistent basis for a high-quality result.

The boundaries of the confidence interval are a range of values which inform on the uncertainty of the estimate. It is also an estimate on how sampling contributes to uncertainty of the relation between the true value of the safety target candidate and the estimate of that value. The confidence interval is the range where the true value of the RCS safety target is expected to be, on the basis of the chosen sample.

5.1.4.5 Step 4: Trends for Traffic Growth and “Reference Year”

As the role of an RCS is to support the safe design of future ATM functional systems, it is necessary to define the point in the future at which the system should be designed including all its major improvements. This point in the future will be the "reference year".

The average values for annual traffic growth until now are close to 5%. Taking into account the number of accidents with ATM contribution at European level, it is necessary to estimate traffic levels in the reference year as the next step in deriving values for the safety targets.

[3] *Standard error or Coefficient of variation.*

The estimated values for traffic growth are affected by a number of uncertainties. EUROCONTROL studies forlong-term forecast flight movements (2006-2025) have shown a wide range of factors that impact traffic growth, including economic choices, evolution of prices and types of passenger demand. Taking into account those factors, the studies have further identified several ranges of traffic growth, with low and high boundaries:

- now-2012 : max 4.5% min 3%
- 2013-2015 : max 3.9 % min 2.3%
- 2016-2020 : max 3.5% min 2.6%
- 2021-2025 : max 2.7% min 2.7%

years	progressive yearly traffic growth forecast nb of flights 2006-2030			
	max		**min**	
2006	2,42E+07		2,42E+07	
2007	**2,5E+07**		**2,5E+07**	**4,5% - 3%**
2008	**2,6E+07**		**2,6E+07**	
2009	**2,8E+07**		**2,6E+07**	
2010	**2,9E+07**		**2,7E+07**	
2011	**3,0E+07**		**2,8E+07**	
2012	**3,1E+07**		**2,9E+07**	**3,9% - 2,3%**
2013	**3,3E+07**		**2,9E+07**	
2014	**3,4E+07**		**3,0E+07**	
2015	**3,5E+07**		**3,1E+07**	
2016	**3,6E+07**		**3,2E+07**	**3,5% - 2,6%**
2017	**3,8E+07**		**3,2E+07**	
2018	**3,9E+07**		**3,3E+07**	
2019	**4,0E+07**		**3,4E+07**	
2020	**4,2E+07**		**3,5E+07**	
2021	**4,3E+07**		**3,6E+07**	**2,7%**
2022	**4,4E+07**		**3,7E+07**	
2023	**4,5E+07**		**3,8E+07**	
2024	**4,7E+07**		**3,9E+07**	
2025	**4,8E+07**		**4,0E+07**	
2026	**4,9E+07**		**4,1E+07**	
2027	**5,0E+07**		**4,2E+07**	
2028	**5,2E+07**		**4,3E+07**	
2029	**5,3E+07**		**4,4E+07**	
2030	**5,5E+07**		**4,6E+07**	

Table 10 shows a projection of traffic levels in the EU area until 2030 (the normal range for long-term forecasts). Taking into account long-term ATM developments and, in particular, the projected completion date for the SESAR project, the RCS calculation focuses on 2020 as being the "reference year".

The values in the table are established over a longer period than the SESAR project. The values relating to 2020 are therefore taken into account in the establishment of the safety targets. The increase in traffic until2020 is foreseen as between a minimum of 40% and a maximum of 73%. The calculation of the RCS uses the maximum traffic growth figure.

Table 10: Forecast traffic growth

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5.1.4.6 Step 5: Estimation of Safety Targets for Severities 1 to 4 (in 2020)

At regulatory level , the safety target is arisk acceptance criteria. Taking into account the improvements of the ATM functional system which are foreseen in the coming years, this acceptance criteria cannot be established on the values of the ALS.

The increase of automation and the probablechange of the paradigm of the development of the ATM functional system, relying on alerts and accuracy of the airborne part of the ATM systems will put more requirements on the quality and reliability of the design of the ATM functional system as a whole with regard to equipments, people and procedures.

The safety target(s) of an RCS represents the overall objective(s) to be taken into account when designing a system, or a change to a system. Setting ambitious safety levels will drive the development and implementation of best practices in ATM.

The effective establishment of a safety target for the overall future of ATM also reflects a political will to improve the overall safety, the European Commission expressed the need for a tenfold improvement of safety by 2020 and previously the ATM2000+ strategy also advocated for improving safety levels.

5.1.4.6.1. Interpretation of the tenfold improvement of the ATM safety made by SESAR.

The goal of a tenfold improvement in safety for 2020 which has been given by the European Commission expresses the need to ensure an extremely high level of safety when building ATM functional systems, taking into account future foreseen operational and technological changes, including SESAR. It also represents both a goal that the ATM community has to support, and a societal expectation which it is necessary to achieve taking into account the traffic capabilities foreseen for 2020. This tenfold improvement also needs to be reflected in the safety targets of the RCS. Within SESAR, it is assumed that the improvement is to be incorporated into the design between now and the completion of the Programme in 2020.

The safety targets are figures expressing the need to maintain or improve safety when future developments are implemented in ATM. Moreover, taking into account the important changes foreseen in ATM resulting from SESAR, which will require increases in both ATM capacity and efficiency, setting a safety objective for ATM based purely on a projection of the current ALS would not represent a sufficient improvement in safety sufficient to meet stakeholder expectations.

However, the levels of risk need to be judged with appropriate balance. If the risks are under-estimated, it is possible that, even if the safety targets are met, the number of occurrences would still increase. On the other hand, if the risks are over-estimated, the safety targets may be excessively strict and expensive to achieve.

Therefore this tenfold ratio has to be applied to the historical data to elaborate the safety targets. It is further assumed that the tenfold increase includes forecast traffic growth. In itself, traffic growth will account for the need for *a three-fold increase* in safety (based on the traffic growth estimates presented above in 5.1.8 in 2020) in order not to exceed the current numbers of accidents.

Without setting these ambitious safety targets, long-term success in ATM safety cannot be assured. This increase must be applied to ATM developments designed and implemented based on the use of safety objective established to achieve this target of the overall system.

5.1.4.6.2. Values of the common safety targets

Taking into account the argument on the uncertainty and the variability of the ALS of the system which are presented in chapter 5.1.7, it has been proposed:

- To apply the *3-fold factor* to the accidents (severity1), in order to achieve the value “highly improbable” (per flight hours).
- For severity 2, *the 3-fold factor is not applied*. The reported value should be confirmed over time; therefore it is considered that the number of severity 2 effect should be considered stable over time per flight hours. The ALS calculated in chapter 5.1.7.1 is kept as being a maximum safety target.
- For severity 3 and 4, *the 3-fold factor is not applied*. The reported values are not reliable enough, specific efforts in reporting and classification should be made by the states. If it has been chosen to establish values of the common safety targets for severity 3 and 4 taking into account the maximum values presented in table 7 (maximum order of magnitude, rounded to the closest power of ten).

The table below represents the common sate of safety targets obtained:

- Safety target for severity 1 is “highly improbable” as mentioned in the rule,
- Safety target for severity 2 to 4 are identified in the rule, their values are a maximum tolerable level of risk which could be tolerated by the State.

Severity	*Effect*	*Common set of safety targets (per flight hours)*	*Reference to the RCS Implementing Rule*
1	Accident	10^{-8}	Highly Improbable
2	Serious incident	10^{-5}	
3	Major incident	10^{-4}	
4	Significant incident	10^{-2}	
5	No effect	No target	Not referred in the rule

5.1.4.7 Step 7: Periodic Verification of Safety Targets

As observed above, the initial data-capture exercise to determine the Safety Targets at European level will be subject to uncertainty. It is therefore proposed to undertake a regular review of the RCS defined in Table 10 above, by repeating the process as described above, to ensure that the highest-quality RCS values are used and maintained.

Table 11, establishing the level of confidence, should also be regularly reviewed and the interval of review should be reduced over time.

It is therefore proposed to review the European RCS every year from 2008 to 2013, in order to ensure that the variability of the data does not increase, and preferably decreases. This annual review will help to confirm the baseline of the RCS. After 2013, it is anticipated that the RCS will be reviewed every 5 years.

It should be stressed that an annual review does not imply that the targets will be changed annually. The purpose of the review is to monitor incoming data quality as it affects the calculated results, to improve levels of confidence and to determine trends which may lead to a revision of safety targets over a longer periodicity.

5.2 Guidance for the apportionment of the RCS by the states.

The safety targets calculated in the above sections define the maximum tolerable probability of ATM contributing to an occurrence (accident or incident) of a certain severity. These values are overall values established at European level and are not directly applicable to the classification of individual hazards having an effect of a certain severity.

A RCS safety target is expressed in terms of risk (e.g. a combination of frequency and severity of harmful events). This implies that the specific apportioned safety targets should also be expressed in terms of risk, more specifically as a portion of the overall residual risk.

In order to achieve a classification at these specific levels, a method of apportionment of the overall safety target to the constituent parts of the ATM functional system needs to be applied. The apportionment process aims to estimate the part of the overall budget to be distributed over the different parts of the overall ATM system in order to ensure that the individual safety objectives of the changes can be implemented, keeping the overall safety target stable.

This apportionment may be done per phase of flight and/or per accident type(s) and/or per unit. It is also possible to use a distribution function to distribute the overall risk budget over several categories of risk. Whatever the methodology chosen by the States, an apportioned safety target is a part of the overall safety target that is appropriate to distribute over a structure. The way to distribute this overall safety target and the structure may be different.

The apportioned targets established by the State are inputs to ATM design, more generally they are inputs, as being safety targets, to the organisation / ANSPs' design activities dealing with the safety assessment and mitigation process when ATM functional systems, or its different parts, are developed.

The safety targets have been established only for the improvement of the design of the ATM functional system. There is no direct link, mathematically established, between the safety target and the achieved level of safety or the performance indicators. It is assumed that a demanding ATM design will positively influence the achieved level of safety of the overall ATM functional system.

5.2.1 Apportionment at State's level

This document focuses particularly at States' level, different strategies of apportionments can be chosen by the states**.**

The organisation / ANSP can as well use different ways to perform their apportionment, for instance by using recognised methodologies[4]. For information, it should be compared the approach taken for the ATM functional

[4] For instance the Eurocae standard ED125 provide an apportionment methodology for the design of the ATM functional system

system and the establishment of safety objectives related to airworthiness, for very large aircrafts[5].

Being recognised as being a way to ensure and control safety in an ATM total system approach, the safety targets should not depend on variations of aspects related to the implementation of the ATM functional system. Some functions provided today by the ground systems can be, in the future, provided partly by airborne systems or delegated to pilots.

At regulatory level, it is preferred to limit the impact of the implementation considerations. Obviously this independence should be achieved by the States only to a certain extend. A total independence is not possible; however the ATM functional system should be apportioned as far as possible independently from the most variable elements such as:

- The amount of traffic,
- The geographical characteristic,
- The type of technical equipments,
- The risk time exposure, etc... .

In some cases, apportionment at state level does not exist but their organisation / ANSPs have already experienced different types of apportionment methodologies and the States have accepted them for design purpose:

- The nature of the ATS provided (en route, approach, aerodrome, etc…);
- The flight phases;
- The type of accidents.
- Use of bow tie model and distribution as presented in Ed 125.

The States should consider whether if those apportionments already in place can be recognised and be suitable at National level to ensure the control of the overall safety of ATM in a total system approach.

Similarly to the establishment of the common set of safety targets at European level, the historical data provide information but cannot be considered as a unique source. A good illustration of this is the case of a small regional airport hosting a new low-cost airline. The airport's traffic will

[5] EASA CS 25-1309 Book 2 – AMC Sub Part F §6.a Page2-F-5 : "For a number of years aeroplane systems were evaluated to specific requirements, to the "single fault" criterion, or to the fail-safe design concept. As later-generation aeroplanes developed, more safety-critical functions were required to be performed, which generally resulted in an increase in the complexity of the systems designed to perform these functions. The potential hazards to the aeroplane and its occupants which could arise in the event of loss of one or more functions provided by a system or that system's malfunction had to be considered, as also did the interaction between systems performing different functions. This has led to the general principle that an inverse relationship should exist between the probability of a Failure Condition and its effect on the aeroplane and/or its occupants (..). In assessing the acceptability of a design it was recognised that rational probability values would have to be established. Historical evidence indicated that the probability of a serious accident due to operational and airframe-related causes was approximately one per million hours of flight. Furthermore, about 10 percent of the total were attributed to Failure Conditions caused by the aeroplane's systems. It seems reasonable that serious accidents caused by systems should not be allowed a higher probability than this in new aeroplane designs. It is reasonable to expect that the probability of a serious accident from all such Failure Conditions be not greater than one per ten million flight hours or 1×10^{-7} per flight hour for a newly designed aeroplane. The difficulty with this is that it is not possible to say whether the target has been met until all the systems on the aeroplane are collectively analysed numerically. For this reason it was assumed, arbitrarily, that there are about one hundred potential Failure Conditions in an aeroplane, which could be Catastrophic. The target allowable Average Probability per Flight Hour of 1×10^{-7} was thus apportioned equally among these Failure Conditions, resulting in an allocation of not greater than 1×10^{-9} to each. The upper limit for the Average Probability per Flight Hour for Catastrophic Failure Conditions would be 1×10^{-9} , which establishes an approximate probability value for the term "Extremely Improbable". Failure Conditions having less severe effects could be relatively more likely to occur."

certainly change significantly, and while past data should be one input to the decision-making with regard the changes that this airport has to make, those data cannot represent a complete baseline to define the individual safety targets applicable to its equipments, procedures and personnel in order to ensure that the change is implemented safely. The planned traffic growth, the further exposure to risk and the higher complexity of the traffic would all need to be taken into consideration, together with other relevant factors. Therefore the individual apportioned safety targets are established taking into account the projected safety impact of the expected changes into the new environment of operation.

5.2.2 Example of the Functional Apportionment methodology

In order to illustrate the methodology it is proposed to develop further the functional apportionment. As previously explained, the apportionment itself cannot be totally standardised and a single valid apportionment of ATM does not exist. The strategy for apportionment can be different, but a generic process can be defined. This section provides an example of a generic process to achieve a functional apportionment at Unit level. It should be considered as an illustration of apportionment mechanisms and not as a prescriptive recommendation. The next paragraph introduces other types of apportionment methodologies.

The main principle of apportionment consists of splitting the overall safety targets into different components. In this example the components are functions. Safety target values at different level of the breakdown structure can be developed by extrapolating on the constituents the potential harmful effects of the ATM changes, and / or the expected traffic evolution.

Therefore:

1) As the viewpoint for the apportionment has an impact on the components of the breakdown, the strategy of the apportionment should be decided,

2) The components of the breakdown structure should be identified,

3) The mechanisms for the generation and propagation of the risk into the breakdown structure should be identified. (see 1 and 2 in the figure below)

4) The criteria to stop the breakdown should be defined.

The functional approach focuses on all the phases, functions and processes taking place in the ATM operation. It identifies the effects of hazard that may occur from these functions before evaluating the potential resulting risks associated with each function, process and subsequently the phase of operation. Alternatively, it allows apportioning the global risk to each phase, functions and process.

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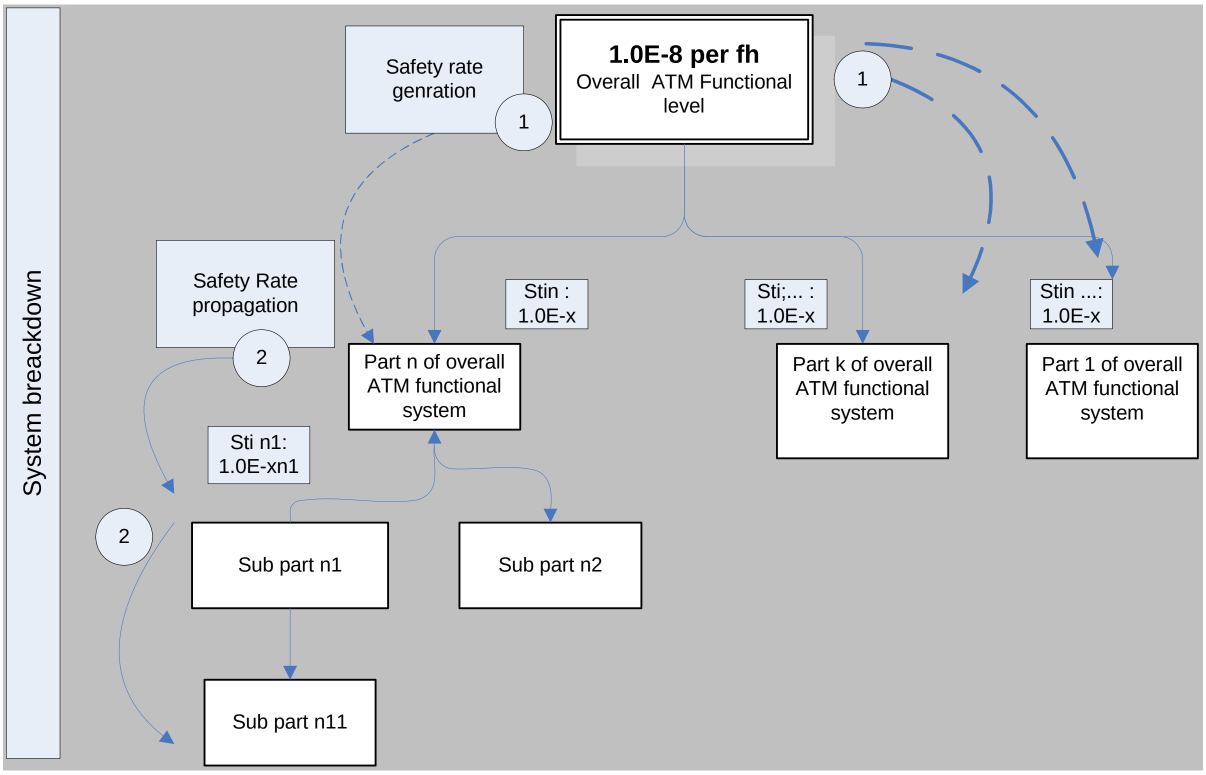

Figure 11: breakdown structure for safety target apportionment

The proposed Risk Apportionment Methodology focusing on the risk for each ATM function will therefore include:

- At the top of the breakdown, **the safety target for accidents** of the overall ATM functional system represents the design target as regards the overall system,

- A breakdown of ATM functions should be established at highest level. It can be built on the basis of the flight phases and the units and/or functions involved in providing information or services to the aircrafts during the different flight phases. The individual functional packages, high level functions or services, should be as independent as possible. However, it is impossible to ensure a complete independence of the contribution to the overall risk, especially at the interfaces with the technical part of the ATM functional system when the role of human operators is essential and the software is involved in any ATM function. The breakdown into subcomponents of the ATM functional system should stop before that implementation aspects appear in the structure. More specifically, human and software contributions to functions, as being part of the implementation, should be clearly identified outside the breakdown structure at functional level.

- A generation of safety targets (1 in the figure) applicable to different parts of the ATM functional system breakdown should be done in order to achieve the safety target for accidents at the top level.

- In breaking down the ATM functional system into elements at lower level, the links between those elements should be minimised.

- With regard the propagation (2 in the figure) of the safety target through the functional breakdown, a simple mechanism of calculation shall be defined by the experts of each function. In other words, a breakdown method should provide a risk apportionment in terms of effectiveness. For instance, the apportioned safety targets which are allocated to each part of the breakdown structure should be calculated on the basis of an estimated percentage which represents the contribution of this function to an accident, or, on the basis of the time exposure of a flight to a risk of accident. The estimations of the percentages should be developed by a group of experts for each function.

- The apportioned safety targets (should be reviewed).The level of tolerable risk for each function is fixed by the apportioned safety target in compliance with the overall risk for accidents. Then, to comply with this level of risk, the values which have been already allocated may be revisited. The homogeneous vision of each level of the functions should meet the European Safety directives. Therefore the process should be a standard applicable to functional analysis in risk apportionment. To make the developed breakdown method applicable in practice, certain considerations and breakdown rules have to be established.

5.2.3 Other types of Apportionment methodology

Several other types of apportionment can be taken into consideration, for instance:

- Breakdown by Hazard Types: In this approach, the global residual risk is apportioned between all possible generic system level hazards which can lead to accidents. The main advantage of this strategy is that the safety targets are independent of technical achievements and implementation.

- Breakdown by Accident Types: A list of typical ATM accidents has to be agreed on. Then global residual risk (per group categories) is apportioned to the different accident types, by using statistics. Like the previous approach, a breakdown by accident types provides an unambiguous apportionment but it is not very helpful to derive safety requirements. It requires an accurate occurrence analysis identifying the causes and the influences of the environment to ensure the completeness of the apportionment.

- The risk budget can be distributed over all risks by using distribution function, in some other cases Bayesian approaches may be used.

5.2.4 Constraints Applicable to the Apportionment Process

The apportionment process aims to distribute an overall ATM safety target over the parts (constituents) of the ATM functional system implemented by an organisation.

The values calculated for the safety targets are applicable to the overall functional system within a total ATM functional system approach. As each part of the ATM functional system can have an impact on accidents, it is necessary to know to which extent the different parts of the ATM functional system used by the organisation or ATC unit under consideration can impact the overall value.

The TLS apportionment methodology should therefore take into account all parts of the ATM functional system and their interactions, and needs to be:

- Realistic, in order that a designer can adopt the values with confidence,
- Independent, the methodology for apportion should limit as far as possible the dependences between components,
- Unbiased, as the use of historical data which are not representative of the local situation can lead to unsatisfactory safety targets,
- Practical to achieve in operation,
- Useful, expressing targets in ways that are meaningful to designers,
- Traceable, as the origin of each target should be defined, as well as its contribution to the overall safety target,
- Robust, so that the targets are not unduly sensitive to assumptions in the apportionment methodology.
- Flexible, so that targets can be obtained for any country, unit or ATM constituent, including constituents newly introduced.

5.2.5 Process supporting an apportionment

The steps of the generic process to achieve an apportionment are defined as follows:

- **Step 1: Decide the strategy for the apportionment**
  - The focus of the apportionment process, and therefore of the safety targets should be defined in terms of the criteria for apportionment, for example:
  - State's Overall ATM functions
  - The ATM function within an Airport,
  - Several type of airports,
  - ATM service(s) (such as ACCs),
  - Type(s) of accidents.
  - The identification of this objective should lead to define the boundaries of the risk area.
- **Step 2: Identify the components on which the apportionment will rely , for instance :**
  - The functions supporting services,
  - The types of safety occurrences,
  - Phases of flight in relation to the services provided by an organisation (on the basis of a set of standard/defined phases).
- **Step 3: Gather and identify appropriate data**
  - risk exposure which should be taken into account
  - safety occurrences per units
- **Step 4: Identify the most appropriate units of measurement for the calculation**
- **Step 5: Identify the design constraints for the future, and project the safety targets accordingly**
- **Step 6 : Identify the flight exposure to the risk**
- **Step 7 : Apportion the safety budget : to build the breakdown structure in accordance with the objective of the apportionment**
- **Step 8: Verify periodically the apportioned safety targets**

Several criteria apply to each of these steps, and can have significant effect on the results of the apportionment process. The steps are therefore explained in further detail, as follows:

5.2.5.1 Step 1: To decide the strategy for the Apportionment

The need to apportion the safety targets is raised by the need to ensure adequate safety assessment and mitigation of changes to the ATM functional system in the context of changes to ATM functions or services to ATM components as airspaces, surveillance, communication, etc …. This apportionment is a means to support appropriate decision-making when changes to the ATM functional system are planned. Apportionment can apply to a variety of different objectives. For instance:

- en-route units could focus on RVSM airspace and transition areas,
- aerodromes may have a specific interest in the safety of ground operations,
- Member States could wish to have a harmonised framework of apportioned safety targets for certain types of organisations/units.

The different types of apportionment should necessarily ensure that their objectives address, as a minimum, the following criteria:

- types of services which are provided under the responsibility of organisations,
- types of airspace under consideration,
- period of reference for the calculated targets (e.g. from now to 2020),
- planned changes and their potential impact on the service(s) during that period,
- traffic changes (for instance introduction of a new airline),
- new concepts of operation.

5.2.5.2 Step 2: Identify the breakdown of the apportionment

Because of potentially different interpretations of the terms defining phases of flight, it is necessary to establish the apportionment process (when addressing organisations/units or specific phases of flight) based on a set of standard phases of flight for which boundaries are clearly defined.

The ICAO CAST[6] project has developed a common taxonomy for defining the phases of flight and, in order to ensure standardisation, it is proposed to use this taxonomy for specifying the phases of flight for apportionment purposes However, it should be stressed that:

- its application may vary depending on the service(s) provided by organisations/units within each Members State, and
- the example of grouping shown in Table 13 should be adapted to the responsibilities of each organisation or unit, and slightly different groupings may apply depending on the interpretation given to the sub-phases in column 3. (For example, the sub-phase "holding" can be considered as within the en-route phase, but also as part of the approach phase).
- once chosen, the grouping used should be applied in a consistent manner, and should also be consistent with the way in which historical data has been gathered.

The CAST taxonomy should be considered as a way to group category of incident, in order to achieve as far as possible accurate data. At NSA or

6 CAST, Common Taxonomy Team, ICAO, Phase of flight definitions and usage notes, February 2006, version 1.0.1 regulatory level, the CAST taxonomy will only be used to gather information due to its level of detail. It is strongly advised to group the phases of flight. For example as indicated in the first and last columns of Table 13 below. The preferred starting point of an apportionment at regulatory level is :

- Approach
- En route
- Ground and taxi
- Departure/Arrival

The lower level of the breakdown should identify the functions/services/ processes which are in the scope of the RCS.

ATM grouped phases (example)	CAST phase of flight	CAST sub-phase of flight	ATC unit concerned (example)
	Standing (STD)	Engine(s) Not Operating	No ATC
		Engine(s) Start-up	
		Engine(s) Operating	
		Engine(s) Shutdown	
Ground and Taxi	Pushback/towing (PBT)	Assisted, Engine(s) Not Operating	Aerodrome control service/ TWR
		Assisted, Engine(s) Start-up	
		Assisted, Engine(s) Operating	
		Assisted, Engine(s) Shut Down	
	Taxiing (TXI)	Taxi to Runway	
		Taxi to Takeoff Position	
		Taxi from Runway	
Departure	Take-off (TOF)	Take-off	
		Rejected Take-off	
	Initial climb (ICL)		
	En route (ENR)	Climb to Cruise (can be considered as en route)	
En route		Cruise	Area control service/ACC
		Change of Cruise Level	
		Descent	
Arrival		Holding (can be considered as en route)	Approach control service/APP
	Approach (APR)	Initial Approach (IFR)	
		Final Approach (IFR)	
		Circuit Pattern – Downwind (VFR)	
		Circuit Pattern – Base (VFR)	
		Circuit Pattern – Final (VFR)	
		Circuit Pattern – Crosswind (VFR)	
		Missed Approach/Go-Around (can be considered as landing)	Aerodrome control service/ TWR
	Landing (LDG)	Flare	
		Landing roll	
Specific Phase used in analysis	Manoeuvring (MNV)	Aerobatics	Out of scope
		Low Flying	
	Emergency Descent (EMG)		Specific situations or phases used for the description of occurrences.
	Uncontrolled Descent (UND)		
	Post-impact (PIM)		
	Unknown (UNK)		

Figure 12 : CAST flight phases and example of grouping

5.2.5.3 Step 3: Gather and Identify Appropriate Historical Data

As observed, historical data-gathering forms one part of the information necessary for apportionment. Nevertheless, as safety targets aim to ensure the safety of ATM changes in the SES context, and in order to eliminate discrepancies with regard to the sampling of data, it is recommended as far as possible to:

- establish the target on the basis of a national data set(s), or
- if national data do not exist, establish the targets on the basis of a corresponding European data set of safety occurrences,
- include accidents as defined by ICAO (i.e. not only fatal accidents)
- take into consideration all GAT in controlled airspaces, (i.e. apportionment should not be limited to commercial aircraft of a certain weight)

The apportionment process can be very sensitive to the sampling of safety occurrences and to the operational role of the organisation to which the apportionment applies. For example, when an organisation comprises an en-route centre, not all phases of flight need to be taken into consideration and the sampling of occurrence data can be limited to a selected range of safety occurrences.

A comparison of the different apportionment studies[7] conducted has shown several discrepancies between their results. Those discrepancies can be explained by the focus of the studies which gave specific orientation to their results. The results of each of those studies are very specific to a certain objective and cannot be used in other circumstances than the ones for which they have been developed.

The discrepancies between these results are to be expected, because the samples used by the studies concerned have been built in order to focus on specific concerns. It should be stressed that these examples of apportionment did not use the same methodology for apportionment, nor harmonised samples, and cannot therefore be transposed into another context.

The exposure to the risk

Aircraft are exposed to risks of different types of occurrence depending on their phase of flight. The exposure time to the risks also varies on the same basis.

For example, an aircraft in en-route flight can be exposed to en-route risks, such as mid-air collision, level-busts etc. for (potentially) long periods of time. In the approach and landing phase, on the other hand, different risks can occur (e.g. controlled flight into terrain, runway incursion), but the risk exposure time can be comparatively much shorter.

The period of time during which an aircraft could be exposed to a specific risk, and the type(s) of risk being faced, should be identified in accordance with the objective of the apportionment.

Table 15 below presents examples of time exposure per phase of flight, which may be used in apportionment calculations. If the State, organisation or unit has more accurate values, these should be used in preference to those below.

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7 *See chapter 6, References 1 and 10.*

ATM phases (example)	Exposure [8] In Europe	Exposure In Navigation (in SAM, example)	CAST phase of flight	CAST sub-phase of flight
Taxi	0.30 flight hour 2 ground movements (taxi in and taxi out)	2 ground movements	Taxiing (TXI)	Taxi to Runway
				Taxi to Takeoff Position
				Taxi from Runway
Departure	1 per flight 0.23 flight hour	1 take off per flight	Take-off (TOF)	Take-off
		1 departure per flight 0.25 flight hour		Rejected Take-off
			Initial climb (ICL)	
			En route (ENR)	Climb to cruise
En route	0.80 flight hour	1.22 flight hour world wide 0.92 ECAC		Cruise
				Change of Cruise Level
				Descent
Approach	0.28 flight hour			Holding
			Approach (APR)	Initial Approach (IFR)
		0.917 flight hour (precision) 0.083 (NPA)		Final Approach (IFR)
				Circuit Pattern – Downwind (VFR)
				Circuit Pattern – Base (VFR)
				Circuit Pattern – Final (VFR)
				Circuit Pattern – Crosswind (VFR)
Landing	1 per flight	0.917 flight hour (precision) 0.083 (NPA)		Missed Approach/Go-Around
			Landing (LDG)	Flare
				Landing roll

Figure 13 : Examples of Time Exposure per Phase of Flight

Some discrepancies from a State to another or from a view point to another are normal. The examples to illustrate this are presented as follows:

Study in the navigation domain

Here, the accident data set is not the same as in the Single European Sky context, but consists of a set of fatal accidents world-wide involving large Western commercial jets during the period 1990-2002[9]. Only accident categories relevant to the NAV domain have been analysed.

According to this sample of accidents, the ATM (direct) contribution to a Taxiway collision is 10%.

Study provided by a service provider related to an airport

In this case, the accident dataset is a world wide sample of ATM related accidents. The sample of accidents consists of commercial aircraft with maximum take-off weight of 5.670kg, and the time window is 1980 to 2005. The sample includes not only jets, but also turbo prop and piston-engined aircraft. A set of safety occurrence categories has been identified and accidents related to malfunction of landing aids have been excluded. The safety occurrences under consideration are:

- Wake vortex turbulence;
- Collision/near collision with aircraft – both airborne;
- Collision between aircraft – one airborne;
- Collision between aircraft, both moving and both on the ground;
- Collision between aircraft on the ground, one moving, one not;

8 Sources CODA, CFMU, data 2006

- Collision between an aircraft and vehicle(s);
- Collision between an aircraft and animal(s); and

In this sample, focusing on airports, the ATM (direct) contribution to accidents in the taxiing phase is calculated to be 60%.

Example of apportioned safety target from AST per phase of flight and per type of accident

Table 14 below presents a table with apportioned data for different types of accidents, derived from AST data analysis (1999 – 2006) and to which the SESAR objective for the Reference Year 2020 has been applied.

The AST reporting allows the different types of occurrences (mid air collision, CFIT, several categories of ground collision) to be identified for each phase of flight. The calculation has been made based on the following factors:

- All type of accidents (as defined by ICAO, not only fatal) with ATM contribution (direct plus indirect),
- GAT,
- Traffic from CFMU data for 29 European States (not Worldwide),
- Average frequency calculated on the values for the 8 year period (1999-2006),
- The SESAR objective has been applied.

5.2.5.4 Step 4: Identify the Most Appropriate Units of Measurement

The calculation of the apportioned risks can be established by using different units of measurement:

- Per phase of flight per Flight Hours, or
- Per movement, or
- Per flight.

For instance, for an en-route apportionment, a measurement per-flight hour is more relevant than a measurement per movement or per flight. For an airport, the unit of measurement "per movement" may well be more applicable. A basic set of preferable units per phases of flight can be proposed for apportionment of safety targets, as follows:

- **Taxi** – per number of movements/flights,
- **Take-off** – per number of movements/flights,
- **Departure** - per number of movements/flights but in some cases, the number of flight hours in the departure phase may be more relevant,
- **En-route** - per number of flight hours,
- **Arrival** - per number of movements/flights,
- **Final approach** - per number of movements/flight,
- **Landing** - per number of movements/flight.

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5.2.5.5 Step 5: Identify Design Constraints for the Future

In considering the future context of the apportionment outcome, it is necessary to identify the relevant constraints when projecting future safety targets. This involves the following steps:

(a) **The date of reference for the apportioned safety targets should be 2020.** Safety targets established for design purposes should focus on the safety performance that the system should achieve after the implementation of changes. This target does not mean that the overall system should be entirely reviewed; it means that the organisation should define its safety objective in accordance with apportioned target. The safety target remains the same, and the system will be incrementally improved through safety assessment and mitigation process. The overall process should be considered as a plan to improve the safety of the system, not a value against which the system in operation should be monitored year by year.

(b) **to identify a risk model which will take into account the changes.**

- Several risk models[10] exist; the designer should carefully assess them before using them for apportionment
- As several risk models exist, and as those models each have their strengths and weaknesses, it is recommended that the choice of a particular risk model is justified. It is also recommended that additional arguments are proposed in order to address, and where possible mitigate, any known weaknesses or limitations of the risk model in use.
- If the change involves a new concept of operation, it is necessary to take into account the envisaged future ATM functional system rather than the system in place at present, and the safety impact on the overall system should be developed. For less ambitious changes, the model should be able to be applied to the system in current operation.
- The risk model should include the new concept of operation (as was done, for example, for the introduction of RVSM in ECAC airspace). More specifically, if a change impacts an organisation/unit (for instance new infrastructure), it should be assessed quantitatively by using a risk model.

(c) **to use <u>relevant</u> historical data as a basis for future projection.** The safety occurrences per phase of flight, per flight or per type of accident are projected in the future.

(d) **to use the risk model to estimate the risks** bearing on the part of the ATM functional system showing clearly how each component affects the overall risk. It should be realistic and consistent with the requirements for safety target(s) at European or national levels.

5.2.5.6 Step 6: Verify the Apportioned Safety Targets

The practical achievability of these apportioned targets should be verified periodically. If the targets cannot be viewed as achievable, a more realistic target should be developed, and compensating changes should be made to other ATM elements if compliance with the overall safety target is to be maintained.

States must ensure that the process of apportionment does not lead to a situation in which the aggregation of the apportioned safety targets lead to not meeting the overall safety target.

10 See chapter 6, References 3 and 8

5.3 Qualitative Aspects to satisfy RCS targets

The establishment of *quantitative* targets is the objective of this mandate however *qualitative* aspects cannot be ignored and they have to be considered rigorously when it is necessary to use them in order to complement *quantitative* approach.

As the ATM system includes technical elements as well procedures and human aspects, at organisation level it is not always possible to ensure a comprehensive quantitative measurement. Part of the ATM functional system design, for instance software aspects, are also difficult to be controlled by using exclusively a *quantitative* approach for design. The robustness and the integrity of the ATM functional system to the systemic errors are not always totally quantifiable. In this cases, it is recommended to develop approaches to complement the quantitative targets.

EC regulation 2096/2004[11], allows in certain circumstances that *quantitative approach should be complemented by qualitative* arguments for the design of the ATM functional system under the responsibility of the organisation / ANSP.

The qualitative aspects are not really part of the RCS, however qualitative safety objectives provided by the organisation can be taken into consideration to demonstrate that the RCS targets required at regulatory level are implemented.

The safety perspective of the total ATM functional system, and a better integration between airborne and ground ATM functional systems, should encourage the use of *safety assurance levels* approaches during the development of ATM functional systems. In addition, they are recommended by the software regulation transposing ESARR 6 (EC regulation 482/2008). The assurance levels approaches can be used for software and human factors. In any case it should be proved that they these approaches are able to control the risk with *qualitative* considerations.

With the support of safety experts, the *qualitative* safety requirements should be integrated *quantitatively* when sufficient experience is achieved regarding qualitative aspects in order to ensure that all safety aspects and safety arguments are taken into consideration consistently.

The identification of the risk level involves an estimate of the potential harmful consequences and their frequencies of occurrence acceptable to the public and the professionals as well. The qualitative safety targets are not safety requirements for implementation but an estimation of the tolerable risk change. Depending of the assumed consequences of the risk and their estimated tolerable frequencies, various actions can be taken during the design of the change in order to control the risk.

In order to control the consequences of the occurrences of such risks it is advised to implement systemic actions to provide sufficient confidence in the capability of the system to mitigate the identified risks. This approach assumes that the risk should be classified qualitatively.

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[11] EC regulation 2096/2004 (section 3.2.2 (b) and section 4 *"As a necessary complement to the demonstration that established quantitative objectives are met, additional safety management considerations shall be applied so that more safety is added to the ATM functional system whenever reasonable".*

The arguments and evidence related to the decision of the action should be developed, agreed and documented. They give assurance that the part of the system concerned by the change satisfies given safety requirements. The implementation of a level of assurance to the system should be done in a structured and systematic way:

- The consequences should be classified with regard to a severity classification similar to the presented in the EC regulation 2096/2005. For instance, a range from 1 (risk of accident) to 5 (no risk) can be used to classify the risk.
- The likelihoods of these effects (i.e. the tolerable frequencies of the occurrence of an effect of a certain severity), have to be identified qualitatively on the basis of the experts' judgements.
- A **level of assurance** is based upon the contribution of the part of the system under consideration to potential consequences of its anomalous behaviour as determined by the system safety assessment process. The level of assurance implies that the level of effort recommended in order to show that the Safety Requirements will be implemented with an adequate assurance. It varies with the severity of the potential effect of an abnormal behaviour of the system and likelihood of occurrence of the effect.
- The safety assessment and mitigation process allows the classification of the risk in accordance to a qualitative risk classification scheme.
- For each association of a severity and an acceptable frequency, it is necessary to identify actions to be applied to the design of the system. These actions are required by the **levels of assurance.** They are different depending on the estimated consequences of the risk. The level of actions chosen should be decided by the experts: air traffic controllers, technical personnel and also by other experts, human factors and/or software specialists in the case of new systems.

The actions required by the assurance level process are means to demonstrate that safety requirements are satisfied. These actions are: specific design methods, specific verification and demonstrations, level of testing activities, required authorizations or licenses, working organization, procedures, training, etc. It relies on a preventive approach which is a consequence of the safety assessment process. The level of assurance does not replace Safety Requirements, but sets the level at which Safety Requirements have to be satisfied.

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