Separation Minima Standards:

Research of Current Applicable Minima Laid Down and Foundations

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***Abstract*— Separation Minima (SM) is the minimum distance a/c need to fly apart from each other at all times to ensure safety. This applies to the three axes: Vertical, Lateral and Longitudinal Separations Minima (See Figure 1. A/c Separation Axes). Many Standards of Separation Minima were defined based on expert judgment and technology available at the time were laid down them, the leap in technology since then makes the SM standards must be updated. However, many of them have not been modified to reflect modern technological capabilities. Due to how SM have been defined (in many cases) makes each region around the world have laid down different values for same operational case or separation rules were laid down with different criteria and context descriptions. As demand is expected to treble by 2020, one of the ATM system challenges is to manage the expected increase in air traffic demand and, reducing SM becomes a potential solution part that would contribute to achieve this challenge, keeping always in mind that a/c Separation Standards reduction increases airspace capacity but can also reduce safety levels, which must be preserved as part of the challenge.**

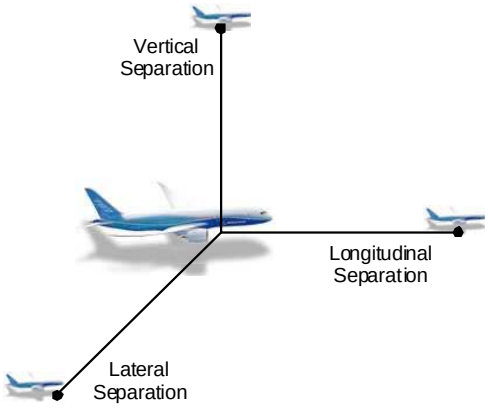

Figure 1. A/c Separation Axes

The best starting point in order to identify which reductions in SM could be realized is undertaking a research of the current separations minima and their foundations. Answering the questions what? and why?, will make it someday possible to answer the question how?. The work that the present paper originated from was focused on extracting information from several international regulations and (ICAO, FAA, British Regulations, Australian Regulations, Canadian Regulations and Eurocontrol). These regulations/documents include a/c separation minima cases, description of SM values classified by PoF, a/c operation, direction/tracks/routes, conditions and operational context, technology involved, separation axis. In addition, identifying aerodynamic factors, human factor, hazard/risks, equipment precision, surveillance mode, models identification, etc were also investigated. The valuable results of this research are unprecedented in their contents and for the useful way to they are presented.

TABLE I. ACRONYMS

Acronym	Meaning
a/c	Aircraft
ENR	En-Route
FAA	Federal Aviation Administration
ICAO	International Civil Aviation Organization
PoF(s)	Phase of Flight(s)
SM	Separation Minima
SMS	Separation Minima Standard
TMA	Terminal Manoeuvering Area
WV	Wake Vortex
RWY(s)	Runway(s)

I. INTRODUCTION

A. Background

RESET (Reduced Separation Minima) project, funded by the European Commission Directorate General – Transport and Energy inside the 6th Framework Program is a project lead by AENA and formed by 15 partners around Europe with the collaboration of the FAA.

Within this project efforts to research current separation minima status were carried out in Work Package 2 (WP2) and their foundations in WP3.1, both WP were lead by Isdefe with the collaboration of RESET partners.

ISBN: 978-0-615-20720-9

B. Objectives

The objective of this paper is to describe the current status of SMS laid down (ICAO, Local regulations and Eurocontrol) which is further described by the Separation Minima List. On this list is possible to check different separation minima cases and to identify differences between the different standards. The analysis of the current regulations and separation minima requirements applicable to the different PoFs provides a starting point to make an attempt to reduce separation minima. The current status of separation minima is the product of WP2 and WP3.1 of RESET project. In order to achieve this, several tasks were carried out, hard documentary research and productive results have been obtained. This document describes the objectives pursued, the inputs used, a process description and the methodology followed along the research, the output obtained and its structure. With the information obtained through separation minima research and foundations research, a checklist containing the applicable separation minima for different PoFs was created. In the list, standards will be further categorized and classified, taking into account the PoF and the various factors that are considered in each particular regulation. This will be delivered as an input to studies such as the building a model, prioritization and integration of results, dissemination, and whenever possible, areas where such regulations can be improved, in terms of minima reduction and best practices used, tasks to be carried out inside RESET project.

II. RESEARCH METHODOLOGY

A. SMS

The first activity carried out was getting inputs, searching associated documentation for building input repository; the input documentation repository used to documentary research is listed on TABLE II. PrINCIPAL Documents Analysed for SMS identification hereunder.

TABLE II. PRINCIPAL DOCUMENTS ANALYSED FOR SMS IDENTIFICATION

Source/Autor	Code
ICAO	Docs: 4444, 9476, 9830, 9426, 9574, 9613, 9689, 9643, 7030, 9854, Annex 2, Annex 11.
FAA	Order 7110.65
Civil Aviation Authority	CAP 493
TC Civil Aviation	Standard 821
Civil Aviation Safety Authority	CASR Part 172

A template to be completed was laid out according to ICAO 4444 document. Information from other ICAO documents and regulations from EUROCONTROL and the American (FAA), British (BAA), Canadian and Australian regulatory bodies were incorporated.

Next step was a lay-out for being filled with separation minima data (Excel worksheet template) defined and based on ICAO 4444 document. The separation standards were classified in a useful way to facilitate the work to be performed by those who consults the Separation Minima List. In order to classify the separation standards according to the methodology used by ICAO document 4444 it was essential that this template, which will be the same one used for all other standards and regulations, was agreed among all different points of view and contributors to increase coherency. The documentary research carried out has consisted of analyzing regulations, extracting from these, values of separation minima laid down, PoF and operational conditions and constrains applicable, as well as merging information. This information was added to the output table named Separation Minima List.

Once the input documentation has been obtained, the methodological road followed starts with the elaboration of a layout of the checklist containing PoFss to classify regulations. The structure of the list is in accordance to ICAO 4444 document. The list was completed with ICAO and non ICAO SMS data, identifying in respective documentation: PoF, operational conditions/constrains/context and their applicable separation minima values.

It was important to decide which local regulations should be included in the list. This study considers British, Canadian and Australian regulations. EUROCONTROL regulation was also considered to investigate the future regulation environment. All separation minima cases analyzed were represented by rows in table. Checklists were later refined to integrate them in a common one. Finally, a draft poster was produced in order to facilitate dissemination work as much as possible.

The current status of SMS is provided by means of separation minima cases contained in the output named Separation Minima List (located on RESET website http://www.reset.aena.es), a self-explanatory table that contains information about the standards laid down in regulations. The header columns described in the table, whose fields were completed with information related to each separation minima case, are the following: *PoFs*, *Operation*, *Characteristics*, *Direction/Tracks/Routes*, *Conditions*, *Context*, *Means*, *Control by*, *Picture*, *Separation*, *Based on*, *Separation Minima laid down*, *Reference*, *Observations*.

The Separation Minima cases were organized according to the above mentioned columns, so the information can be sorted by columns, by means of a filter tool, to find the data needed or identify the differences among different current standards by comparison. Under the qualities of this way to present the results there are the following advantages: it allows the introduction of new separation minima regulations and makes it easy to update the included information.

B. SMS, Foundation Research

Once all SMS were identified, next steps resulted into the identification of the foundations that support the Separation Minima Standard Definition.

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The applied methodology follows a five stages approach, each stage with a specific objective as is described hereunder:

Stage1. Analyze the current foundation of the SMS.

Stage 2. Identify how current minima separation have been quantified.

Stage 3. Complete and classify the list of factors for the selected relevant cases.

Stage 4. Selection of the SMS that will be analyzed in more detail.

Stage 5. Group the SMS to be studied by "thematic areas".

The acknowledge of these five stages, should conclude in answering the following questions:

Where was the definition of the Separation Minima Standard established?, How were the separation minima standard established? How strong are the foundations? and which factors contribute to the Separation Minima definition?, Which from the identified SMS are most relevant to be analyzed in more detail?, Do these SMS have some similar characteristics?, Is there a way to study the standards by groups?, Is all the information needed to analyze each group of Separation Minima Standard available?

The following paragraphs, explains how each step were developed, main conclusions and products.

*1) **Stage 1**. Analysis of current foundations of SMS.*

The main objective within this stage was to analyze the current foundations of all SMS identified previously.

To acknowledge that, the SMS Current Status list was considered as input and all the main documents were distributed in order to start the "looking & finding process" of all the foundation for each SMS, or (by default) any clue or piece of information that could contribute to the understanding of the SMS definition.

The documents that were analyzed for foundations are listed in the table hereunder:

TABLE III. DOCUMENTS ANALYSED FOR FOUNDATIONS

Doc 4444, Doc 9426, Doc. 7030/4, Doc 9830, Doc 9643, FAA Order 7110.65, Annex 2, Annex 11, British Regulation, Australian Regulation, Canadian Regulation, ATISN 93, CARE-ASAS

The results of this process were documented in the SMS Current Status List in order to guarantee the link of each Separation Minima and its Foundations.

*2) **Stage 2**. Identification of how current SMS have been quantified.*

This stage aims to qualify the stage 1 results, by a complete "auto evaluation" of the research process. To accomplish this indicator called Foundation Research Assessment (FRA) was created within four possible options: *Success, Few Possibilities, Uncertainty, Unaware.* Each researcher was asked to check each SMS with one of the options, generating this way common criterion to evaluate the foundation strength and availability.

TABLE IV. FOUNDATION RESEARCH ASSESSMENT, OPTIONS

Success	The foundation was found.
Few Possibilities	The foundation research was carried out within a lot of effort and looking in deeply in a lot of information sources but finally the foundation was not found. In some cases just some clues were recorded.
Uncertainty	Within the effort and time allocated it was not possible to carry out a deeper foundation research.
Unaware	Within the effort and time allocated it was not possible to carry out the foundation research.

The results of the Foundation Research Assessment are shown in the table hereunder.

Figure 2. Foundation Research Assessment, Output

Separation Type	(Todas)				
..	Phase of Flight				
Foundation Research Assessment	Aerodrome	Arrival (TMA)	Departure (TMA)	En-route	Total general
FEW POSSIBILITIES	80	13	57	156	306
SUCCESS	5	16	14	57	92
UNAWARE	5	1		2	8
UNCERTAINTY	93	19	19	85	216
Total general	**183**	**49**	**90**	**300**	**622**

*3) **Stage 3**. Research and Identification of the contributing factors to the SMS.*

To acknowledge this objective after several discussions, brainstorming, etc. some new columns were added to the table. These columns contained the following information:

Identification of Contributing Factors.

Aerodynamic Effects. Aerodynamics factors and/or effects that have influence on the separation case.

Human Factors. Human factors that have influence on the separation case: controllers, pilots, etc.

Hazards/Risk. Identified the separation minima reduction hazards.

Equipment Precision. Precision of system, equipment or device for applying this separation or on which it is based on.

Surveillance. Considerations about surveillance have an influence on the separation application.

Each Separation Minima Standard was analyzed within this factors list in order to identify which of these have impact on the SMS definition and once identified it was recorded in the SM Current Status List.

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Product: An excel file with all the SM Standards that perform the three established criteria.

*4) **Stage 4**. Analysis and selection of the SMS to be studied in more detail.*

The main objective of this stage was to identify the most important and/or relevant SMS where reducing some separation could have an important impact on accomplishment doubling capacity. To acknowledge it criteria for the identification of the Separation Minima cases more relevant to be study in more detail in future steps was created. This criteria was established as it follows.[1]:

- Standards associated to operations in Europe will be preferred to others.
- Most commonly used standards are preferable.
- Standards based upon the most advanced technology will be preferred to others.
- All the different PoFs (Airport, TMA/Departures, TMA/Departures, ENR) should be covered.

Starting from these criteria, a Criteria Check Analysis was performed for each separation minima standard. Inside the Separation Minima List a column called Criteria Check Analysis (CRA) was created with two possible options: YES/NO.

After this, and in order to be as much effective as possible, it was decide not only to analyze the SMS that were considered more relevant to be studied in more detail, but also were considered those that have strong foundations and those whose contributing factors have been identified.

Finally the SMS selected to be studied in more detail were those which:

- Have been *marked with a YES in the Criteria Check Analysis* (stage 4 input).
- Have been *marked with a SUCCESS or a FEW POSSIBILITIES in the Foundation Research Assessment* (stage 2 input).
- Have been it corresponding *Contributing Factors identified* (stage 3 input).

At the end of this stage the initial Separation Minima List of 622 standards were filtered and reduced to 157 standards to be studied in future stages.

Product: An excel file with all the SM Standards that match the three established criteria.

*5) **Stage 5**. Grouping of the SMS by "thematic area".*

The main objective of this step was to group all the ID´s that correspond to the same or very similar cases, in other words by "thematic area".

[1] 1st technical meeting minutes, section 4 *Definition of Criteria and selection of Standards for Factors Completion*, page 4.

To acknowledge this objective the final customer of this grouping needed to be identified. It was agreed that this work should focus on the *Modeling Phase* therefore this grouping should address the needs of this phase.

As the *Modeling Phase* needed to document and to compile all the mathematical models, simulation models, collision risk models, formulas or equations, etc. that have been used to define the SM Standard, it was agreed to group the SM Standards selected in step 4 by "thematic area".

Two "step by step" grouping methodologies were defined for *Aerodrome* and *TMA/ENR*. These methodologies were defined as it follows:

TABLE V. GROUPING METHODOLOGY FOR ENR & TMA

Five Steps were defined in this methodology
- First Step: PoF - Second Step: Type of Control (Radar/Procedural/ADS) - Third Step: Type of Separation (Longitudinal/Lateral/Vertical) - Fourth Step: Based on (Time/Distance) Fifth Step: - (RNAV/Navigation aids/WV)

TABLE VI. GROUPING METHODOLOGY FOR AERODROME

Seven Steps were defined in this methodology:
- First Step: PoF - Second Step: Operation (Land/Take off/Interlaced) - Third Step: Rwy Configuration (Same/Parallel/Crossing) - Fourth Step: Type of Control (Radar/Procedural) - Fifth Step: Type of Separation (Longitudinal) - Sixth Step: Based on (Time/Distance) - Seventh Step: - (WV/Rwy Separation)

At the end of this stage the FILTERED Separation Minima List of 157 standards were grouped and reduced to 21 groups of SMS.

Product: An excel file with all the SM Standards grouped by thematic area, and two PDF files with the methodology applied when grouping the SM Standards for TMA/En route and Aerodrome phases.

III. SEPARATIONS MINIMA AND FOUNDATIONS CURRENT STATUS

All Separation Minima and Foundations information obtained from this research was integrated in an excel table, which is a Separations Minima Data Base (located on RESET website).

A. POFS (PoF)

During a flight an a/c goes trough different PoFs which have different hazards and risks and therefore different Separation Minima are applied. RESET research, specifically all the foundation assessment was focused on the flight path. The four phases defined in RESET were:

- *Aerodrome (including take offs, lands and taxi).*

ISBN: 978-0-615-20720-9

- *TMA Departures (including climb, same level)).*
- *ENR (including same level, climbing and descent).*
- *TMA Arrivals (including descent, same level).*

In the lines hereunder these each PoF and their associated operations are explained in more detail.

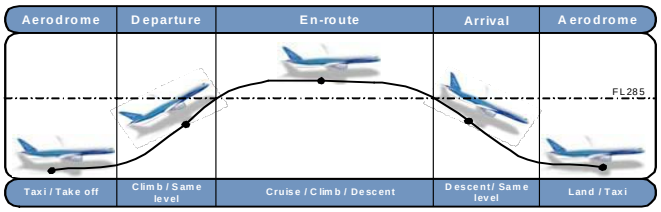

Figure 3. PoFs

1) Aerodrome

Once the push back & start up clearance is given to the pilot and the a/c has started taxiing to the active rwy its interaction with other a/c in both the apron and the taxi ways requires the establishment of Separation Minima to guaranty the a/c's safety. This PoF (within RESET project) is defined from that event to the take off (including initial climb).

The research carried out in this PoF identified in a total of 183 SMS identified. Under this category 3 Operations were analyzed: *Taxi, Take off and Land.*

The information that could be found in the *RST-WP3-ISD-004-Separation Minima List* regarding this PoF is exemplified in the following paragraph:

ID0062

This Standard is a longitudinal separation based on distance in a radar scenario that is defined by ICAO document 9643 in section 2-3 as 3NM between both a/c doing a dependent parallel instrument approaches (mode 1) or a dependent parallel instruments approaches (mode 2) unless more separation is required due to WV influence.

During the research process on this standard, have been identified several contributing factors as aerodynamics effects, human effects, and so on and despite a deep research was carried out the foundation was not found within the time and effort allocated in the project.

2) TMA/Departure & TMA/Arrival

This PoF was split into two, one from the initial climb to FL285 (TMA Departures) and the other one from FL285 to the initial approach (TMA Arrival).

The research carried out within this PoF identified in a total of 139 SMS identified, divided in 90 SMS for TMA/Departure and 49 for TMA/Arrival. Under this category four Operations were analyzed: *Climb, Cruise (same level), Hold and Descent*.

The information that could be found in the *RST-WP3-ISD-004-Separation Minima List* regarding this PoF is exemplified in the following paragraph:

ID0100

This Standard is a longitudinal separation based on distance in a radar scenario that is defined by Canadian Regulations in chapter 3 section 3.0 as 6NM between two a/c climbing (the preceding heavy and the follower light) in the same route due to WV effects.

During the research process on this standard have been identified several contributing factors as equipment precision, surveillance, aerodynamics, etc. Regarding the foundation, despite a deep research was carried out the foundation was not found within the time and effort allocated in the project, but it was identified CARS part 8 standard 8213.1 as possible reference of understanding the SM standard definition.

3) ENR

ENR PoF (within RESET definition) starts once FL285 is passed and cruise altitude is reached, and ends when descending bellow FL285.

The research carried out within this PoF identified in a total of 300 SMS was identified. Under this category four Operations were analyzed: *Climb, Cruise (same level), Hold and Descent*.

The information that could be found in the *RST-WP3-ISD-004-Separation Minima List* regarding this PoF is exemplified in the following paragraph:

ID0542

This standard is a longitudinal separation based on distance in a ADS scenario that is defined by ICAO document 4444 in section 5.4.2 as 30NM between two a/c flying in the same route and using ADS with a maximum of 14 minutes of periodic reporting interval and with an RNP=4.

During the research process on this standard have been identified several contributing factors as relative a/c position and velocities, a/c reaction, environment, WV profile, etc. Regarding the foundation within the time and effort allocated in the project it was possible to find some foundations based on a Collision Risk Model.

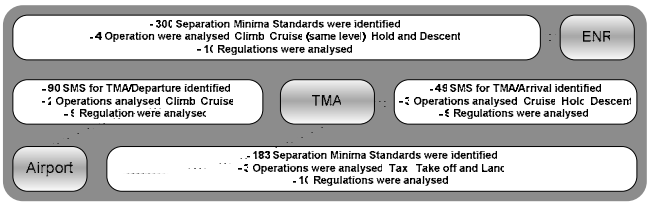

Figure 4. Summary of SMS & Foundation characteristics per PoF.

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B. *WV Separation: Minima of Minimas*

WV separations analysis was carried out separately due to differences in the categorization in each regulation. The only way to compare them was by means of the weight (See Figure 5. WV category broken down in Weight Range).

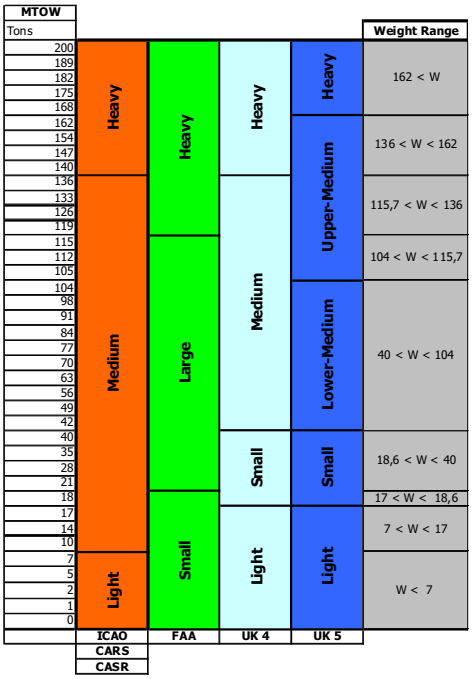

Figure 5. WV category broken down in Weight Range

Looking across different regulations brings out nine weight ranges; this division amongst regulations allows the determination of the smallest minima and a comparison of separation minima applicable among standards (See Figure 6. WV SM laid each regulation down according to weight ranges). As shown, SM between one a/c followed by another varies many times depending on place (regulation) where the a/c operation is being performed. This implies that WV separation would be settled in different way for same a/c. For instance, one A300 a/c followed by one Saab 340 would be separated 6 NM or 5NM depending on if the operations are being carrying out in the USA or in another country, where ICAO regulations are adopted. Apart from, regulations analyzed do not apply to a/c with over 200 tons-MTOW a/c.

Preceding	Following	ICAO	Canadian	Australian	FAA	UK 4	UK 5	Minima of Minimas
162 < W	200 < W	4 NM	4 NM	**3 NM**	4 NM	4 NM	4 NM	**3 NM**
162 < W	162 < W < 200	4 NM	4 NM	4 NM	4 NM	4 NM	4 NM	4 NM
162 < W	136 < W < 162	4 NM	4 NM	4 NM	4 NM	4 NM	5 NM	4 NM
162 < W	115,7 < W < 136	5 NM	5 NM	5 NM	**4 NM**	5 NM	5 NM	**4 NM**
162 < W	104 < W < 115,7	5 NM	5 NM	5 NM	5 NM	5 NM	5 NM	5 NM
162 < W	40 < W < 104	5 NM	5 NM	5 NM	5 NM	5 NM	5 NM	5 NM
162 < W	18,6 < W < 40	5 NM	5 NM	5 NM	5 NM	6 NM	6 NM	5 NM
162 < W	17 < W < 18,6	5 NM	5 NM	5 NM	6 NM	6 NM	6 NM	5 NM
162 < W	7 < W < 17	5 NM	5 NM	5 NM	6 NM	8 NM	7 NM	5 NM
162 < W	W < 7	6 NM	6 NM	6 NM	6 NM	8 NM	7 NM	6 NM
136 < W < 162	162 < W	4 NM	4 NM	4 NM	4 NM	4 NM		4 NM
136 < W < 162	136 < W < 162	4 NM	4 NM	4 NM	4 NM	4 NM	**3 NM**	**3 NM**
136 < W < 162	115,7 < W < 136	5 NM	5 NM	5 NM	4 NM	5 NM	**3 NM**	**3 NM**
136 < W < 162	104 < W < 115,7	5 NM	5 NM	5 NM	5 NM	5 NM	**3 NM**	**3 NM**
136 < W < 162	40 < W < 104	5 NM	5 NM	5 NM	5 NM	5 NM	**4 NM**	**4 NM**
136 < W < 162	18,6 < W < 40	5 NM	5 NM	5 NM	5 NM	6 NM	**4 NM**	**4 NM**

Figure 6. WV SM laid each regulation down according to weight ranges

C. *TYPE OF SEPARATION*

1) *Longitudinal Separation*

Around 203 SMS were identified. For the Aerodrome PoF, a/c taxiing operation, a 200 meter separation is applied, considering a taxi speed of 30 kt. No influence of aerodynamics is considered, but with separation contributing factors like: Pilot monitoring/situational awareness, Pilot response time, Controller/Pilot communication/coordination, Controller monitoring/situational awareness, the response time of any control function should be less than 0.5 second, Controller display target position error, Accuracy of measured position after processing, Reporting interval, Radar surface. According to Advanced Surveillance Movement Guidance an Control System (ICAO 9830). The contribution factors to separation contributing are: Atmosphere Parameters (temperature, air density, pressure, thermal stratification, Eddy dissipation rate, wind direction), horizontal and vertical positions and closing angles, vertical path separation at crossing point, speed, airplane weight, dimensions and geometry, pilot monitoring/situational awareness, Controller/Pilot communication, Controller monitoring/situational awareness, Controller workload, Surveillance (Update rate, Controller display target position error, accuracy of measured position after processing, reporting interval. The main hazard could be presented are WV Encounter (WVE) and possible crew/passenger injury, loss of control and/or structural damage. For the Departure (TMA) PoF, climbing operation, in ICAO is laid down to be separated 2 min, but if separation needs to be maintained or increased while vertical separation does not exist, then 5 min (while vertical separation does not exist if a departing a/c will be flown through the level of a preceding departing a/c and both a/c propose to follow the same track). In FAA different standards are laid down according to specific conditions: 1 min when preceding a/c turns immediately after take off, 2 min (within 5 min after take off) or 3 min for changing level. Based on distance could be separated 3 NM (within 13NM DME/ATD after take off) or 5 NM (between DME equipped a/c; RNAV equipped a/c using ATD and between DME and ATD a/c provided the DME a/c is either 10,000 feet or below or outside of 10 miles from the DME NAVAID). The main separation contributing factors are: Human (Monitoring/ situation awareness, Pilot response time, Controller response time Controller workload), there is no consideration to on-board equipment and there is no use of any surveillance system except visual means. This separation is based on the probability of mid-air collision due to the leading a/c been caught up by the a/c behind, mainly due to a drift in the speed or own position calculation by any or both a/c. The hazards could be presented principally are: Mid air collision, Lost of longitudinal separation and WV encounter and consequently resulting in a lost of control. According to Australian regulations WV separation varies depending on the following a/c climbing to the higher level or following a/c climbing to the lower level, following a/c climbing to the same level. This regulation considers separation based on distance by means of RNAV, which involves equipment precision factors (Navigation sensor

ISBN: 978-0-615-20720-9

error, Airborne receiver error, Flight technical error, Navigation reliability, Navigation system integrity, A/c certified for RNP-10 or RNP-4). In Canadian regulations is laid down in following way, 3 minutes until altitude levels are crossed (prior to reaching 15 miles from the departure rwy, the following a/c will climb through the altitude of the leading a/c, and both a/c will follow the same track until vertical separation is established) or 5 min (when the following a/c will climb through the altitude of the leading a/c and both a/c follow the same track until vertical separation is established), and based on distance, 10 NM until altitude levels are crossed (the following a/c will climb through the altitude of the leading a/c, and both a/c use DME and follow the same track to or from the same DME NAVAID immediately after take-off). For the Arrival (TMA) PoF, descending operation are almost the same as climbing operations for changing level, but now for descent. For the ENR PoF, cruising and maintaining same level, there are many different separation cases, the most homogeneous one is control by mach number technique, where all regulations coincide. When the preceding a/c is Mach 0.02, 0.03, 0.04, 0.05 or 0.06 faster than the following a/c, 9, 8, 7, 6 or 5 minutes separation applies respectively. The human factors involved are: Pilot monitoring/situational awareness, Pilot response time, Cockpit Resource Management, Crew workload, Controller/Pilot communication/coordination, Controller monitoring/situational awareness, Controller response time, Controller workload, Controller interaction with displays / automation / decision aids. Here it is important that longitudinal separation minima are based upon quality of meteorological information available. For this PoF there are so many and diverse specific conditions laying down different separation minima cases.

2) Vertical Separation

Around 37 SMS were identified. For the Aerodrome PoF there is not vertical separation. For Departure (TMA), Arrival (TMA) and ENR PoFs, for changing level and cruising maintaining same level operations, the vertical separation minima separation are based on distance and regulations are very standardized and aligned. This is due to this standard is very well documented in ICAO Doc 9536 - Sixth Meeting RGCSP/6 Review of the General Concept of Separation Panel - Volumes 1 and 2, and ICAO 9574 - Appendix A. The value of 300 meters applies for vertical separation below FL 290, between above FL 290 and below FL 410 could applies 300 or 600 meters separation (within designated airspace), and at or above FL 410 the vertical separation is 600 meters. The separation value corresponding to Unlawful Interference is 150 meters (500 feet) according to Attachment B – ICAO Annex 2. Among contributing factors to separation which were considered are aerodynamics factors apart from maneuver response capabilities, vortices will not normally descend more than about 400 – 500 ft they can descend further if there are significant downdraughts, or they may be presented due to an a/c has climbed or descended. Human factors involved for instance are: Controller confidence, Pilot confidence, Consensus of the users, Pilot monitoring/situational awareness, Pilot response time, Cockpit Resource Management, Crew workload, Controller/Pilot communication/coordination, Controller monitoring/situational awareness, Controller response time, Controller workload, Controller interaction with displays/automation/decision aids, Training/experience. Collision is main risk for this separation, it was calculated considering a Target Level Safety (TLS) value of 2.5 × 10-9 fatal accidents per a/c flight hour. Based on a Collision Risk Model (CRM) the risk of collision modeled is that due to the loss of procedural vertical separation between a/c flying above FL 290 in a given portion of airspace. WV encounter is a potential risk due to occasionally vortices will descend further and be encountered by a/c flying only 1000ft below when Reduced Vertical Separation Minima (RVSM) are in operation, vortices will not normally descend more than about 400 – 500 ft they can descend further if there are significant downdraughts, or they may be present because an a/c has climbed or descended.

3) Lateral Separation

Around 64 SMS were identified. For the Aerodrome PoF, different values of separation minima are applied for landing and taking off operations, considered among them: Independent parallel instrument approaches, Dependent parallel instrument approaches, Simultaneous use of parallel rwys, Segregated operations on parallel rwys, Separation between rwys centre line, Successive departures, Simultaneous departures. For these kind of separations minima equipments such as ILS and/or MLS are necessary on both rwys, suitable surveillance radar available, satisfactory two-way radio communication. For the Departure PoF (climbing operation) according to Australian regulation different values are laid down based on distance for several cases such as: for a/c turns of 16 degrees through 90 degrees, for a/c turns of 91 degrees through 180 degrees, in addition to the 14/17 of a mile protected on the over flown side of the track. For the En Route PoF (cruising and maintaining same level) are laid down separations, some of them based on Angle/distance, the contexts described can be for instance: for turns of 15º or less, for turns from 16º through 90º, for turns from 91º through 180º, oceanic procedures, North Atlantic ICAO region, Caribbean ICAO region, Pacific ICAO region, North America ICAO region-Arctic CTA, by requiring a/c to fly on specified tracks which are separated by a minimum amount appropriate to the navigation aid or method employed, non real time radar monitoring or control of the lateral deviation is exercised; distance between 2 VOR less than 278 km (150 NM), protected on the over flown side of the track.

IV. CONCLUSIONS

The first conclusion is that there are so many separations minima rules, around 622 cases. Among existing SM standards, some differences have been detected between the values applied for the same standards by different regulators. The regulators should agree and study standards in order to improve and standardize SM. For instance, WV separation minima analysis reflects several differences among regulations based on this conclusion the most restricted one

ISBN: 978-0-615-20720-9

could be extended to the rest of the states or studying if minima of minima complies with safety conditions and applies it, reducing separations. To make sure the studies of what standards are applicable or sensitive to be reduced, it is necessary to carry out in depth studies into the foundations and the models and principles upon which were they are based. The foundations analysis defines the background to these rules and enables to know if it is possible to improve or reduce separations.

Foundations were found mainly in Regulations. For the 600 SMS identified in WP2 a "Foundation Research" was carried out starting from International regulation as ICAO, EUROCONTROL and then looking at local regulation such as: British, Canadian, Australian, FAA.

From the 622 SMS identified.

- For 15% of the cases the foundations were found
- For 49% of the cases the foundation research was carried out within a lot of effort and looking in deep in a lot of information sources but finally the foundation was not found. In some cases just some clues were recorded.
- For 35% of the cases within the effort and time allocated it was not possible to do a deeper foundation research on these SMS.
- For the 1% of the cases within the effort and time allocated it was not possible to do the foundation research on these SMS.

These figures results on the following answer: foundations are not too much strong as they could be, so their definition's improvements could impact directly on the Separation Minima Reduction.

Mainly in the definition of a Separation Minima Standard a group of factors is involved.

The groups of factors identified on the 600 SMS identified were Aerodynamics Effects, Human Factors, Hazards & Risk, Equipment Precision, Surveillance.

Within the effort and time allocated to perform these studies, 600 SMS were too many. Therefore it was discussed which ones were more relevant to be analysed much more deep and it was agreed that: separation minima cases more relevant for further studies must acknowledge the following criteria:

- Standards associated to operations in Europe will be preferred to others.
- Most commonly used standards are preferable.
- Standards based upon the most advanced technology will be preferred to others.
- All the different areas (airport, TMA, en route) should be covered.
- Foundation Research Analysis resulting on SUCCES or FEW POSSIBILITIES.
- At least one Contributing Factors Identified.

Once this analysis was performed it was result on 157 SMS that acknowledge within these criteria, in other words, that will be study in more detail.

Several SMS are quite similar by concept, therefore it has been analysed and them created a Grouping Methodology which main objective was to bring together all the SMS that are similar in order to facilitate their further studies. Finally 21 groups were created for Aerodrome, TMA and ENR SMS.

For these kind of studies "too much information" is not enough, specifically for the modeling definition, therefore the answer should be no. But in terms of "what we have found" the answer is:

- 25 documents were analyzed (ICAO, FAA, AIAA, WakeNet, NLR, Eurocontrol, Cambridge University, etc.).
- 36 references to mathematical models, simulation models, collision risk models, SM foundation, etc. were captured.
- The groups with more quantity of references were the ones related to Wave vortex.

ACKNOWLEDGEMENTS

We would like to recognize the valuable contributions to this research carry out by all RESET partners, specially the ones involved in Reset WP2 and WP3.1.

Note: All documents included on this paper are available on RESET website http://reset.aena.es.

DISCLAIMER

Opinions, interpretations, recommendations, and conclusions contained herein are those of the authors and are not necessarily endorsed by the European Commission or other RESET partners.

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 ISBN: 978-0-615-20720-9