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INOUI

INNOVATIVE OPERATIONAL UAS INTEGRATION

Instrument: STREP (Specific Targeted Research Project)

Thematic Priority: AERO-2005-4.g Open Upstream Research

D5.0A SAFETY CRITERIA - SCOPE OF RISKS

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Contents

1 Introduction

1.1 Background

The INOUI project is a response to the challenge of integrating UAS as new airspace users (besides Business Aviation, General Aviation and Military Aviation) into the future ATM system.

The project is related to the Research Domain 4.g « Innovative Air Traffic Management Research » of the FP6-2005-AERO-4, Research Area « Open Upstream Research ».

The driving force behind creating the INOUI project is stemming from the fact that UAS operations will be more and more demanded by organizations, institutions, corporations and the society in general, and thus, they will need to operate in the airspace as another airspace user. Regardless of the fact that UAS are already conquering the skies, although either at a very low altitude, or in segregated airspace due to their mostly military nature, the integration in the non-restricted airspace is left aside. In particular, the topic UAS is almost totally absent from SESAR and its high-level Definition Phase (Phase I). INOUI aims at complementing SESAR by compensating for this flaw of leaving out UAS. This will be achieved by developing documents providing a roadmap to the future of UAS in the context of the ever changing ATM environment.

The long-term targets of SESAR have been defined as political vision and goals for the design of the future ATM System, and as EC objectives of the SESAR programme. They are to achieve a future European Air Traffic Management (ATM) System for 2020 and beyond which can, relative to today's performance:

- Enable a threefold increase in capacity which will also reduce delays, both on the ground and in the air;
- Improve the safety performance by a factor of 10 (see Section 2.2.2.6 and [SESAR Safety Target] for more information on this);
- Enable a 10% reduction in the effects flights have on the environment; and
- Provide ATM services at a cost to the airspace users, which is at least 50% less.

The relationship with SESAR is clear since INOUI considers it as one of the main references for its work, as SESAR defines the common future ATM system in Europe.

The real challenge for INOUI is to propose procedures to integrate the operation of UAS without any major impact on the current users of the airspace. It is forecast that air traffic will be three times higher than the current levels. And this is without UAS on it. Thus UAS operation will suppose an additional increase in the air traffic volume, it is INOUI's task to assess the feasibility of using these new operational solutions also with the UAS and its impact, or proposing new operational solutions in order to not jeopardize the performance of the future ATM system.

INOUI defines an operational concept, proposes operational procedures and assesses the technologies to support them in order to facilitate the integration of the UAS in the airspace and airport paradigm foreseen for 2020 and beyond. The overall objective of INOUI is to assess different domains of the ATM system of today and 2020 to develop a roadmap on how to integrate UAS into the operational concept for the future. This activity will complement the activities of the SESAR definition phase and fill the gaps with regard to the particularities of UAS.

1.2 Purpose of the Document

The purpose of this deliverable is to propose **Safety Criteria** for the introduction of UAS into non-segregated airspace in Europe, with focus on the ATM aspects. These criteria might be adopted by SESAR and/or the European Commission.

Annex 1 – Description of Work mentions [ESARR 4] as safety criteria to be applied. However, as [ESARR 4] is to be applied for changes in ATM and as it sets limits for ATM's direct contribution to risk, it does not match the aims of INOUI well where the change consists of the introduction of UAS and where the restriction to the risk for which ATM is primary factor, as considered in [ESARR 4], is less appropriate.

Apart from assessing whether the risks associated with a change are sufficiently small, safety criteria are also needed to derive Safety Objectives and Safety Requirements, which are to support the development of the change. Even further back in the development process of the change, the scope of risks concerned by the safety criteria and assessment needs to be set, as this determines the scope within which hazards are to be identified.

The present INOUI deliverable D5.0a is aimed at setting the scope of risks that are to be analyzed when introducing UAS in non-segregated airspace, whereas the extended update D5.0b is to provide the quantitative criteria for the risks within this scope.

The development of the scope of risks reported in this document involves:

- The review of a series of documents relevant for safety criteria;
- Workshops with experts on safety, ATM and UAS to develop an appropriate scope of risks; and
- Combining the results of the review and workshops to formulate the scope of risks.

INOUI deliverable D5.0b, which will be an extended update of the present document, will develop quantified safety criteria and assess to which extent these match the aims formulated and what ideas from the summarised criteria they involve.

1.3 Document Structure

This document is divided into the following sections:

- Section 1 – Introduction;
- Section 2 – Brief overviews of documents relevant for Safety Criteria;
- Section 3 – Deriving the scope of risk;
- Section 4 – Deriving quantified safety criteria (to be done for INOUI deliverable D5.0b);
- Section 5 – Comparing derived criteria with aims and other safety criteria (to be done for INOUI deliverable D5.0b); and
- Section 6 – Conclusions.

1.4 Applicable and Reference Documents

Reference tag	Document description
[14CFR 23]	Code of Federal Regulation – Part 23
[AENA Safety Target]	Resolucion de la Direccion General de Aviacion Civil por la que se Establecen los Niveles Objetivo de Seguridad para el año 2007
[AIRCHIEF 2003]	European Air Chief Conference 2003
[Andersson and Tegner, 2004]	Evaluation of taxonomy and system support for risk based analysis within the Swedish Aviation Safety Authority, M. Andersson and S. Tegner, 13-02-2004
[ATM 2000+]	EUROCONTROL ATM Strategy for the Years 2000+, 2003 Edition, approved by the Permanent Commission for the Safety of Air Navigation, on 10 April 2003, available at http://www.eurocontrol.int/eatm/gallery/content/public/library/ATM2000-EN-V1-2003.pdf
[CAST ICAO Occurrence Categories]	Aviation Occurrence Categories; Definitions and Usage Notes, November 2008 (4.1.4), the CAST/ICAO Common Taxonomy Team, available at http://www.intlaviationstandards.org/Documents/CICTTOccurrenceCategoryDefinitions.pdf
[Clothier, Walker, Fulton and Campbell]	A casualty risk analysis for Unmanned Aerial System (UAS) Operations over Inhabited areas. R. Clothier, R. Walker, N. Fulton and D. Campbell
[DFS SA Handbook]	Safety Assessment Handbook, Version 2.0, DFS Deutsche Flugsicherung GmbH, Corporate Safety and Quality Management (VY),15 December 2004
[EASA AMC 25.1309]	EASA Acceptable Means of Compliance for Certification Specification 25.1309
[EASA CS-25]	EASA CS-25. Certification Specifications for Large Aeroplanes. Amendment 5 – September 5th, 2008
[EASA A-NPA No 16/2005]	Advanced Notice of Proposed Amendment (NPA) No 16/2005. Policy for Unmanned Aerial Vehicles (UA) Certification.
[EASA CS-23]	EASA CS-23. Certification Specification for normal, utility, aerobatic and commuter category airplanes. Initial Issue – 14/11/2003.

Reference tag	Document description
[EC Common Requirements]	COMMISSION REGULATION (EC) No 2096/2005 of 20 December 2005 laying down common requirements for the provision of air navigation services, Official Journal of the European Union (English) L 335/13-30, 21.12.2005
[EC No. 549/2004]	Regulation (EC) No 549/2004 of the European Parliament and of the Council of 10 March 2004 laying down the framework for the creation of the single European sky (the framework Regulation), 31.3.2004 EN, Official Journal of the European Union L 96/1
[ESARR 2]	EUROCONTROL Safety regulatory Requirement ESARR 2, Reporting and Assessment of Safety Occurrences in ATM, Edition 2.0, 3 November 2000, available at http://www.eurocontrol.int/src/gallery/content/public/documents/deliverables/esarr2_awareness_package/esarr2e20ri.pdf
[ESARR 4]	Risk Assessment and Mitigation in ATM, Edition 1.0, 5 April 2001, http://www.eurocontrol.int/src/gallery/content/public/documents/deliverables/esarr4v1.pdf
[Eurocontrol OAT Spec 0102]	Eurocontrol Specifications for the use of Military Unmanned Aerial Vehicles as operational Air Traffic outside segregated airspace, Eurocontrol-Spec-0102. M. Strong, 26/07/2007
[EUROCONTROL SRC SCS]	EUROCONTROL SRC - Severity Classification Scheme for Safety Occurrence in ATM, 12-11-1999
[FAA AC 23.1309-1C]	Federal Aviation Administration Advisory Circular, “Equipment, Systems, and Installation in Part 23 Airplanes,” AC 23.1309-1C, March 1999
[FAA AC 25.1309-1A]	Federal Aviation Administration Advisory Circular, “System Design & Analysis,” AC 25.1309-1A, June 1988
[FAA Order 8040.4]	Federal Aviation Administration Order 8040.4 - Safety Risk Management (SRM). 26-06-1998.
[FAA SSH]	Federal Aviation Administration. System Safety Handbook. 30 December, 2000
[ICAO Annex 11]	Annex 11 to the Convention on International Civil Aviation, Air Traffic Services, Thirteenth Edition July 2001
[ICAO Annex 13]	Annex 13 to the Convention on International Civil Aviation, Aircraft Accident and Incident Investigation, Ninth Edition July 2001
[ICAO Doc 4444]	International Civil Aviation Organization, Doc 4444, Procedures for Air Navigation Services, Air Traffic Management, Fourteenth Edition — 2001
[ICAO Doc 9082/7]	ICAO’S Policies on Charges for Airports and Air Navigation Services, Doc 9082/7, Seventh Edition – 2004
[ICAO Doc 9574]	ICAO Doc 9574-AN/934, Manual on Implementation of a 300 m (1 000 ft) Vertical Separation Minimum between FL 290 and FL 410 Inclusive, Second Edition – 2002, Corrigendum 16 April 2002
[ICAO Doc 9689]	ICAO Doc 9689-AN/953, Manual on Airspace Planning Methodology for the Determination of Separation Minima, First Edition – 1998, Amendment 30 August 2002
[INOUI Annex 1]	INOUI (Innovative Operational UA Integration) Annex 1 – “Description of Work”, Proposal/Contract no 037191, date of preparation 10 April 2007, signed August 2007

Reference tag	Document description
[LVNL Safety Criteria]	LVNL Safety Criteria, Hans H. de Jong (DFS) and J.C. (Hans) van den Bos (LVNL), paper presented at the Eurocontrol Safety R&D Seminar in Rome, 2007
[Minutes 2 and 3 September 2008]	Minutes of INOUI Technical Meeting 2 and 3 September 2008, distributed by Marita Lintener (DFS) on 4 November 2008
[Minutes WP5 KOM]	INOUI WP5 Kickoff Meeting 23-24 July 2008, Minutes by Diana Durrett and Hans de Jong, Version 1.0 of 22 August 2008
[NATS SPS 2004]	NATS Strategic Plan for Safety, 2004
[NATS SPS 2007]	NATS Strategic Plan for Safety, 2007
[SAF-SAM1-FHA]	EUROCONROL Institute of Air Navigation Services -Training Document SAF-SAM1-FHA, 12-11-2007
[SESAR Safety Target]	White Paper on the SESAR Safety Target, Episode 3, Deliverable D2.4.3-01, Owner: Eric Perrin, Eurocontrol, Version 1.2 (Draft)
[SRC Policy Doc 1]	EUROCONTROL Safety Regulation Commission Policy Document 1, ECAC Safety Minima for ATM, Edition 1.0, 14 February 2001
[STANAG 4671 - Draft]	STANAG 4671 (Edition 1) – Unmanned Aerial vehicle Systems Airworthiness Requirements (USAR) - Draft version
[UA Task Force 2004]	UA Task-Force Final Report. A concept for European Regulations for civil Unmanned Aerial Vehicles (UAs). The Joint JAA/Eurocontrol Initiative on UAs, May 11th, 2004
[Van Es, 2003]	G.W.H. van Es, Review of Air Traffic Management-related accidents worldwide: 1980 – 2001, NLR Technical Publication 2003-376, August 2003
[Weibel and Hansmann, 2005]	Safety Considerations for Operation of Unmanned aerial vehicles in the NAS. R.E. Weibel and R.J. Hansmann. Report No, ICAT-2005-1. March 2005
[Work plan WP5]	INOUI Work plan WP 5 “Safety Analysis”, Diana Durrett and Hans de Jong (DFS), Version 0.1 of 16 July 2008

1.5 Glossary

Abbreviation	Written in full
A-NPA	Advanced Notice of Proposed Amendment
AC	Advisory Circular
ACC	Area Control Centre
ADREP	ICAO Accident/Incident Data Reporting System
AENA	Aeropuertos Españoles y Navegacion Aerea (Spain)
AIS	Aeronautical Information Service
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
APP	Approach
ASA	Aviation Safety Authority
ASM	Airspace Management
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATFCM	Air Traffic Flow Control Management
ATM	Air Traffic Management
ATS	Air Traffic Services

Abbreviation	Written in full
CAA	Civil Aviation Authority (UK)
CMIC	Civil/Military Interface Standing Committee
CNS	Communication Navigation and Surveillance
CS	Certification Specification
DFS	Deutsche Flugsicherung (Germany)
DGAC	Dirección General de Aviación Civil
EASA	European Aviation Safety Agency
EC	European Commission
ECAC	European Civil Aviation Conference
ESARR	EUROCONTROL Safety Regulatory Requirement
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAA	Federal Aviation Administration
FHA	Functional Hazard Analysis
FIS	Flight Information Service
FMS	Flight Management System
FP	Framework Programme
GCS	Ground Control Station
ICAO	International Civil Aviation Organisation
IFR	Instrumental Flight Rules
INOUI	Innovative Operational UAS Integration
JAA	Joint Aviation Administration
KOM	Kick Off Meeting
kt	knots
LVNL	Luchtverkeersleiding Nederland (Air Traffic Control The Netherlands)
MET	Meteorological Services
MTOW	Maximum Take Off Weight
NAS	National Air Space (USA)
NATO	North Atlantic Treaty Organization
NATS	National Air Traffic Services
NDB	Non-Directional Beacon
OAT	Operational Air Traffic
PCO	Project Coordinator
RVSM	Reduced Vertical Separation Minimum
SAR	Search and Rescue
SES	Single European Sky
SESAR	Single European Sky ATM Research
SPS	Strategic Plan for Safety
SSE	Safety Significant Event
SSH	System Safety Handbook
STANAG	Standardization Agreement
TCAS	Traffic Collision Avoidance System
TF	Task Force
TWR	Tower
UAS	Unmanned Aircraft Systems
UA	Unmanned Aircraft
USAR	UA System Airworthiness Requirements
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional Range
WP	Work Package

2 Brief overviews of documents relevant for Safety Criteria

A series of documents providing safety criteria or ideas relevant for their development are reviewed and summarized according to the following topics:

- Reference
  - Any articles, reports, white papers, et cetera where the safety criteria are explained further will be mentioned within this section.
- Formal status
  - For whom are these criteria compulsory, which ANSP or other organisation is using them, or are they research work?
- Scope of Risk
  - Describe the kinds of risks concerned, such as only collisions between aircraft, all occurrences with direct contribution by ATM, risk to people on the ground, et cetera.
- Range of severities considered
  - Only accidents or for instance the whole spectrum from occurrences with no safety effect to accidents?
- Frequency metrics used
  - Per flight, per flight hour, per operational hour of the ATC centre, et cetera.
- Risk tolerability
  - Which risk levels are acceptable/negligible, tolerable respectively unacceptable?
- Apportionment
  - Is only a ‘total risk budget’ specified or is it explained how parts of this budget apply to parts of the operation, as for instance flight phases, accident types, kind of ATC provided, et cetera?
- Derivation
  - What is the reasoning behind the criteria? On what are they based?
- Range of applications
  - In which assessments have these criteria been applied? For what operational contexts and timeframes?
- Applicability for INOUI WP5
  - How can the criteria be applied within the context of INOUI WP5?

A thorough bibliographic review of the safety criteria available was conducted. Firstly, references concerning applications to unmanned vehicles were selected. Then the original sample was completed with more generic methodologies for the determination of safety criteria in the manned aviation and ATM arenas.

For each publication selected, an assessment was performed to determine the **main areas** covered by the article (e.g. aircraft systems, airworthiness, regulatory design changes, military UAS integration, et cetera) as well as the **scope of the risks** that were evaluated (e.g. people or property on the ground, airworthiness, accidents, et cetera). In those cases where there were more than one article covering the same topic or with similar risk scope, only one of them was selected for INOUI D5.0a.

Furthermore, any reference to **safety methodologies** was also compiled. Finally the innovative aspects of the sample were analyzed and its relevance as potential safety criteria for INOUI WP5 was determined, thus resulting in the below series of documents.

Before reading the various criteria presented hereafter, the reader should take into account that it is not the aim of this deliverable to establish a comparison between criteria that have little to do with each other. Rather, the intention is to have a diverse sample where new ideas and/or strategies for INOUI can be taken from Figure 1 illustrates how different approaches are mixed together.

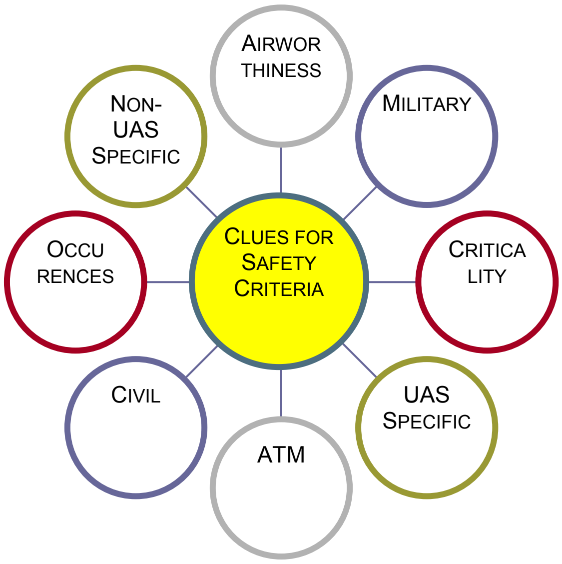


Figure 1 Aspects of the clues for safety criteria

In order to facilitate their comprehension, the different criteria have been classified further as follows:

1. **UAS-specific safety criteria**: Here specification and criteria that have already been applied to UAS have been compiled. They have been subdivided further into:
    a. Criteria related to airworthiness:
        i. Applications in non-segregated airspace (i.e. civil applications); and
        ii. Applications in segregated airspace (i.e. military applications).
    b. Criteria related to ATM:
        i. Applications in non-segregated airspace (i.e. civil applications); and
        ii. Applications in segregated airspace (i.e. military applications).

2. **Non UAS-specific safety criteria**: This is a more generic set of criteria that have not been tailored yet to UAS. They have been applied mainly in the manned aviation arena. No distinction between segregated and non-segregated applications has been made here since all the criteria examined are in the civil (therefore non-segregated) airspace They can be classified further as follows:
    a. Criteria related to airworthiness;
    b. Criteria related to ATM; and
    c. Criteria related to inspection reports.

2.1 UAS-specific Safety Criteria

2.1.1 Criteria related to Airworthiness

2.1.1.1 Applications in non-segregated airspace

2.1.1.1.1 The kinetic energy approach

Reference	[EASA A-NPA No 16/2005], [Clothier, Walker, Fulton and Campbell] and [Weibel and Hansmann, 2005]
Formal status	This approach defines safety levels, which involve the impact kinetic energy of the air vehicle, thereby creating a direct correlation with the capability of the UA to cause injury and damage.
Scope of Risk	Only risk to people and property on the ground (third party risk) due to discontinuance of flight is considered. Hence, mid-air collisions are excluded. The method correlates the accident probability to the population density.
Range of severities considered	The approach restricts to fatal injury to ground personnel and general public, which is usually classified as a HAZARDOUS (or severity II) event according to established risk classification methodologies (e.g. [FAR CS 23.1309-1C or 25.1309-1A])
Frequency metrics used	Per flight hour
Risk tolerability	Several approaches can been found. Some examples are cited below: 1. Conservative tolerability: Use currently established tolerability for manned aircraft (FAR/CS 23.1309 and CS 25.1309) which classifies the fatal injury to ground personnel and general public as **hazardous** and allow for **a maximum frequency of occurrence of once per ten million (10^7) flight hours**. This is used for the definition of areas where the population density allows safe flight of a certain type of UA. 2. Relaxed tolerability: Define an “acceptable” probability for on ground victims per UA flight hour, based on historical data. a. By considering statistics of ground victims due to flying machines as light and transport aircraft, military aircraft or helicopters, one can set a similar **maximum acceptable probability of one victim per million (10^6) UA flight hours** [Clothier, Walker, Fulton and Campbell]. b. By looking at fatalities among people on the ground (not involved as crew or passengers) due to air carrier accidents, a **maximum acceptable probability of 5 victims per ten million (10^7) flight hours** is derived [Weibel and Hansmann, 2005]. Both general aviation and commercial operations exhibit similar levels of safety. However, one statistical study shows that the risk increases by two orders of magnitude in the vicinity of airports.
Apportionment	The aforementioned maximum acceptable probabilities per UA flight hour are total risk budgets, not apportioned further

Derivation	The method consists of an estimation of the energy of the UA and an estimation of the lethal crash area with radius d. For an explosion energy is a cubic function of the radius ($E=d^3$) and lethal area a square function of the radius ($Ac=d^2$) $$Ac=k*E^{2/3}$$ 1. Aircraft energy on impact is considered proportional to its kinetic energy, which depends on the mass and the velocity of the air vehicle. 2. Using design parameters of the air vehicle (e.g. mass, wind surface), the lethal crash area is calculated. 3. Then the ground victims are calculated based on the lethal crash area (Ac), over flown population density and crash probability per flight hour. 4. Setting a target number for the ground victims, one can obtain a crash probability objective.
Range of applications	This method has been applied to ▪ Place restrictions on the nature of the territories a UAS is permitted to over-fly; and ▪ Mandate technology-based mitigation measures in the absence of prescribing regulations.
Applicability for INOUI WP5	This approach is only used for *airworthiness* and therefore of reduced application for INOUI. It can be argued that ATM involvement in accidents and incidents that harm people and property on the ground is much less significant than their role in properly managing traffic and avoiding collisions.

2.1.1.1.2 JAA-Eurocontrol UAV Task Force Recommendations

References	[UAV Task Force 2004]
Formal status	The UAV Task-Force was established to develop a concept for the regulation of civil UA with respect to safety, security, airworthiness, operational approval, maintenance and licensing. It does not include the development of a concept for the regulation of civil UA with respect to ATM.
Scope of Risk	It is mainly focused on **airworthiness**. From the airworthiness point of view, the risk to third parties on the ground is expected to become the most important risk to be minimized. UAS Airworthiness safety criteria aim at providing an equivalent safety level based on a rationale similar to the one adopted for manned airworthiness requirements, but they consider the particular characteristics of UA System design viewed as a whole and not only confined to the Air Vehicle.
Range of severities considered	▪ Catastrophic or **Severity I** event may be defined as the UA's inability to continue controlled flight and reach any predefined landing site (i.e. an uncontrolled UA flight followed by an uncontrolled crash, potentially leading to fatalities or severe damage on the ground).

	Severity categories lower than I may be defined "parallel" to the [EASA AMC 25.1309] categories Hazardous, Major, Minor and No Safety Effect. ▪ **Severity II** would correspond to failure conditions leading to the controlled loss of the UA over an unpopulated emergency site, using Emergency Recovery procedures where required. ▪ **Severity III** would correspond to failure conditions leading to significant reduction in safety margins (e.g. total loss of communication with autonomous flight and landing on a predefined emergency site) ▪ **Severity IV** would correspond to failure conditions leading to slight reduction in safety margins (e.g. loss of redundancy) ▪ **Severity V** would correspond to failure conditions leading to no safety effect.
Frequency metrics used	The ones used in [FAA AC 23.1309-1C] and [EASA AMC 25.1309] are per flight hour.
Risk tolerability	The following guidelines are provided: ▪ The overall (qualitative) Safety Objective for UA System may be e.g. "to reduce the risk of UAS Catastrophic Event (as above defined) to a level comparable to the risk existing with manned aircraft of equivalent category". ▪ As per Advisory Materials such as [FAA AC 23.1309-1C] or [EASA AMC 25.1309], the quantitative probability ranges required for lower severities should be derived from the quantitative required objective of the worst severity.
Apportionment	The implicit apportionment is over the number of failure conditions of a certain severity.
Derivation	Quantitative safety objective for the individual UAS "Catastrophic" or "Severity I" conditions and/or for the sum of all failure conditions leading to a UAS Severity I Event should be set, per UAS category, based upon a rationale similar to the one used in [EASA AMC 25.1309] and [FAA AC 23.1309-1C] considering: ▪ The probability level for catastrophic failure conditions that is considered as acceptable by the airworthiness requirements applicable to manned aircraft of "equivalent class or category"; and ▪ The historical evidence and statistics related to manned aircraft "equivalent class or category", including, where relevant, consideration of subsequent ground fatalities.
Range of applications	Most of the recommendations provided by the report have been endorsed by EASA [see EASA A-NPA No 16/2005] This report is also the starting point for other regulations like for example the ones for light UA systems
Applicability for INOUI WP5	Since the main focus is on *airworthiness*, the criteria are not directly applicable for INOUI; however the derivation of quantitative safety objectives for the individual UAS "Catastrophic" conditions can be helpful and interesting when deriving new criteria for INOUI.

2.1.1.2 Applications in segregated airspace

2.1.1.2.1 STANAG 4671 - UAV System Airworthiness Requirements (USAR) for NATO military UA Systems

References	[STANAG 4671]
Formal status	The NATO Joint Capability Group on Unmanned Aerial Vehicles approved draft STANAG 4671 (Edition 1) on May 9th, 2007. Participating nations agree to adopt the USAR in their national certification standards for **military UAS**, recording national reservations where appropriate. The aim of this agreement is to establish a baseline set of airworthiness standards in relation to the design and construction of military UAS. **The document is still in a preliminary or draft state.**
Scope of Risk	The intention of this document is to correspond as closely as practicable to a comparable minimum level of airworthiness for fixed-wing aircraft as embodied in documents such as [14CFR-23] and [EASA CS-23] (from which it is derived) whilst recognising that there are certain unique features of UA Systems that require particular additional requirements or subparts.
Range of severities considered	**It should be noted that the wording below is still subject of deep discussions between the NATO countries and hence should be used with caution as changes may occur.** o **Catastrophic**: Failure conditions that result in a worst credible outcome of at least uncontrolled flight (including flight outside of pre-planned or contingency flight profiles/areas) and/or uncontrolled crash, which can potentially result in a fatality or Failure conditions which could potentially result in a fatality to UAS crew or ground staff. o **Hazardous**: Failure conditions that either by themselves or in conjunction with increased crew workload, result in a worst credible outcome of a controlled-trajectory termination or forced landing potentially leading to the loss of the UA where it can be reasonably expected that a fatality will not occur. Or Failure conditions which could potentially result in serious injury to UAS crew or ground staff. o **Major**: Failure conditions that either by themselves or in conjunction with increased crew workload, result in a worst credible outcome of an emergency landing of the UA on a predefined site where it can be reasonably expected that a serious injury will not occur. Or Failure conditions which could potentially result in injury to UAS crew or ground staff. o **Minor**: Failure conditions that do not significantly reduce UA System safety and involve UAS crew actions that are well within their capabilities. These conditions may include a slight reduction in safety margins or functional capabilities, and a slight increase in UAS crew workload.

<table>
<tr><td>Frequency metrics used</td><td>Per flight hour

For systems and equipment used only in certain phases of flight (e.g., landing gear), a probability reference of “per flight” instead of “per flight hour” may be used at the discretion of the Certifying Authority (see [FAR AC 23.1309-1C]).</td></tr>
<tr><td>Risk tolerability</td><td>The safety objectives should ensure that systems and equipment design will allow the UA System to achieve an acceptable safety level. A rational and acceptable inverse relationship should exist between the Average Probability per Flight Hour and the severity of failure condition effects. The relationship between probability and severity of failure condition effects is as follows:
<table>
<tr><th></th><th></th><th>Catastrophic</th><th>Hazardous</th><th>Major</th><th>Minor</th><th>No safety effect</th></tr>
<tr><td>Frequent</td><td>> 10⁻³ /h</td><td>▒</td><td>▒</td><td>▒</td><td>▒</td><td></td></tr>
<tr><td>Probable</td><td>< 10⁻³ /h</td><td>▒</td><td>▒</td><td>▒</td><td></td><td></td></tr>
<tr><td>Remote</td><td>< 10⁻⁴ /h</td><td>▒</td><td>▒</td><td></td><td></td><td></td></tr>
<tr><td>Extremely Remote</td><td>< 10⁻⁵ /h</td><td>▒</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Extremely Improbable</td><td>< 10⁻⁶ /h</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
<table>
<tr><td>▒</td><td>Unacceptable</td></tr>
<tr><td></td><td>Acceptable</td></tr>
</table>
</td></tr>
<tr><td>Apportionment</td><td>The apportionment is over failure conditions</td></tr>
<tr><td>Derivation</td><td>Similar to [FAA AC 23.1309-1C]</td></tr>
<tr><td>Range of applications</td><td>Participating nations agree to adopt the USAR in their national certification standards for military UAS, recording national reservations where appropriate.</td></tr>
<tr><td>Applicability for INOUI WP5</td><td>[STANAG 4671] is mainly focused on airworthiness of military UAS and therefore, not applicable directly to INOUI WP5. In addition, this material is still being developed and should be used with caution. The definition of the severity categories proposed in this draft version can lead to new clues in how to classify risks associated to UAS.</td></tr>
</table>

2.1.2 Criteria related to ATM

2.1.2.1 Application in non-segregated airspace

No useful clues for safety criteria have been identified.

2.1.2.2 Applications in segregated airspace

2.1.2.2.1 Eurocontrol UAV-OAT Task Force Approach

References	[Eurocontrol OAT Spec 0102]

Formal status	This is not a risk assessment methodology, but a set of high-level specifications. As the result of a need articulated at [AIRCHIEF 2003], and a request made subsequently through the Civil/Military Interface Standing Committee (CMIC), EUROCONTROL formed the UAV-OAT Task Force (TF) to draft air traffic management (ATM) specifications for the use of military unmanned aerial vehicles (UAV) flying as Operational Air Traffic (OAT) outside segregated airspace. Membership of the TF comprised EUROCONTROL civil and military staff, national military experts and representatives from other interested organisations[1].
Scope of Risk	High-level generic specifications. The specifications are written for military UAS operations which interact with other airspace users within the European ATM system. They are only considering their interaction with manned aviation. They do not consider all classes of UAS, and do not take into account UA versus UA encounters, with associated reduced safety margins.
Range of severities considered	None provided
Frequency metrics used	None provided
Risk tolerability	No quantitative absolute safety target is mentioned. States will subject the specifications to their own risk assessment based upon [ESARR 4] when incorporating them to the national regulations.
Apportionment	Apportionment is left for States using [ESARR 4].
Derivation	The specifications are based on three basic principles: 1. UAS operations should not increase the risk to other airspace users; 2. ATM procedures should mirror those applicable to manned aircraft; and 3. The provision of air traffic services to UAS should be transparent to ATC controllers. The specifications are also innovative insofar as they are not constrained by limitations in current UAS capability such as sense-and-avoid. These specifications will only be practicable once industry develops this and other necessary technology.
Range of applications	These high level specifications can be used to derive lower level requirements and quantitative safety targets.
Applicability for INOUI WP5	The scoping is similar to INOUI WP5, but no safety target or methodology is provided. Some of their principles might be useful for INOUI Safety Assessment. The scope is limited only to UAS versus manned aircraft encounters.

[1]Specifications were chosen as the most appropriate category from the EUROCONTROL Regulatory and Advisory Framework because their voluntary status would leave individual states free to decide whether or not to incorporate them into their own national regulations. This was also the rationale for keeping the specifications high-level and generic.

2.2 *Non UAS-specific Safety Criteria*

2.2.1 Criteria related to Airworthiness

2.2.1.1 FAA System Safety Guidelines

Reference	[Weibel and Hansmann, 2005], [FAA SSH]
Formal status	[FAA Order 8040.4] specifies that a risk management process should be applied to all high-consequence decisions by the FAA, which includes the incorporation of a new class of aircraft in the NAS. Published in support of [FAA Order 8040.4], the FAA System Safety Handbook [FAA SSH] provides general guidance to FAA personnel and contractors on implementing a risk management process but does not supersede existing regulations. Other system safety regulations include advisory circulars for systems in Part 23 and 25 aircraft. The three above mentioned FAA system safety policies were used as guidance to investigate the safety considerations for operation of UAS in the NAS.
Scope of Risk	Risk to human workload, well being, health and lives (public users) as a consequence of aircraft system failures.
Range of severities considered	The FAA defines five classes of severity of consequences in [FAA SSH], ranging from "catastrophic" to "no safety effect." The explanations of effects that fall under each level of severity are included below. The severity definitions included the SSH are consistent with the advisory material for system safety of Part 23 and Part 25 aircraft. Part 25 does not include the subcategory of hazardous events.

Severity Level	Definition
Catastrophic	Results in multiple fatalities and/or loss of the system
Hazardous	Reduces the capability of the system or the operator ability to cope with adverse conditions to the extent that there would be: - Large reduction in safety margin or functional capability - Crew physical distress/excessive workload such that operators cannot be relied upon to perform required tasks accurately or completely Serious or fatal injury to small number of occupants of aircraft (except operators) Fatal injury to ground personnel and/or general public
Major	Reduces the capability of the system or the operators to cope with adverse operating condition to the extent that there would be - Significant reduction in safety margin or functional capability - Significant increase in operator workload - Conditions impairing operator efficiency or creating significant discomfort - Physical distress to occupants of aircraft (except operator) including injuries - Major occupational illness and/or major environmental damage, and/or major property damage
Minor	Does not significantly reduce system safety. Actions required by operators are well within their capabilities. Includes: - Slight reduction in safety margin or functional capabilities - Slight increase in workload such as routine flight plan changes - Some physical discomfort to occupants or aircraft (except operators) - Minor occupational illness and/or minor environmental damage, and/or minor property damage
No Safety Effect	Has no effect on safety

<table>
<tr><td>Frequency metrics used</td><td>Per flight hour</td></tr>
<tr><td>Risk tolerability</td><td>
Four categories of likelihood are defined by the FAA, ranging from probable to extremely improbable. Each level of likelihood has a qualitative and quantitative definition. The quantitative levels vary across FAA advisory material depending on the system. Definitions are consistent between the advisory circular for Part 25 aircraft and the system safety handbook, except for a lack of a hazardous category in the former. Likelihood definitions vary for different types of Part 23 aircraft in recognition of different realizable equipment reliability levels. A comparison of the likelihood of occurrence definitions across regulatory guidance is shown in below. The broad range of the definition of improbable in [FAA AC 25.1309-1A] reflects the lack of a hazardous classification of consequence. Part 23 further divides aircraft into four classes depending upon propulsion type and weight. The most stringent requirements are dictated by the system safety handbook.
<table>
<tr><th colspan="2">Guidance Source</th><th colspan="7">Likelihood of Occurrence (by order of Magnitude)
10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} below</th></tr>
<tr><td colspan="2">FAA SSH</td><td colspan="2">Probable</td><td colspan="2">Remote</td><td colspan="2">Extremely Remote</td><td>Extremely Improbable</td></tr>
<tr><td colspan="2">AC 25.1309</td><td colspan="2">Probable</td><td colspan="4">Improbable</td><td>Extremely Improbable</td></tr>
<tr><td rowspan="4">AC 23.1309</td><td>Class[1] IV</td><td colspan="2">Probable</td><td colspan="2">Remote</td><td colspan="2">Extremely Remote</td><td>Extremely Improbable</td></tr>
<tr><td>III</td><td colspan="2">Probable</td><td colspan="2">Remote</td><td>Extremely Remote</td><td colspan="2">Extremely Improbable</td></tr>
<tr><td>II</td><td colspan="2">Probable</td><td>Remote</td><td>Extremely Remote</td><td colspan="3">Extremely Improbable</td></tr>
<tr><td>I</td><td>Probable</td><td>Remote</td><td>Extremely Remote</td><td colspan="4">Extremely Improbable</td></tr>
</table>
The risk tolerability matrix shown below is common to the System Safety Handbook and both Part 23 and 25 Advisory Materials:
<table>
<tr><th>Severity/ Likelihood</th><th>No Safety Effect</th><th>Minor</th><th>Major</th><th>Hazardous</th><th>Catastrophic</th></tr>
<tr><td>Probable</td><td>green</td><td>yellow</td><td>red</td><td>red</td><td>red</td></tr>
<tr><td>Remote</td><td>green</td><td>green</td><td>yellow</td><td>red</td><td>red</td></tr>
<tr><td>Extremely Remote</td><td>green</td><td>green</td><td>green</td><td>yellow</td><td>red</td></tr>
<tr><td>Extremely Improbable</td><td>green</td><td>green</td><td>green</td><td>green</td><td>yellow</td></tr>
</table>
</td></tr>
<tr><td>Apportion-ment</td><td>A target Average Probability for catastrophic failures is calculated and apportioned equally among all the catastrophic Failure Conditions (for further details see ‘derivation’ below).</td></tr>
</table>

Derivation	For Part 23 aircrafts – see [FAA AC 23.1309-1C]: 1. Historical evidence indicates that the probability of a fatal accident in restricted visibility due to operational and airframe-related causes is approximately one per ten thousand hours of flight for single-engine airplanes under 6,000 pounds. 2. Furthermore, from accident databases, it appears that about 10 percent of the above (?) total was attributed to Failure Conditions caused by the airplane's systems. It is reasonable to expect that the probability of a fatal accident from all such Failure Conditions would not be greater than one per one hundred thousand flight hours or 1×10^{-5} per flight hour for a newly designed airplane. 3. It is also assumed, arbitrarily, that there are about ten potential Failure Conditions in an airplane that could be catastrophic. The allowable target Average Probability Per Flight Hour of 1×10^{-5} was thus apportioned equally among these Failure Conditions, which resulted in an allocation of not greater than 1×10^{-6} to each. 4. The upper limit for the Average Probability per Flight Hour for Catastrophic Failure Conditions would be 1×10^{-6}, which establishes an approximate probability value for the term "Extremely Improbable." Failure Conditions having less severe effects could be relatively more likely to occur. Similarly, airplanes over 6,000 pounds have a lower fatal accident rate; therefore, they have a lower maximum acceptable probability value for Catastrophic Failure Conditions. A similar derivation is given for the probabilities assigned for commercial transport aircraft, except that the probability of a fatal accident due to airplane system failures is assumed to be less than 10^{-7}, with approximately 100 potential failure conditions that could be catastrophic, and a mean flight duration of one hour—giving the 10^{-9} per flight hour requirement.
Range of applications	Wide range of applications for the introduction of new aircraft systems.
Applicability for INOUI WP5	The above criteria deal mainly with airworthiness issues and therefore are not directly applicable for INOUI. They may be useful to relate criteria for 'small' aircraft to those of large aircraft. [FAA AC 23-1309-1C] has been issued historically to enable the use of pilot assistance systems like terrain warning systems. The evaluation of consequences due to the failure of these systems should show that the use is more beneficent to aviation than not to use them. [FAA AC 25-1309-1A] has a different scope. Here the approach has been used to certify flight critical parts!

2.2.1.2 EASA 25.1309 Safety Criteria

Reference	[EASA CS-25]
Formal status	Certification Specifications for Large Aeroplanes, defining the basic safety specifications for airworthiness approval of aeroplane systems and provides an acceptable means of demonstrating compliance with this rule.
Scope of Risk	Risk to people on-board derived from aeroplane systems and equipment failures.
Range of severities considered	▪ **No Safety Effect**: Failure Conditions that would have no effect on safety; for example, Failure Conditions that would not affect the operational capability of the aeroplane or increase crew workload. ▪ **Minor**: Failure Conditions which would not significantly reduce aeroplane safety, and which involve crew actions that are well within their capabilities. Minor Failure Conditions may include, for example, a slight reduction in safety margins or functional capabilities, a slight increase in crew workload, such as routine flight plan changes, or some physical discomfort to passengers or cabin crew. ▪ **Major**: Failure Conditions which would reduce the capability of the aeroplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in crew workload or in conditions impairing crew efficiency, or discomfort to the flight crew, or physical distress to passengers or cabin crew, possibly including injuries. ▪ **Hazardous**: Failure Conditions, which would reduce the capability of the aeroplane or the ability of the crew to cope with adverse operating, conditions to the extent that there would be: 1. A large reduction in safety margins or functional capabilities; 2. Physical distress or excessive workload such that the flight crew cannot be relied upon to perform their tasks accurately or completely; or 3. Serious or fatal injury to a relatively small number of the occupants other than the flight crew. ▪ **Catastrophic***:* Failure Conditions, which would result in multiple fatalities, usually with the loss of the aeroplane. (Note: A “Catastrophic” Failure Condition was defined in previous versions of the rule and the advisory material as a Failure Condition which would prevent continued safe flight and landing.)
Frequency metrics used	Per flight hour

Risk tolerability

Effect on Aeroplane	No effect on operational capabilities or safety	Slight reduction in functional capabilities or safety margins	Significant reduction in functional capabilities or safety margins	Large reduction in functional capabilities or safety margins	Normally with hull loss
Effect on Occupants excluding Flight Crew	Inconvenience	Physical discomfort	Physical distress, possibly including injuries	Serious or fatal injury to a small number of passengers or cabin crew	Multiple fatalities
Effect on Flight Crew	No effect on flight crew	Slight increase in workload	Physical discomfort or a significant increase in workload	Physical distress or excessive workload impairs ability to perform tasks	Fatalities or incapacitation
Allowable Qualitative Probability	No Probability Requirement	<---Probable---->	<----Remote---->	Extremely <------------------> Remote	Extremely Improbable
Allowable Quantitative Probability: Average Probability per Flight Hour on the Order of:	No Probability Requirement	<------------------> $<10^{-3}$ Note 1	<------------------> $<10^{-5}$	<------------------> $<10^{-7}$	$<10^{-9}$
Classification of Failure Conditions	No Safety Effect	<-----Minor------>	<-----Major------>	<--Hazardous-->	Catastrophic
Note 1: A numerical probability range is provided here as a reference. The applicant is not required to perform a quantitative analysis, nor substantiate by such an analysis, that this numerical criteria has been met for Minor Failure Conditions. Current transport category aeroplane products are regarded as meeting this standard simply by using current commonly-accepted industry practice.					

Apportionment	Apportioned over failure conditions
Derivation	Similar to [FAA AC-25.1309-1A]
Range of applications	This set of requirements is applied for the certification of systems of turbine powered large aeroplanes under EASA mandate.
Applicability for INOUI WP5	[EASA CS-25] are intended for airworthiness and therefore do not cover the same scope as INOUI WP5.

2.2.2 Criteria related to ATM

2.2.2.1 ESARR 4

Reference	[ESARR4, SRC Policy Doc 1]
Formal status	The States in the ECAC/Eurocontrol region have agreed with each other to use the Eurocontrol Safety Regulatory Requirements (ESARRs). ESARRs 2 – 6 particularly concern ANSPs, while ESARR 1 concerns the States' National Supervisory Authorities. [ESARR 4] stipulates risk assessment and mitigation and is to be applied for all changes to ATM.

<table>
<tr><td></td><td>[ESARR 4] as well as ESARRs 3 and 5 has largely been incorporated in the [EC Common Requirements] and underlying documents, which are binding for the Members of the European Union. However, the quantified expression for the safety minimum in [ESARR 4] (see the topic ‘Risk tolerability’ below) has not been incorporated.</td></tr>
<tr><td>Scope of Risk</td><td>Risk with a direct contribution of ATM (where at least one ATM event or item was judged to be DIRECTLY in the causal chain of events leading to an accident or incident. Without that ATM event, it is considered that the occurrence would not have happened.)</td></tr>
<tr><td>Range of severities considered</td><td>From 1 (where the effect on operations is ‘accidents’) to 5 (‘no immediate effect on safety’), being defined as follows:

Severity class 1

▪ Effect on operations: Accidents
▪ Examples of effects on operations include:
o One or more catastrophic accidents;
o One or more mid-air collisions;
o One or more collisions on the ground between two aircraft;
o One or more Controlled Flight Into Terrain; and
o Total loss of flight control.

No independent source of recovery mechanism, such as surveillance or ATC and/or flight crew procedures can reasonably be expected to prevent the accident(s).

Severity class 2

▪ Effect on operations: Serious incidents
▪ Examples of effects on operations include:
o Large reduction in separation (e.g., a separation of less than half the separation minima), without crew or ATC fully controlling the situation or able to recover from the situation; and
o One or more aircraft deviating from their intended clearance, so that abrupt manoeuvre is required to avoid collision with another aircraft or with terrain (or when an avoidance action would be appropriate).</td></tr>
</table>

	Severity class 3 ▪ Effect on operations: **Major incidents** ▪ Examples of effects on operations include: o Large reduction (e.g., a separation of less than half the separation minima) in separation with crew or ATC controlling the situation and able to recover from the situation; and o Minor reduction (e.g., a separation of more than half the separation minima) in separation without crew or ATC fully controlling the situation, hence jeopardising the ability to recover from the situation (without the use of collision or terrain avoidance manoeuvres). **Severity class 4** ▪ Effect on operations: **Significant incidents** ▪ Examples of effects on operations include: o Increasing workload of the air traffic controller or aircraft flight crew, or slightly degrading the functional capability of the enabling CNS system; and o Minor reduction (e.g., a separation of more than half the separation minima) in separation with crew or ATC controlling the situation and fully able to recover from the situation. **Severity class 5** ▪ Effect on operations: **No immediate effect on safety** ▪ Examples of effects on operations include: o No hazardous condition (i.e. no immediate direct or indirect impact on the operations).
Frequency metrics used	Per flight hour and per flight
Risk tolerability	The ECAC Safety Minimum has been expressed as a “maximum tolerable probability of ATM directly contributing to an accident of a Commercial Air Transport aircraft of 1,55 * 10^{-8} accidents per Flight Hour”, where accident has been defined as in ICAO Annex 13. The maximum tolerable probabilities for severity classes 2, 3, 4 and 5 remain to be determined. This has to be done at a national level.
Apportionment	The ECAC Safety Minimum of [ESARR 4] has not been apportioned.

Derivation	[SRC Policy Doc 1] provides the reasoning behind the ECAC Safety Minimum: 1. Review from ICAO ADREP data from 1988 to 1999 yielded that a total of 374 accidents occurred in the ECAC region for aircraft with a maximum take-off weight (MTOW) of at least 2 250 kg, which amounts to 31.17 accidents per year; 2. A UK CAA study is referenced for the estimate that there is at least one primary ATC cause for 1.1% of the fatal accidents for public transport aircraft with an MTOW of at least 5 700 kg; 3. As ATM encompasses not only ATC (but also Air Traffic Flow Management and Airspace Management, and other forms of Air Traffic Services) it was estimated that ATM would directly contribute to 2% of the accidents, hence 0.6234 accidents per year; 4. The number of flight hours regarding Commercial Air Transport aircraft in the ECAC region in 1999 is estimated at 14 207 969, which yields an accident rate of 4.38 * 10-8 per flight hour; and 5. In order not to let the absolute number of accidents increase, this figure is divided by 1.06716 = 2.82 to compensate for traffic growth from 1999 up to 2015 with an expected annual rate of 6.7 % to yield the 1.55 * 10-8 accidents per flight hour for ATM directly contributing to an accident of a Commercial Air Transport aircraft.
Range of applications	Numerous applications from 2001 (publication) respectively 2004 ([ESARR 4] effective) by Eurocontrol and ANSPs in the ECAC/Eurocontrol region to changes in ATM.
Applicability for INOUI WP5	[ESARR 4] deals only with changes in ATM. Furthermore, in the documents underlying [ESARR 4] it was estimated that ATM contributes directly to about 2% of Commercial Air Transport aircraft accidents. It seems that INOUI should have a broader scope than just the accidents ATM has directly contributed to.

2.2.2.2 DFS Risk Matrix

Reference	[DFS SA Handbook]
Formal status	Implementation of [ESARR 4] by DFS, to be applied for all changes to ATM under responsibility of DFS
Scope of Risk	Risk with a direct contribution of ATM is included, as required by ESARR 4
Range of severities considered	Like in [ESARR 4]: From 1 (accidents) to 5 (no safety effect). Two aspects of effects are considered: ▪ Effects on safety in air traffic; and ▪ Effects on people.

<table>
<tr><td>Frequency metrics used</td><td>Once every …hours/days/months/years for the whole DFS operation</td></tr>
<tr><td>Risk tolerability</td><td>The severity and frequency of an effect of a hazard together define the risk. The risk tolerability is defined according to the following DFS risk matrix:
<table>
<tr><td rowspan="3">Frequency of effect („once every...“)</td><td colspan="5">Severity of effect</td></tr>
<tr><td>Catastrophic</td><td>Major</td><td>Medium</td><td>Minor</td><td>No effect</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>< 1 hour</td><td>a</td><td>a</td><td>a</td><td>b</td><td>d</td></tr>
<tr><td>1 hour ... 5 days</td><td>a</td><td>a</td><td>b</td><td>c</td><td>d</td></tr>
<tr><td>5 days ... 18 months</td><td>a</td><td>b</td><td>c</td><td>d</td><td>d</td></tr>
<tr><td>18 months ... 150 years</td><td>b</td><td>c</td><td>d</td><td>d</td><td>d</td></tr>
<tr><td>150 years ... 15,000 years</td><td>c</td><td>d</td><td>d</td><td>d</td><td>d</td></tr>
<tr><td>> 15,000 years</td><td>d</td><td>d</td><td>d</td><td>d</td><td>d</td></tr>
</table>
The risk tolerability classes a, b, c and d are defined as follows:
<table>
<tr><td>Risk class</td><td>Interpretation</td></tr>
<tr><td>a</td><td>Unacceptable</td></tr>
<tr><td>b</td><td>Undesirable; tolerable only for a limited time with the agreement of the Board of Managing Directors, as long as it is not possible to further reduce the risk</td></tr>
<tr><td>c</td><td>Tolerable, but only with the agreement of operational management (e.g. head of Business Unit „Control Centre“, head of BU „Tower“)</td></tr>
<tr><td>d</td><td>Acceptable</td></tr>
</table>
</td></tr>
<tr><td>Apportionment</td><td>The DFS risk matrix can be considered as an apportionment of the ECAC Safety Minimum in [ESARR 4]: the matrix is to be applied to individual risks (a risk is a combination of a hazard and an effect with a certain severity).</td></tr>
<tr><td>Derivation</td><td>A simplified reasoning is as follows:

The starting point for the DFS risk matrix is the safety minimum in the ECAC area from [ESARR 4] of a maximum tolerable probability of an accident involving direct ATM contribution of 1.55×10^{-8} accidents/ flight hour, to be achieved by 2004. Taking into account:

2.6×10^{6} flights controlled by DFS in 2000,
an annual growth rate of 5.2%, and
the average time a flight controlled by DFS is 35 minutes,

</td></tr>
</table>

	the ECAC safety minimum translates into a maximum of one accident with DFS direct contribution every 30 years. Assuming there are five catastrophic risks yields an upper bound for the tolerable frequency of a catastrophic risk of once in 150 years. The upper bound of the acceptable frequency of a catastrophic risk is set a factor 100 lower, in order to provide a safety buffer. Starting from this frequency and these risk classes, the risk matrix can be reconstructed using the following rules: ▪ Each frequency class covers a range of two orders of magnitude, i.e., a factor 100; and ▪ If the severity of an effect is reduced by one, the associated risk may occur 100 times as often. A more elaborate reasoning presumes a distribution of the number of accidents risks as a function of the accident's frequency. If this distribution is truncated at once per 150 years, the total accident risk will not exceed once per 30 years.
Range of applications	Well over 200 safety assessments for changes of ATM within the responsibility of DFS have been made since about 2001. The stated safety criteria have been applied in all of these.
Applicability for INOUI WP5	As [ESARR 4], it is only applicable to changes in ATM (under responsibility of DFS). The introduction of UAS in non-segregated airspace is not exactly a change in ATM. A broader scope is needed for INOUI.

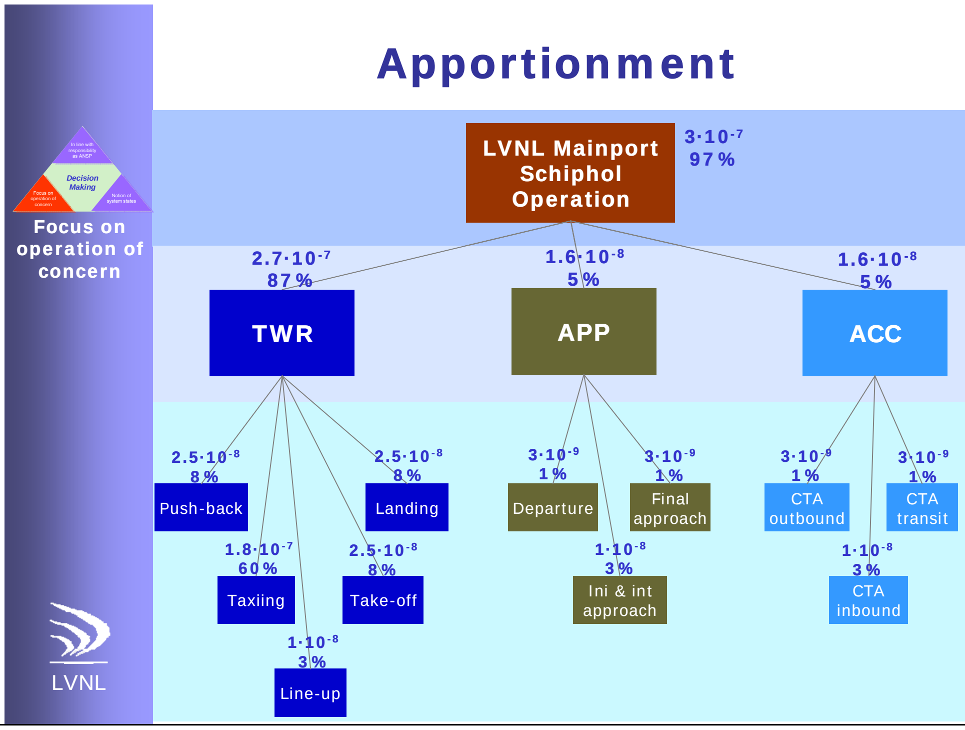
2.2.2.3 LVNL Safety Criteria (Version 2)

Reference	[LVNL Safety Criteria]
Formal status	Applied for changes in LVNL's ATC operation, for which quantitative risk analysis are used
Scope of Risk	ATC related risk, which by definition concerns accidents due to collisions between aircraft and other aircraft, wake vortices and vehicles. Prevention of these collisions is the primary purpose of ATC, see [EC No. 549/2004 and ICAO Doc 4444] For ATC related risk, it is not relevant who or what caused it – it is only the occurrence category (see [CAST ICAO Occurrence Categories] that matters.
Range of severities considered	Only accidents are considered (incidents are excluded)
Frequency metrics used	Per flight

<table>
<tr>
<td>Risk tolerability</td>
<td>
Below are given, the available ATC related risk budgets for:

- LVNL as a whole;
- LVNL’s TWR, APP and ACC business units; and
- The 11 ATC subproducts:

are given below:



</td>
</tr>
<tr>
<td>Apportionment</td>
<td>
LVNL’s Safety Criteria have been apportioned in two levels according to:

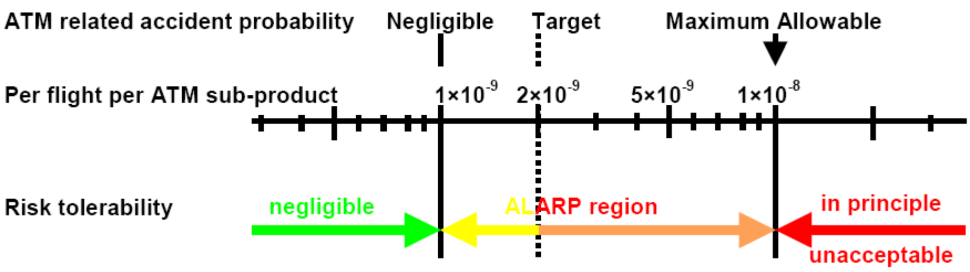
- Business unit level; and
- ATC subproducts.

More precisely, the apportionment of the total risk budget is according to:

- ACC:
  - CTA inbound;
  - CTA outbound; and
  - CTA transit.
- APP:
  - Departure;
  - Initial and intermediate approach; and
  - Final approach.
- TWR:
  - Landing;
  - Line-up;
  - Start-up and pushback;
  - Take off; and
  - Taxiing.
</td>
</tr>
</table>

Derivation

The simplified derivation for the earlier Version 1 of the LVNL Safety Criteria is given, which is defined by the following risk-tolerability diagram to be applied per ATM subproduct:



Version 1 contains more ATM subproducts (than Version 2 contains ATC products) and distributes a slightly larger total budget in a uniform way. The following criteria were used to establish the accident sample:

1. The selected accident must fulfil the definition in [ICAO Annex 13];
2. The accidents involved aircraft operated by commercial operators (including only aircraft in the take-off weight category of 5,670kg and higher);
3. Accidents due to sabotage, terrorism and military actions are excluded;
4. Russian built aircraft and business jets are excluded due to lack of complete and accurate flight exposure data;
5. The time frame chosen was 1980-1999. This time frame was considered large enough to provide a statistically acceptable number of accidents and exposure data;
6. With respect to ATM related accidents, the following types are considered:
    - Wake vortex induced accidents;
    - Accidents involving two or more aircraft;
    - Accidents involving one aircraft and one or more ground vehicles; and
    - Accidents involving problems with landing aids; and
7. Accidents in the flight phase “standing” were excluded.

These queries resulted in an overall rate of 5.6 accidents per million flights, 8.2% of which were ATM related. The worldwide ATM related accident probability is thereby 4.6×10^{-7} per flight.

	An approach as in [EASA AMC 25.1309] is used to apportion this rate, from the perspective of a single flight. The ATM related accident probability is defined as the risk budget for the entire ATM operation. In order to apportion the risk budget over the ATM operation, it is assessed that an aircraft during a flight encounters a maximum number of 40 parts within ATM service provision with the potential for an ATM related accident, referred to as ATM sub-products. The division has been made such that it reflects the different ATM processes such as ACC, APP, TWR and Ground and sub-processes of these. It was decided to distribute the ATM related accident probability evenly over these sub-products, giving the Maximum Allowable Accident Probability of $1x10^{-8}$ per ATM sub-product, per flight. The Target Accident Risk is based on the ambition to improve on historical performance. LVNL has chosen a factor 5 for this, which gives a Target Accident Risk of $2x10^{-9}$ per ATM subproduct, per flight. For safety management it is convenient to define a level of safety below which risks are considered negligible. LVNL has chosen a factor 2 for this, giving a Negligible Accident Risk of $1x10^{-9}$ per ATM sub-product, per flight. As mentioned before, in Version 2 the 40 ATM subproducts of Version 1 have been clustered to 11 ATC subproducts, the total available risk budget has been actualised and distributed non-uniformly over the ATC subproducts in a manner corresponding to accident statistics and expert judgement.
Range of applications	Used in quantified risk analysis for changes
Applicability for INOUI WP5	The scope of risks considered by [LVNL Safety Criteria] is broader than that of [ESARR 4], since ATC related accidents concern about 8% of all accidents, while accidents with direct ATM contribution about 2%. Moreover, ATC related accidents are independent of the cause, which makes these criteria more suitable for the introduction of UAS, where the restriction to risk with direct ATM contribution is less appropriate. In addition, [LVNL Safety Criteria] provides solid and transparent statistical data and an apportionment method that can be applied beyond LVNL. A limitation of [LVNL Safety Criteria] is that it applies to aircraft with MTOW > 5,670kgs operated by Commercial Operators. Hence statistical figures cannot be transferred to aircraft and UAS flying in different contexts and/or being (much) lighter. The apportionment method may still be valuable but figures must be adopted.

2.2.2.4 The NATS severity and risk scheme for Safety Significant Events

Reference	[NATS SPS 2004, NATS SPS 2007, SAF-SAM1-FHA]

<table>
<tr><td>Formal status</td><td>NATS internal measure for assessing the severity of incidents and the risk acceptability of corresponding frequencies</td></tr>
<tr><td>Scope of Risk</td><td>Incidents in which ATC error causes a loss of separation between aircraft, or would have led to a loss of separation if it had not been for intervention by ATC. These incidents are called by NATS Safety Significant Events (SSE). Under the NATS SSE scheme every report where NATS was in error (not only Airprox) are assessed internally for severity.</td></tr>
<tr><td>Range of severities considered</td><td>From Category 1 to Category 4, where Category 1 is more severe than Category 4. Categories are defined as:

Category 1: Sudden inability to provide any degree of Air Traffic Control (including Contingency Separation Measures) within one or more airspace sectors for a significant period of time.

Category 2: The ability to maintain Air Traffic Control is severely compromised within one or more airspace sectors without warning for a significant period of time.

Category 3: The ability to maintain Air Traffic Control is impaired within one or more airspace sectors without warning for a significant period of time.

Category 4: No effect on the ability to maintain Air Traffic Control in the short term, but the situation needs to be reviewed for the requirement to apply some form of contingency measures if the condition prevails.

There is a not a one-to-one mapping between NATS severity classes and [ESARR 4] Severity classes.</td></tr>
<tr><td>Frequency metrics used</td><td>Probability of event per operational hour per sector</td></tr>
<tr><td>Risk tolerability</td><td>
<table>
<tr><th colspan="2" rowspan="3">Probability:
P_s (Probability per operational hour per sector)</th><th colspan="4">Risk Classification</th></tr>
<tr><th colspan="4">Severity Class</th></tr>
<tr><th>4</th><th>3</th><th>2</th><th>1</th></tr>
<tr><td>Frequent</td><td>$P_s > 10^{-3}$</td><td>C</td><td>A</td><td>A</td><td>A</td></tr>
<tr><td>Probable</td><td>$10^{-3} \geq P_s > 10^{-4}$</td><td>D</td><td>B</td><td>A</td><td>A</td></tr>
<tr><td>Occasional</td><td>$10^{-4} \geq P_s > 10^{-5}$</td><td>D</td><td>C</td><td>B</td><td>A</td></tr>
<tr><td>Remote</td><td>$10^{-5} \geq P_s > 10^{-6}$</td><td>D</td><td>D</td><td>C</td><td>B</td></tr>
<tr><td>Improbable</td><td>$10^{-6} \geq P_s > 10^{-7}$</td><td>D</td><td>D</td><td>D</td><td>C</td></tr>
<tr><td>Extremely Improbable</td><td>$P_s > 10^{-7}$</td><td>D</td><td>D</td><td>D</td><td>D</td></tr>
</table>

The risk classification (A – D) is to be interpreted as follows:

▪ Class A SSE are unacceptable;
▪ Class B SSE are undesirable, but may exceptionally be acceptable with the approval of the relevant Director;
▪ Class C SSE are acceptable with the endorsement of the appropriate Local Manager; and
▪ Class D SSE are acceptable.
</td></tr>
</table>

Apportionment	The matrix applies to all Mandatory Occurrence Reports (as established by NATS) where NATS was in error (not only AIRPROX).
Derivation	The tolerability/acceptability classes and their distribution in the matrix were decided empirically based on the totality of NATS operational experience. No further information regarding this aspect is available.
Range of applications	Used in the analysis of all NATS Mandatory Occurrence Reports
Applicability for INOUI WP5	The criteria evaluate risk from the ATC point of view. One interesting aspect of this approach is that includes accident/incident causation by ATC as well as lack of accident/incident prevention. The likely consequences for the aircraft (and its occupants) are not taken into account. Another aspect is that, as opposed to [ESARR 4], the criteria are used retrospectively, i.e. for events that have occurred, instead of prospectively to evaluate the risk consequences of changes. The criteria are not applicable for INOUI since the scope is not to introduce a new ATM service or change, but a new type of air vehicles. In addition, INOUI WP5 needs prospective safety criteria instead of criteria for incidents that have occurred.

2.2.2.5 AENA Safety Criteria

Reference	[AENA Safety Target]
Formal status	Definition of Safety Objectives for AENA's Air Navigation Services and associated systems and elements. The results are used as a reference to know the state and trend of AENA's Air Navigation Services safety levels, determine causal events, mitigation measures and design procedural improvements. It is also applied to the investigation of safety occurrences in ATM. They are based on [ESARR 4] and Spanish DGAC Resolutions.
Scope of Risk	ATM direct and indirect contribution to accidents and incidents.
Range of severities considered	As defined within [Eurocontrol SRC SCS]: ▪ **Accidents**: According to [ICAO Annex 13]: "An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as such persons have disembarked, in which: - A person is fatally or seriously injured (as a result of..) - The aircraft sustains damage or structural failure (which..) - The aircraft is missing or is completely inaccessible" SRC note: *ATM related accidents include more specifically collisions between aircraft, between aircraft and obstacles, Controlled Flight Into Terrain and Loss of Control in Flight due to meteorological conditions and VORTEX.*

<table>
<tr><td></td><td>

Incident – Severity A (Serious Incident): According to [ICAO Annex 13]: “An incident involving circumstances indicating that an accident nearly occurred. Note: The difference between an accident and a serious incident lies only in the result.”
SRC note: ATM related serious incidents would include more specifically critical near collisions between aircraft, between aircraft and obstacles, critical near Controlled Flight Into Terrain and critical near Loss of control in flight due to meteorological conditions and VORTEX.
Incident – Severity B (Major incident): An incident associated with the operation of an aircraft, in which safety of aircraft may have been compromised, having led to a near collision between aircraft, with ground or obstacles (i.e., safety margins not respected which is not the result of an ATC instruction).
SRC note: ATM related major incidents would include more specifically near collisions between aircraft, near collisions between aircraft and obstacles, near Controlled Flight Into Terrain.
Incident – Severity C (Significant incident): An incident involving circumstances indicating that an accident, a serious or major incident could have occurred, if the risk had not been managed within safety margins, or if another aircraft had been in the vicinity.
SRC note: ATM related significant incidents would include more specifically situations where collisions/near collisions could have occurred in other conditions.
Incident – Severity D (No safety effect): An incident which has no safety significance.
Incident – Severity E (Not determined): Insufficient information was available to determine the risk involved or inconclusive or conflicting evidence precluded such determination.

These definitions are similar with [ESARR 4] and FAA/EASA terminology.
</td></tr>
<tr><td>Frequency metrics used</td><td>Per 100.000 movements</td></tr>
<tr><td>Risk tolerability</td><td>For the year 2007, the maximum tolerable frequencies for the first three categories were (per 100.000 movements):
<table>
<tr><td>Accidents</td><td>Incidents Severity A</td><td>Incidents Severity B</td></tr>
<tr><td>0,003881</td><td>1,005842</td><td>1,924104</td></tr>
</table>
These figures are updated every year.</td></tr>
<tr><td>Apportionment</td><td>The Spanish DGAC specifies the maximum allowable frequency for the ATM contribution to accidents and incidents in the Spanish airspace. AENA estimates the contribution of the ANSP to the national ATM risk. The ANSP shall further apportion these figures over each ATM Unit.

The above matrix represents ‘total’ figures; not figures to apply to individual flight phases or ATM units.</td></tr>
</table>

Derivation	1. For each year the number of accidents/incidents per the severity category is taken into account; 2. The average for a specific range ([SRC POLICY DOC 1] recommends 12 years) is then calculated; 3. This figure is considered as the maximum tolerable frequency for the coming years (coherent with ECAC's [ATM 2000+] strategy); 4. Traffic growth is estimated at a constant rate of 6,7% per year. Therefore $3.21x10^6$ flights are estimated to be controlled by AENA in 2015; 5. For 2007, $1.91x10^6$ flights were estimated to be controlled by AENA; and 6. The maximum frequency of accidents for the year 2015 for the ECAC region is $2.31x10^{-8}$ per flight [ESARR 4]. Under the assumption that the number of accidents will not grow, the figure for the maximum number of accidents per flight for 2007 can be obtained: $X_{2007} = (2.31x10^{-8} * 3.21x10^6)/ 1.91x10^6 = 3.881x10^{-8}$ accidents per flight
Range of applications	The Spanish DGAC updates the Target Level Objectives every year and AENA applies it to the ATM services they provide.
Applicability for INOUI WP5	The above criteria take into account ATM direct and indirect contribution to accidents and incidents, which seems a narrow scope for the introduction of UAS into non-segregated airspace were other contributions may also be important for safety.

2.2.2.6 White Paper on the SESAR Safety Target

References	[SESAR Safety Target]
Formal status	The aim of this white paper is to define the SESAR safety target in sufficient detail to understand how to use it in safety assessments and how to demonstrate compliance using risk modelling. As such, [SESAR Safety Target] intends to inform the SESAR Safety Case development about the transversal, operational and system threads posed by the SESAR work programme. In addition, it aims at feeding the activities of SESAR related to the performance framework and target refinement.
Scope of Risk	The risk of an accident or incident can be said to be within the scope of the SESAR safety target if the cause (or significant contribution to the cause) of an accident/incident either: ▪ Lies within the ATM system loop – irrespective as to whether the problem is in the ground, air or space segment of that loop; or ▪ Lies outside of the ATM loop but ATM could reasonably have been expected to mitigate the initiation or consequences of the causal event. This leads to consider two types of ATM contributions:

	▪ Negative contribution – the risk caused by unsuccessful or erroneous ATM; and ▪ Positive contributions – the benefits of ATM in preventing accidents. The scope of this target includes the following: ▪ **Safety Occurrences** as defined in [ESARR 2] – any type of safety-related event (excluding unlawful related events) with an ATM contribution; ▪ **Involvements** – in the case of collisions, each aircraft involved is counted separately; ▪ **Contribution** – any event that causes the failure of a barrier that normally serves to prevent the accident, or which represents the benefits of ATM in preventing accidents and incidents; ▪ **ATM contribution** – a contribution to an accident or an incident from any person or system (whether ground-based, space-based or airborne) performing an ATM function, or the positive contribution of ATM in preventing aviation accidents and incidents; ▪ It applies to **Air Navigation Services (ANS)**, which rely on the ATM functional system, including CNS, ASM and ATFCM functions. It also applies to the safety levels of AIS and MET data used by these elements. ▪ **Geographical extent** – all of the ECAC region; ▪ Airspace – all types of airspace (whether intended or unknown traffic environments); ▪ **Traffic** – all types of aircraft with MTOW > 2.25 tonnes, operating under IFR; ▪ **Flight phases** – the whole gate-to-gate cycle is included (Figure 3); and ▪ **Time period** – from 2005 to 2020 (initial target of a 3-fold improvement in safety).
Range of severities considered	The [SESAR Safety Target] does not provide a range of severities. Its aim is only to define the safety target sufficiently.
Frequency metrics used	The [SESAR Safety Target] does not provide a frequency metric that can directly be used for safety assessments.
Risk tolerability	The interpretation of the SESAR safety target is that for any specific point in the future, there should be no increase in the expected annual number of accidents with an ATM contribution. Hence this target is in line with the [ATM 2000+] strategy.
Apportionment	The target is defined in absolute terms and its scope is specified above. No further apportionment is provided. Some guidelines on how to distribute the target across different geographical areas are provided. The objective will be to assess a range of different scenarios and show that the relative target of not increasing accidents can be achieved. It will then be desirable to weight – rather than apportion – the safety target to take account of the expected distribution of ECAC traffic across those environments and/or weight it more heavily towards one phase of flight as opposed to another, taking into account the relative level of risk and the exposure time in the specific phases.

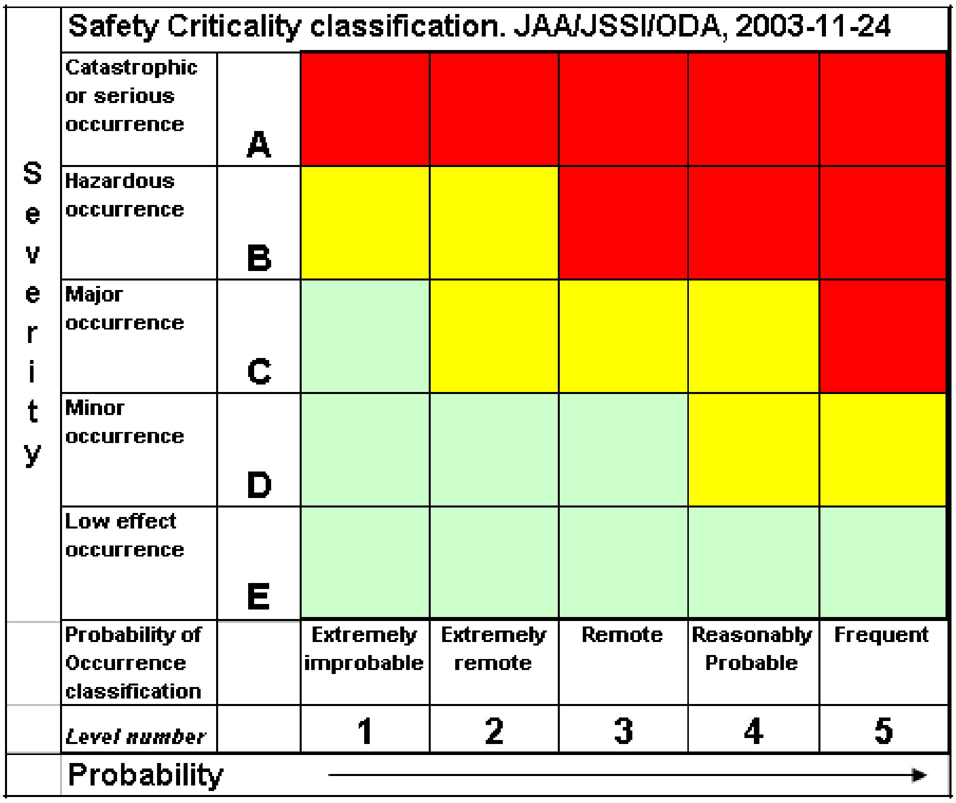
Derivation	Further explanation of how the risk metric of the SESAR safety target has been derived is provided below: ▪ The safety goal for the SESAR programme is to *"improve the safety performance by a factor of 10"*. ▪ In risk modelling terms, this appears to refer to safety performance measured as the probability of collision respectively an infringement between a pair of aircraft in the absence of any action by ATM. When traffic density would then increase, the number of such encounters would grow with the square of the traffic density's increase, as there are more aircraft due to this increase and as the conditional probability to encounter another grows with the same factor. Hence, one could say that the 10-fold improvement is needed to accept a 3-fold traffic increase during the SESAR concept life without any increase in the expected annual number of collisions. ▪ In general, allowing for the possibility of single-aircraft accidents, SESAR requires the safety performance to improve so that there is no increase in the expected annual number of accidents.
Range of applications	The proposed safety target can be applied in safety assessments and to demonstrate compliance using risk modelling within the SESAR context.
Applicability for INOUI WP5	INOUI safety criteria will have to be aligned with SESAR, therefore the SESAR philosophy for future changes to ATM shall be taken into account.

2.2.3 Criteria related to Inspection Reports

2.2.3.1 Swedish Aviation Safety Authority

References	[Andersson and Tegner, 2004]
Formal status	The Swedish Aviation Safety Authority has established a taxonomy to make direct connections between accidents/incidents and deviations found in inspection reports. The standard ICAO ADREP 2000 taxonomy is used a baseline. The Swedish ASA collects and performs data analyses from the aviation system, such as accident and incident reports, or reports from inspections regarding deviations. This enables identification and analysis of potential safety risks so that preventive measures can be taken against these risks.
Scope of Risk	Risks in the following domains shall be identified during inspections: flight operators, airworthiness and maintenance, education, air navigation services and aerodromes.
Range of severities considered	The severity is classified as follows: ▪ **Low effect**: *"No direct or low safety effect. Use of good operational praxis and/or existing safety barriers to avoid safety impact"*;

	▪ **Minor**: *"Operating limitations and/or use of alternative or emergency procedures. Only during rare occasions can the finding develop to an accident. The finding may indicate deficiencies in the quality system. Nuisance to occupants may occur"*; ▪ **Major**: *"A reduction in safety margins but several safety barriers remain to prevent an accident. Reduced ability of the flight crew to encounter adverse conditions as a result of increase in workload or as a result of conditions impairing their efficiency. Minor injury to occupants and/or aircraft may occur"*; ▪ **Hazardous**: *"A large reduction in safety margins. The outcome is controllable by use of existing emergency or non-normal procedures and/or emergency equipment. The safety barriers are none, only one or very few. Minor Injury to occupants and/or minor damage to aircraft may occur. Single fatality or serious injury may occur."*; and ▪ **Catastrophic or serious**: *"Accident, i.e. loss of or substantial damage to the aircraft and/or serious injury or death of occupants. Near accident, i.e. serious incident, where an accident nearly occurs. No safety barriers remaining. The outcome is not under control and could very likely have lead to an accident"*.
Frequency metrics used	Per flight hour
Risk tolerability	When inspectors discover a hazardous event during an inspection, they will have to fill out a risk matrix which resembles the one used to classify occurrences on aircraft systems (see below):



Apportionment	The risk matrix involves an apportionment of the risk over failure conditions(?) analogous to [EASA CS 25.1309-1A]
Derivation	The proposed risk matrix for inspection classification is based on [EASA CS 25.1309-1A], therefore same derivation logic shall apply.
Range of applications	The Swedish Aviation Safety Authority used the risk matrix to standardise a classification system for reporting deviations found in inspections. The purpose of a classification system is that similar deviations always should be reported in the same way since this will enable better decisions regarding different risk areas. The inspectors are therefore constrained to use a standardised classification system and are not free to use their own words when reporting deviations. A hierarchal classification system with predefined phrases is in aviation referred to as taxonomy. Taxonomy is already in use in aviation when reporting accidents and incidents but not when reporting deviations found in inspections. If the taxonomy also could be implemented when reporting deviations found in inspections it would make it possible to find out what kind of accident or incident the deviation has been involved in. To make this connection possible and to enable further analyses the information has to be stored in a database. There is no suitable taxonomy concerning inspection reporting today. In the aerodrome inspections for example the reporting is made in an ordinary Word-document as continuous text. In the inspections the reporting is built on checklists. The fact that the inspection reporting does not resemble the occurrence reporting

	is regrettable in several aspects. Partly it is devastating in an analytical perspective as a continuous text makes it difficult to study several reports and find trends. Partly it is unfortunate since the compatibility and connection between the inspection reports and the occurrence reports becomes more complicated. In the future it is desirable to make connections, which explain present procedures for risk management within Swedish ASA what kind of occurrences the deviations found in inspections have been involved in. This fact assumes nevertheless that the taxonomy for inspection reporting can be close adapted to the taxonomy in occurrence reporting.
Applicability for INOUI WP5	The presented criteria are applied to assess inspection reports, which serves a different purpose than INOUI WP5. In principle, it is not applicable for INOUI, however the taxonomy and severity classification established here are closely related to accident/incident causation. In this case, safety barriers provided by ATM have been incorporated into the classification scheme, which could be an interesting aspect for UAS safety philosophy.

2.3 Safety criteria from ICAO Manuals

[ICAO Doc 9689] – the Manual on Airspace Planning Methodology for the determination of Separation Minima – and [ICAO Doc 9574] – the RVSM Manual – provide Target Levels of Safety in terms of maximum tolerable probabilities of accidents due to collisions per flight hour. As such they provide important examples of ATM safety criteria, which will be summarised for Deliverable D5.0b.

2.4 Safety criteria from Eurocae WG-73 – Unmanned Aircraft Systems

Eurocae Working Group 73 entitled ‘Unmanned Aircraft Systems (UAS)’ is tasked to develop material that will support airworthiness certification and operation approvals such that unmanned aircraft can operate safely without segregation from and in a manner compatible with other airspace users.

It is clear that the aforementioned task of Eurocae WG-73, and the task of INOUI WP5 to perform a high-level analysis of the ATM safety effects of the introduction of UAS in unsegregated airspace are related, and that both can benefit from each other’s results and expertise. At the time of writing this document, the Subgroup ‘Operations’ is commencing work on a suitable safety assessment methodology and development of scenarios for assessment. No finalised results are available at this moment.

For the forthcoming INOUI deliverable D5.0b, the members of the INOUI team that participate in Eurocae WG-73 will be asked to provide a brief overview of relevant material. The present deliverable will be brought under the attention of the working group.

2.5 Overview of summarised documents relevant for safety criteria

In this section, an overview is given of a number of key features of the summarised documents relevant for the safety analysis of integration of UAS.

This overview is given in the table on page 45.

The safety criteria review shows how several attempts exist in the airworthiness arena to provide safety objectives for UAS, but none in the ATM side that is tailored specifically to UAS.

As far as **airworthiness** is concerned, although outside of the scope of INOUI WP5, there is some change in the scope of risks. Since UA normally do not carry crew or passengers on-board, the safety focus has shifted towards the protection of people and property on the ground. In order to pave the ground for the development of UAS, manned specifications in that respect have been adapted to take into account the special features of UAS. Different specifications might be applicable depending on the type of UA (e.g. taken into account by kinetic energy considerations).

Regarding **mid-air collisions**, the separation provision seems to be an operational issue, whereas collision avoidance (i.e. sense and avoid) is more complex. Sense and Avoid systems are not a primary system related to safe and continuous flight of a UAS. The need for a Sense and Avoid capability stems from operational regulations related to the pilots' responsibility in the prevention of collisions. Top level criteria for Sense and Avoid will be developed by ATM safety regulations[2]. Once these specifications are available, EASA can then certify Sense and Avoid Systems.

As information regarding the airworthiness aspect of the Sense and Avoid system, complementary to the present document, the reader is referred to the forthcoming INOUI deliverable D3.2 on UAS Certification.

A first discussion of the direct applicability of the identified and summarised criteria is given;

1. The first conclusion that can be drawn is that the search for safety criteria has not yielded ready to use safety criteria. This implies that INOUI is covering new ground and there is an opportunity to find innovative solutions;
2. [ESARR 4] does not match the aims of INOUI well because this project considers the introduction of UAS, which is different from an ATM change. In addition, [ESARR 4] restricts to the risk where ATM is the primary factor, which a priory seems not adequate for INOUI;
3. It has been shown that most safety criteria used by ANSPs (e.g. NATS, AENA, DFS) are of [ESARR 4] type, hence having the same problems as [ESARR 4] itself;
4. The 'kinetic energy approach' is mainly concerned with 3rd party risk (i.e. external risk), which is widely applied when considering the potential loss of the aircraft, but not so appropriate if ATM aspects or mid-air collisions are to be considered.
5. EASA and FAA 1309, JAA-Eurocontrol UAV Taskforce and STANAG 4671 are for airworthiness. The apportionment is made over the assumed number of safety critical large aircraft systems.

[2] EASA proposed that EUROCAE WG73 addresses the issue by developing a Special Condition based on the [Eurocontrol OAT Spec 0102]].

6. Eurocontrol UAV-OAT does not provide clues for safety criteria. However, they are restricted to UAS-manned encounters
7. The LVNL Safety Criteria provide an interesting apportionment over business units and ATC subproducts that can be used as a starting point to derive suitable safety criteria for the integration of UAS in managed airspace. Furthermore the scope of risks covered is broader than [ESARR 4] as it considers collisions independent of cause and is therefore of interest for INOUI WP5.

In summary, **none of the criteria mentioned before are directly applicable for the scope of the INOUI safety work**: either because they deal only with airworthiness or because they follow the [ESARR 4] approach whose scope is still too narrow to be applied directly. It is therefore necessary to come up with a new way to approach this task. Several considerations for deriving new safety criteria are provided in the following sections.

	Safety Criteria	Civil/ Military	Area affected		Scope of risk		
			Airwor-thiness	Opera-tions	People on-board	Third Party (people and property on the ground)	ATM/ATC contributions
Non UAS-Specific	ESARR 4	Civil		X			ATM (direct)
	DFS Risk Matrix	Civil		X			ATM (direct)
	LVNL Safety Risk Criteria	Civil		X			ATC (accidents)
	NATS Safety Criteria	Civil					ATC (incidents)
	FAA System Safety Guidelines	Civil	X		X		
	EASA 25.1309 Safety Criteria	Civil	X		X		
	AENA Safety Criteria	Civil		X			ATM (direct and indirect)
	Swedish Aviation Safety Authority	Civil	X		X		
	SESAR White Paper	Civil		X			ATM (direct and indirect)
UAS - Specific	The kinetic energy approach	Civil	X			X	
	Eurocontrol UAV OAT Task Force Approach	Military		X			ATM
	JAA-Eurocontrol UAV Task Force Recommendations	Civil	X			X	
	STANAG 4671 - USAR for NATO for military UAV Systems	Military	X			X	

Table 1: Safety Criteria Summary Table

3 Deriving the scope of risks

In this section, statements and results with relevance for determining an appropriate scope of risks, have been collected from a series of INOUI references. On the basis of these, and using elements from the safety criteria overviewed in the previous section, a scope of risks is determined.

3.1 Consulting INOUI references

In this section, a number of INOUI references and decisions are consulted to collect the information to base the derivation of a suitable scope of risk on. The references consulted are [INOUI Annex 1] [Work plan WP5], [Minutes WP5 KOM] and [Minutes TM 2-4 September 2008].

3.1.1 Statements contained in [INOUI Annex 1]

In Section 7.4.1.5 “Step 5: Assess and identify Safety issues” it is stated that:

I. *“INOUI has to assess, on a high level, the impact and effect the integration of UAS has on the ATM System”*

Section 7.6 “Work package descriptions” contains the following passages:

II. *“examine the argument that civil UAS operations as air traffic in non-segregated airspace will be acceptably safe in reference to the currently existing target levels of safety”*
III. *“This safety assurance will thus be confined to the ATM aspects of UAS operations”*
IV. *“it has to be assessed whether the risks associated with civil UAS operations in non-segregated airspace are not greater than equivalent manned aircraft operations under the premise that present operations by manned aircraft are acceptably safe”*
V. *“This work will be conducted according to the EUROCONTROL ESARR 4 safety methodology”*

A brief summary of these statements is that the ATM aspects of integrating UAS in non-segregated airspace are to be considered, that the associated safety risks should not be larger than for manned aircraft and that the ESARR 4 safety assessment methodology is to be used.

3.1.2 Statements contained in [Work plan WP5]

Section 2.1 “Description of work WP 5” states:

VI. *“In WP5, the safety issues related to the integration of UAS into the future ATM System shall be identified”*

Section 4.1 “Description of work WP 5.0” contains the following statements:

VII. *"[ESARR 4] states that 'maximum tolerable probability of ATM directly contributing to an accident of a Commercial Air Transport aircraft of 1,55x10^{-8} accidents per Flight Hour'."*

VIII. *"In the documents underlying ESARR 4 [6] it was estimated that ATM contributes directly to about 2% of Commercial Air Transport aircraft accidents. It seems that INOUI should have a broader scope than just the accidents ATM has directly contributed to."*

IX. *"In a review of Air Traffic Management-related accidents [7] it was shown that the proportion of ATM related accidents – roughly speaking the kind of accidents ATC is to prevent, such as collisions between aircraft and aircraft and vehicles – is about 8%"*

X. *"One could argue that an accident only involving UAS is much less serious than one with passengers and crew, and hence safety criteria could be loosened. In addition, similar targets as for Commercial Air Transport aircraft might be difficult to achieve"*

These statements indicate that although the ESARR 4 methodology is to be used (which is normally to be applied for changes to ATM), the ESARR 4 scope of risk – ATM contribution to risk – is not appropriate for assessing the safety of integrating UAS.

An alternative is to consider collisions between aircraft, irrespective of what caused or contributed to it. The question is raised whether UAS should be as safe as manned aircraft.

3.1.3 Questions contained in [Work plan WP5]

The work plan for Work package 5 also indicates a series of questions whose answers are to sharpen the safety criteria to use and hence also the underlying scope of risks to consider.

XI. *"The above references restrict to 'internal risk', i.e. risk to the aircraft and their eventual crew and passengers. Should external risk posed to people living on the ground e.g. in the neighbourhood of an airport also be considered?"*

XII. *"Some UAS applications may concern uncontrolled airspace where the role of ESARR 4 [read: ATM] is minimal"*

XIII. *"ESARR 4 provides a total budget for Commercial Air Transport aircraft accidents with ATM direct contribution. How is this budget attributed to accidents of a particular kind or to accidents within certain flight phases?"*

XIV. *"Only internal or also external risk?"*

XV. *"Only accidents or also incidents?"*

XVI. *"Concentrate on the effects on 'normal' traffic, or consider also occurrences only involving UAS?"*

XVII. *"Consider only controlled airspace or also uncontrolled?"*

XVIII. *"Discern different kinds of UAS and different kinds of applications?"*

XIX. *"What should be the underlying thought of the criteria (e.g. the changed situation should involve no more accidents of a certain type than today, even when there is traffic growth?)"*

XX. *"What is the timeframe we are looking at, and the expected traffic growth in the mean time?"*

After deriving quantified safety criteria in the next section, these questions are revisited in Section 5.

3.1.4 Decisions made in [Minutes WP5 KoM]

XXI. *"We do not analyze airworthiness (we assume that UAS are certified)"*

XXII. *"We do not consider 3rd party risk (risk to people on the ground and financial loss)"*

Based on this decision alone, one could argue that UAS-UAS encounters are outside the scope as they present only risk to people on the ground and financial loss. However, UAS-UAS encounters are not to be excluded in INOUI WP5.

XXIII. *"Choose specific airspace class which is used in most/all countries (probably Class C)"*

XXIV. *Inside ATM, concentrate on ATC and CNS*

The statements from [INOUI Annex 1] expressing that the safety effects on ATM of integrating UAS are to be assessed, are made more precise by excluding the analysis of airworthiness and risk to people on the ground.

It is decided to restrict to a specific class of controlled airspace, which has later been relaxed to restricting to controlled airspace: The PCO has reacted to Decision XXIII that in the 2020 ATM System to be considered by INOUI, the airspace classes A to G will have been replaced by managed and unmanaged airspace, and hence that managed airspace is to be considered.

However, as the changes of the 2020 ATM System with respect to the current situation are considerable and still largely to be developed, a safety assessment of integration of UAS in the 2020 ATM System would demand an unforeseeably large effort for clarifying and analysing this ATM System, instead of focusing on the integration of UAS. It has therefore been proposed that the first priority is to assess the integration of UAS into the present or near future ATM System and secondly to estimate how the results would change due to the development of the ATM System. This approach has been accepted by the PCO.

3.1.5 Key findings of [Minutes TM of 2 September 2008]

XXV. *"The available statistics for "ATC-related risk" (WP5.0a) are not valid for uncontrolled flights nor for very small UA"*

XXVI. *"The biggest number of UA might be flying in uncontrolled / unmanaged airspace"*

During the technical meeting of 2 September 2008, it became clear that collision statistics for commercial air transport aircraft underlying [LVNL Safety Criteria], which have been discussed in Section 2.2.2.3 are not representative for flights being performed by different aircraft. For instance, these statistics are not to be used for flights in uncontrolled airspace, which generally holds for very small UA. It must be remarked that [ESARR 4] suffers from the same limitation (in addition to restricting to effects with direct ATM contribution.

As it was noticed as well that many UAS applications do not take place in controlled airspace, and as the INOUI Safety Analysis does not consider UAS integration outside controlled airspace (see the above section), it follows that the INOUI Safety Analysis leaves a large number of UAS applications – those in controlled airspace – out of consideration.

3.2 Deriving the scope of risks

The scope of risks is derived along a few steps, the first of which is specifying ATM and ATC in the context of all Air Navigations Services, and ATC in the context of the various airspace classes. Next, the occurrence categories to be considered in the safety analysis are specified, the aircraft for which these occurrences will be analysed and the flight elements to which the accompanying safety criteria can be apportioned. Finally, the classes of severity to be considered are determined.

3.2.1 The focus of the safety analysis in terms of services

As a preparatory step in deriving the scope of risk, an overview of the services in Air Navigation Services (ANS) is given in Figure 2. This overview clarifies the relation between Air Traffic Management (ATM) and Air Traffic Control (ATC), which is provided in controlled airspace.

The boxes all indicate ANS services. On a first level these consist of ATM, Aeronautical Information Services (AIS), Meteorological Services (MET), Search and Rescue (SAR) and Communication, Navigation, Surveillance (CNS). SAR is marked grey as it is not part of ANS according to the Single European Sky regulations.

On a second level, ATM consists of Air Traffic Services (ATS), Air Traffic Flow Management (ATFM) and Air Space Management (ASM). The first of these – ATS – is further subdivided into Air Traffic Control (ATC), Flight Information Services (FIS) and Alerting Services, of which ATC is the most important service to be provided in controlled airspace. The safety analysis concentrates in the first place on ATC, and on CNS in the second place as ATM and ATC in particular cannot be considered independently from CNS services. The other services within ATM are not addressed in detail, although for instance possible causes for hazards are taken into account.

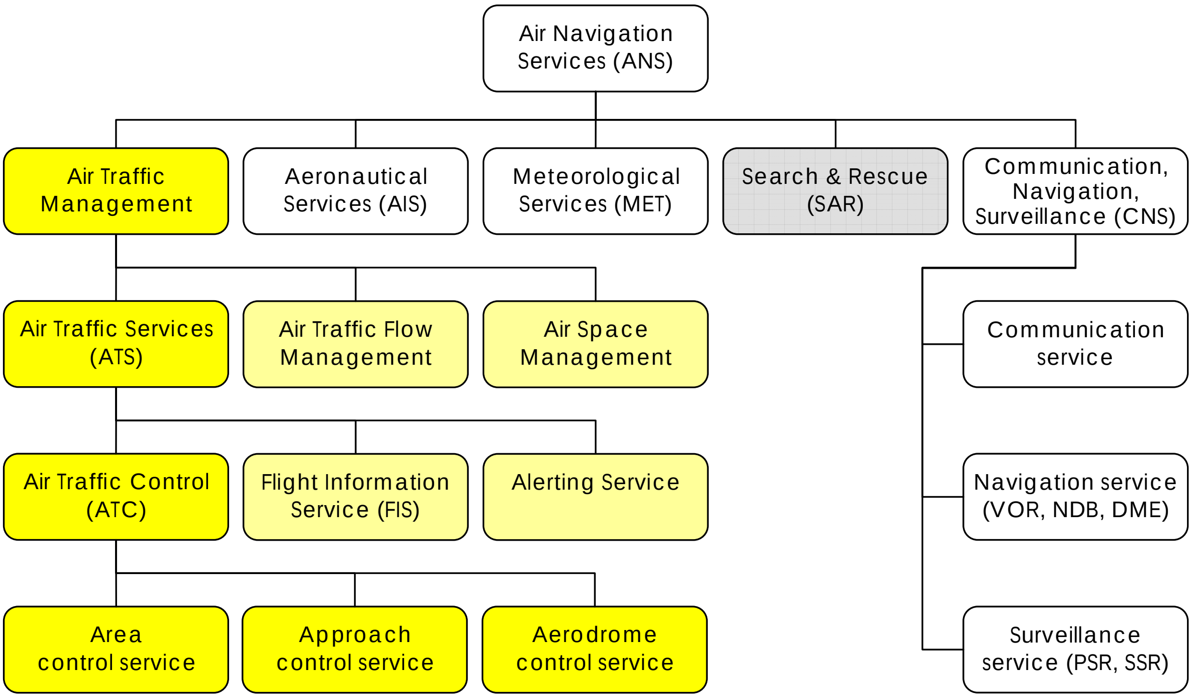


Figure 2: Overview of Air Navigation Services according to [ICAO Doc 9082/7]

[EC No. 549/2004] and [ICAO Doc 4444] state that ATC is the service provided for the purpose of:

- Preventing collisions:
  - between aircraft and
  - on the manoeuvring area between aircraft and obstructions; and
- Expediting and maintaining an orderly flow of air traffic.

In other words, in the air, the purpose of ATC is to separate aircraft.

As a clarification of the airspaces where ATC and other Air Navigation Services are provided, as well as the corresponding flight requirements, Appendix 4 from [ICAO Annex 11] has been taken over in Table 2.

Class	Type of flight	Separation provided	Service provided	Speed limitation*	Radio communication requirement	Subject to an ATC clearance
A	IFR only	All aircraft	Air traffic control service	Not applicable	Continuous two-way	Yes
B	IFR	All aircraft	Air traffic control service	Not applicable	Continuous two	Yes
	VFR	All aircraft	Air traffic control service	Not applicable	Continuous two	Yes
C	IFR	IFR from IFR IFR from VFR	Air traffic control service	Not applicable	Continuous two	Yes
	VFR	VFR from IFR	1) Air traffic control service for separation from IFR; 2) VFR/VFR traffic information (and traffic avoidance advice on request)	250 kt IAS below 3050 m (10 000 ft) AMSL	Continuous two	Yes
D	IFR	IFR from IFR	Air traffic control service, traffic information about VFR flights (and traffic avoidance advice on request)	250 kt IAS below 3050 m (10 000 ft) AMSL	Continuous two	Yes
	VFR	Nil	IFR/VFR and VFR/VFR traffic information (and traffic avoidance advice on request)	250 kt IAS below 3050 m (10 000 ft) AMSL	Continuous two	Yes
E	IFR	IFR from IFR	Air traffic control service and, as far as practical, traffic information about VFR flights	250 kt IAS below 3050 m (10 000 ft) AMSL	Continuous two	Yes
	VFR	Nil	Traffic information as far as practical	250 kt IAS below 3050 m (10 000 ft) AMSL	No	No
F	IFR	IFR from IFR as far as practical	Air traffic advisory service; Flight information service	250 kt IAS below 3050 m (10 000 ft) AMSL	Continuous two-way	No
	VFR	Nil	Flight information service	250 kt IAS below 3050 m (10 000 ft) AMSL	No	No
G	IFR	Nil	Flight information service	250 kt IAS below 3050 m (10 000 ft) AMSL	Continuous two-way	No
	VFR	Nil	Flight information service	250 kt IAS below 3050 m (10 000 ft) AMSL	No	No
* When the height of the transition altitude is lower than 3 050 m (10 000 ft) AMSL, FL 100 should be used in lieu of 10 000 ft.						

Table 2: ATS airspace classes — services provided and flight requirements (Appendix 4 of [ICAO Annex 11])

The overview illustrates that in controlled airspace – i.e. Classes A to E (inclusive) – IFR flights are always separated from each other and, depending on the precise class, VFR flights:

- are not allowed (Airspace class A),
- separated from all flights (B),
- from IFR flights (C) or
- are mentioned in traffic information (and traffic avoidance advice on request) to all traffic (D), respectively
- not separated from any flights (E).

3.2.2 Selecting the occurrence categories to consider in the safety analysis

In view of the safety analysis' restriction on controlled airspace and in view of the purpose of ATC to separate aircraft, collision probability per flight (or per flight hour) is a sensible starting point for indicating safety of integrating UAS in controlled airspace. As indicated in the previous section, there is still a wide range of variety in controlled airspace. The safety analysis to be performed in WP5.1 – 3 therefore needs to specify the airspace serving as context.

Regarding 'collisions', it has been decided to look at the following occurrence categories:

- Collisions between aircraft;
- Collisions between aircraft and vehicles; and
- Wake vortex encounters.

See [CAST ICAO Occurrence Categories] for an overview and definitions of all occurrence categories. The reason for this selection is that good Commercial Air Transport aircraft accident statistics [Van Es 2003, LVNL Safety Criteria] are available for these, and that they match well with the aim of ATC, which is primary focus of the safety analysis in INOUI WP5. Although these statistics are not applicable for other aircraft kinds, they provide an example distribution of accidents over flight phases that might help to choose an apportionment of risk budget for aircraft kinds where such detailed statistical data is not available.

The above collision kinds largely overlap with those that ATC is to prevent according to [EC No. 549/2004] and [ICAO Doc 4444]. Differences with respect to the collisions considered by the latter documents are:

- Wake vortex encounters in the air ARE considered; and
- Collisions with other obstacles than vehicles on the manoeuvring area are NOT considered.

The addition of occurrences due to wake vortex encounters is valuable as it represents an occurrence category for which ATC has responsibility. Collisions with obstacles only have relevance on the manoeuvring area for which, at the time of writing, the safety assessment is still to be defined in WP5.4 "Airport safety analysis".

3.2.3 For which aircraft to consider these occurrence categories?

After having determined the occurrence categories to consider, a next question is for which aircraft the safety analysis should consider these collisions and wake vortex encounters. Some possible answers are:

1. All collisions/encounters involving aircraft and/or UAS;
2. Only collisions/encounters with causes lying with UAS; or
3. Only collisions/encounters involving at least one UAS?

The first alternative would imply a lot of work for the safety analysis, and dilute attention for the integration of UAS as many collisions/encounters have nothing to do with UAS.

The second alternative – collisions/encounters with causes lying with the UAS – would target effort on UAS. There will however be collisions/encounters between UAS and manned aircraft with other causes, e.g. a level bust by a manned aircraft leading to a collision with an overflying UAS. Hence this alternative would not yield the total extra collision/encounter probability due to the integration of UAS. Another complication is that collisions may not be caused by a single and clearly attributable cause. Moreover, for this alternative the risk depends sensitively on the number of UAS being integrated. This is hard to match with the objective that UAS are "as safe as" manned aircraft in which case risk would rather depend on the total traffic volume.

For the third alternative the effort is also focussed on UAS, and it does not suffer from the exclusion of certain causes. Of the given alternatives it therefore is the first choice for the safety analysis.

3.2.4 What severities to consider?

The occurrence categories to be considered in the safety analysis have been determined. The question remains what severities should be considered for these, e.g. only accidents or also less severe results?

There is no question that accidents are to be considered: these are the occurrences for which prevention is the primary purpose of ATC and for which good statistics are available.

Occurrences of the selected occurrences categories of lesser severity are considered in several safety assessment methodologies and corresponding criteria for these severity classes do exist. The motivation of these criteria is normally however considerably weaker. Reliable statistics do not exist in public and often the maximum allowable frequencies for less severe occurrences are simply related to the next severity class by a factor 10 or 100. Nevertheless, the group of people involved in the safety analysis has judged the consideration of less severe effects as useful. Therefore, regarding the selected occurrence categories, the full spectrum from severity class 1 'accident' to 5 'no safety effect' as defined in [ESARR 4] and [DFS SA Handbook] is considered.

The severity 2 to 5 versions of the considered occurrence categories would for instance be a separation infringement or a wake vortex encounter.

3.2.5 Preparation for apportionment

A major step in developing practical safety criteria concerns a method to apportion the total available risk budget to particular elements as for instance flight phases or particular risks. Safety analyses can then concentrate on the particular elements concerned to be studied, instead of having to analyse all risks from gate to gate in all circumstances, when the safety effects of a change affecting for instance only the final approach segment under certain circumstances are to be analysed.

The accident statistics developed for [LVNL Safety Criteria] support such an apportionment of risk over ATC types and generalised flight phases called ATC subproducts:

- Tower Control:
  - Landing;
  - Line-up;
  - Start-up and pushback;
  - Take off; and
  - Taxiing.
- Approach Control:
  - Departure;
  - Initial and intermediate approach; and
  - Final approach.
- Area Control:
  - Control Area inbound;
  - Control Area outbound; and
  - Control Area transit.

4 Deriving quantified safety criteria

<To be done for Deliverable D5.0b>

5 Comparing developed safety criteria with aims and other criteria

It is assessed how the developed safety criteria match the wish lists developed in Section 3.1, which summarises several INOUI references, and what characteristics of the safety criteria briefly described in Section 2 they involve.

<To be done for Deliverable 5.0b>

6 Conclusions

6.1 *Scope of risks*

The safety analysis performed in INOUI WP5 concerns the following occurrence categories:

- Collisions between aircraft;
- Collisions between aircraft and vehicles; and
- Wake vortex encounters.

Aircraft can be manned or unmanned, but only occurrences where at least one UAS is involved are considered in the safety assessment.

In principle, the whole range of severities associated with the above occurrence categories are to be considered. Less severe examples of collisions are separation infringements or aircraft proximities.

An apportionment of risk over the ATC types and generalised flight phases called ATC subproducts can be realised:

- Tower Control:
  - Landing;
  - Line-up;
  - Start-up and pushback;
  - Take off; and
  - Taxiing.
- Approach Control:
  - Departure;
  - Initial and intermediate approach; and
  - Final approach.
- Area Control:
  - Control Area inbound;
  - Control Area outbound; and
  - Control Area transit.

6.2 *Quantified safety criteria*

<To be done for Deliverable 5.0b>