EASA
European Union Aviation Safety Agency

EUROPEAN OPERATORS FLIGHT DATA MONITORING
WORKING GROUP A

SAFETY PROMOTION
Good Practice document

REVIEW OF MID AIR COLLISION (MAC) PRECURSORS FROM AN FDM PERSPECTIVE

Version 1

Contents

I. Summary 3
II. Introduction 3
III. Methodology 3
IV. MAC Risk Monitoring and FDM 5
V. MAC Risk Modeling 5
VI. Contextual Information 6
VII. Precursors to be Monitored 7
VIII. Consolidated Precursors 9

I. Summary

The scope of this document is to identify relevant precursors of *Mid Air Collision (MAC)* to be monitored through Flight Data Monitoring (FDM) programs. This study is published for the consideration of operators and aviation communities to enhance existing FDM programs. In addition, it is submitted to EOFDM Working Group B with a series of recommendations to orient their work related to *MAC* risk.

On the EOFDM homepage [1], further information about EOFDM as a voluntary partnership, the associated working groups, and further publications can be found.

This document shall be considered as an industry best practice document produced for safety promotion purposes. It is neither an official guidance material to European Union rules nor an official EASA recommendation.

II. Introduction

In the context of this study, the following definition for *MAC* based on the *"Aviation Occurrence Categories"* [2] is used:

> Air proximity issues, Traffic Collision Avoidance System (TCAS) / Airborne Collision Avoidance System (ACAS) alerts, loss of separation as well as near collisions or collisions between aircraft in flight.

This definition given by the Common Taxonomy Team for MAC contains list of sub-scenarios that are either included and excluded from the *MAC* definition in the list of *"Aviation Occurrence Categories"*. For the scope of this document, these detailed cases are not considered relevant and are left out.

In the following chapter III, the methodology of WG A for the development of this document is outlined. The characteristics of *MAC* specifically from the FDM perspective are described in chapter IV. In chapter V, the *MAC* risk modeling for this document is described. So-called contextual information are introduced in chapter VI that can be used to further describe flights with an increased *MAC* risk. The *MAC* precursors together with their rationale are presented in chapter VII. Finally, chapter VIII formulates recommendations to support *MAC* analyses in FDM.

III. Methodology

The objective of WG A analysis is to identify among the precursors of *MAC* scenarios the ones that are suitable for monitoring through Operators' FDM (already today with the existing FDM programs available or to be developed further in the future). Those identified precursors are then made publicly available to operators and aviation communities for further consideration, in particular to orient the update of their FDM systems. In addition, they are provided to EOFDM WG B who gathers and develops industry best practices in FDM for the design and coding of events/measurements capturing such precursors. In that respect, the analysis of WG A is structured into two sequential steps.

The first step aims at identifying *MAC* precursors based on the analysis of existing material of *MAC* scenarios publicly available in the aviation industry. This review is focused on systemic studies (that already consider among other a series of individual cases like accident/incident investigation reports from Safety Investigation Authorities). The table below gives an overview of all the public systemic analysis material that was reviewed by WG A in that respect:

1 https://www.easa.europa.eu/easa-and-you/safety-management/safety-promotion/european-operators-flight-data-monitoring-eofdm-forum

2 Aviation Occurrence Categories, Definitions and Usage Notes, Commercial Aviation Safety Team (CAST), International Civil Aviation Organization (ICAO), Common Taxonomy Team, October 2013 (4.6)

Table 1 - Reviewed MAC studies

Source	Title	Resource
BEA	Mid-Air Collisions 1989-1999	https://www.bea.aero/uploads/tx_scalaetudessecurite/mid.air.collisions_01.pdf
EUROCONTROL	Safety Analysis of Airspace Infringements in Europe_final report	https://www.eurocontrol.int/sites/default/files/field_tabs/content/documents/nm/safety/airspace-infringement-risk-analysis-part-i.pdf
SKYBRARY	Mid-Air Collision	http://www.skybrary.aero/index.php/Mid-Air_Collision
SKYBRARY	Airspace Infringement	http://www.skybrary.aero/index.php/Category:Airspace_Infringement
SKYBRARY	Loss of Separation	http://www.skybrary.aero/index.php/Category:Loss_of_Separation
UK CAA (UK Airprox Board)	Helios Class G Risk Study	https://www.airproxboard.org.uk/Topical-issues-and-themes/Helios-Class-G-Risk-Study/
UK CAA (UK Airprox Board)	Collision Avoidance	https://www.airproxboard.org.uk/Topical-issues-and-themes/Collision-Avoidance/
Australian SIA (ATSB)	Loss of separation between aircraft in Australian airspace, January 2008 to June 2012	https://www.atsb.gov.au/publications/2012/ar-2012-034/
EUROCONTROL	EVAIR Safety Bulletins	http://publish.eurocontrol.int/safety/safety-publications?title=&field_term_publication_type_tid=238&date_filter%5Bvalue%5D%5Byear%5D=
EASA	European Plan for Aviation Safety (EPAS)	www.easa.europa.eu/system/files/dfu/EPAS_2017-2021.pdf
EASA	Annual Safety Review (ASR)	https://www.easa.europa.eu/newsroom-and-events/news/easa-annual-safety-review-2016

As a second step, based on the review of this material, main precursors for *MAC* scenarios were identified and further assessed. The precursors most capable of being captured and monitored through FDM programs were short-listed:

- Incorrect altimeter setting or incorrect transition timing
- Lateral deviation
- Level bust
- High rates of climb/descent
- Inadequate use of automation
- Automatic altitude control system off in RVSM conditions
- Last minute change of SID and STAR
- Airborne Collision Avoidance System (ACAS) alerts
- Inappropriate ACAS settings

Each of these precursors was then analyzed to define the best strategy to monitor/capture them via FDM programs. In addition, once captured, the analysis of the working group highlighted that the following contextual factors are relevant to better assess the actual risk of *MAC* for a given scenario:

- High airspace density
- Airspace infringement
- Significant proportion of the flight performed in non-controlled airspace
- Visibility conditions
- Airline network and operation characteristics

IV. MAC Risk Monitoring and FDM

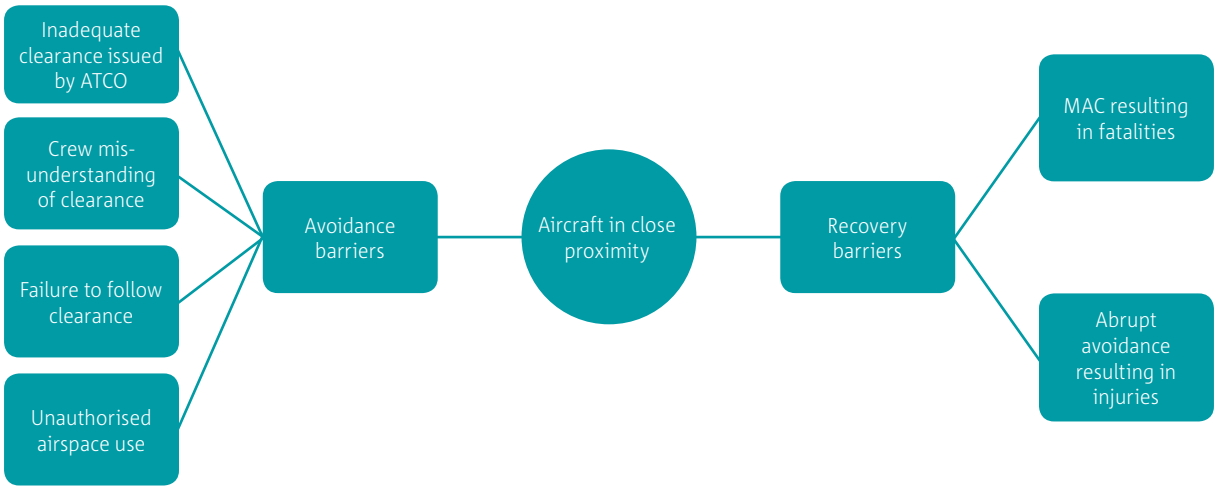
The characteristics of the data recorded on-board aircraft and analyzed within the FDM framework strongly influence the possible investigations. Considering the accident category *MAC*, many contributing factors cannot be identified when only FDM data are available. For example, the actions of the air traffic controller, i.e. the transfer and the perception of the instructions to the flight deck crew are essential but not traceable based on FDM data. Furthermore, always more than one aircraft is involved in a loss of separation event. In general, FDM data is only available for one of the affected aircraft.

There are further challenges in the analyses of *MAC* in civil aviation that are out of the scope of FDM analyses and this document. A recent development that is continuously getting more relevant in terms of *MAC* in civil aviation are drones. General aviation aircraft including gliders often carry minimal equipment onboard so that not all recovery barriers are available. Due to the different nature of operation, *MAC* analyses of helicopters might require additional perspectives.

V. MAC Risk Modeling

For the development of this review of *MAC* precursors from an FDM perspective, EOFDM Working Group A has agreed on a simplified Bow Tie Model that is given in Figure 1. In the center the hazardous event "Aircraft in close proximity" is given. On the left, four hazards (or "triggering events") are listed. To reduce the probability that these events occur and lead to the loss of separation event, some avoidance barriers exist. On the right hand side are two severe potential outcomes of a loss of separation event. To avoid them evolving from an existing loss of separation scenario some recovery barriers are in place.

Figure 1 - Simplified bow tie model for MAC



The precursors discussed in chapter VII are organized according avoidance and recovery barriers.

A central recovery barrier of *MAC* events in civil aviation is the Airborne Collision Avoidance System (ACAS). Information about triggered alerts such as Resolution Advisories (RA) and related details are often captured in the FDM data stream and can be analyzed. In addition, based on these triggers, ACAS alert hotspots can be identified by every airline in case enough data is available.

Once a loss of separation event is identified, more detailed analyses outside FDM can be conducted on an individual and manual basis, potentially considering other sources of information:

- Readouts of onboard ACAS systems memories
- Collect air safety reports of flight deck crew
- Contact ATC for feedback or report
- Investigate ground-based Short Term Conflict Alert (STCA) data from Air Navigation Service Providers (ANSP)

VI. Contextual Information

Once a flight is highlighted by FDM as a flight with increased *MAC* risk (e.g. an ACAS alert was detected), the context around this detected increased risk can be further described with the set of contextual information provided here under. Their natures are different from the *MAC* precursors since they cannot be used to detect a precursor of *MAC* risk event.

• High airspace density

The risk of MAC cannot be directly derived from the level of congestion of the airspace as the level of complexity and the nature/number of the safety nets implemented in the airspace play a key role. However, in case of deviation or failure of existing safety barriers, the potential for a *MAC* in congested airspace might be higher than in less crowded airspace. Also, in cooperation with the ANSP or using available ADS-B data sources (e.g. through ADS-B data Providers) the density of the airspace during the specific period could be estimated (however, this goes beyond the typical FDM systems that are currently implemented by Operators).

• Airspace infringement

In cooperation with ANSP or using aeronautical charts it can be investigated whether the particular aircraft had all the required clearances for the given flight path.

• Significant proportion of the flight performed in non-controlled airspace

Uncontrolled airspace provides considerable less assistance by air traffic controllers compared to controlled airspace. For a particular flight, if an increased *MAC* risk is detected by the FDM system, if this risk is detected in a phase flown in uncontrolled airspace, this might contribute to a higher level of risk of MAC. However, current FDM software are in general not capable to automatically identify the airspace category surrounding the aircraft at a specific time. If this was the case, Operator could as well measure and monitor the proportion of their fleet operations performed in uncontrolled airspace.

• Visibility conditions

Poor visibility is an escalation factor for the risk of *MAC*, especially in uncontrolled airspace where “see and avoid” is the last barrier against the accident. In the case of a *MAC* related incident, crew reports may include mentions to visibility conditions and for occurrences happening in terminal areas, meteorological reports (METARs) might be used to obtain an estimation of the visibility conditions.

• Airline network and operation characteristics

The specific characteristics of the airline operation can have an influence onto the performance of the crew. For example if a flight crew is flying in congested airspace very rarely, the different requirements, e.g. higher amount of interactions with ATC, different procedures, might affect the pilots negatively.

To be noted, for most of these contextual information, it is necessary to use complementary data sources in addition to flight data to be able to properly evaluate them.

VII. Precursors to be Monitored

Within the present document, a precursor is defined as a factor whose occurrence might (but not necessarily have to) indicate an increased risk of a *MAC* event. During the development of this document, EOFDM WG A has discussed the characteristics of the precursors identified (e.g justification of the precursor, data needed to capture the precursor, technical feasibility considered existing FDM systems, etc..).

According to chapter V, the precursors within this document are assigned to the two categories of barriers: avoidance barriers and recovery barriers of loss of separation.

Avoidance barrier precursors:

1) Incorrect altimeter setting or incorrect transition timing

Incorrect reference setting of the barometric altimeter can result in a flight at unintended altitude eventually increasing *MAC* risk. Different procedures throughout the world regarding the correct setting and correct timing of the transition might contribute to this category of occurrences. Considering this *MAC* risk increase, this precursor shall be monitored by FDM.

2) Lateral deviation

Lateral deviation from a prescribed or planned flight path increase the risk of *MAC* as it can result in a loss of separation with other traffic. The intended trajectory can be among other as per SID/STAR procedures, ATC vectoring or RNP procedures and some deviations can occur due to weather avoidance or traffic congestion management. In addition, such deviations shall be monitored by FDM potentially complemented with other sources of data.

3) Level bust

A level bust means the overshoot of the cleared altitude or flight level in a climb or an undershoot during a descent. In both cases, the aircraft is in a condition it has not been cleared for which leads to an increase of *MAC* risk. Monitoring this precursor in FDM is advisable.

4) High rates of climb/descent

Even in the absence of level busts, high vertical speed near the assigned flight level can trigger nuisance ACAS alerts. Many operator SOPs have adopted the ICAO recommendation [3] for reducing of vertical speed of the aircraft as it approaches the cleared flight level or altitude. Monitoring this precursor would enable the assessment of SOP compliance, its effectiveness in mitigating nuisance ACAS alerts and also provide an opportunity to evaluate any possible unintended consequences of such SOPs (such as increased pilot workload).

5) Inadequate use of automation

Civil aircraft are equipped with various automation systems. Even though the main components are similar for different aircraft manufacturers, many differences exist. The adequate use of the specific automation systems is of utmost importance for the flight safety in general and the avoidance of *MAC* in particular. Indeed, an inadequate use of automation related to the flight trajectory can result in discrepancies between the actual flight path and the one targeted by the crew as cleared by the Air Traffic Control (ATC). For example, considering the vertical flight path, the non-engagement of the Go-Around mode on certain aircraft models can result in a temporary difficulty for the crew to maintain the targeted vertical profile as the published missed approach procedure and/or as instructed by ATC.

Consequently, whenever suitable, the adequacy of the use of automation shall be monitored by FDM. Particular FDM algorithms need to be further specified based on the considered scenario and the specific automation systems on board. General rules for the adequacy of every automation system do not exist.

3 At the time of writing of this document, the ICAO recommendation can be found in Annex 6 Part 1, paragraph 4.4.10

6) Automatic altitude control system off in RVSM conditions

Reduced Vertical Separation Minima (RVSM) means a reduction of the vertical separation minima from 2,000 ft to 1,000 ft between FL290 and FL410. EASA regulations require an operative automatic altitude control system while operating in RVSM airspace as a means to ensure the required accuracy to maintain safety margins. The compliance can be monitored by FDM.

7) Last minute change of SID and STAR

Departures from and arrivals to airports mostly follow predefined routes. They are referred as Standard Instrument Departure (SID) and Standard Terminal Arrival Route (STAR). Flight crews brief the assigned routes and subsequently program the Flight Management System (FMS) during the briefing. In case of last minute changes of the planned route, it might increase the workload and might induce deviations from the procedure. These deviations might eventually compromise flight safety and increase *MAC* risk. Therefore, last minute changes of STAR and SID shall be monitored by FDM whenever technically feasible.

Recovery barrier precursor:

8) ACAS alerts

As already mentioned in Chapter V, ACAS systems are a central recovery barrier for *MAC* risk. An occurrence of an ACAS alert should be monitored within FDM as it is a direct precursor for *MAC* incidents. ACAS alert events have to be reported [4] and FDM can assist in detecting cases that are not reported by the flight crew. Pilot reactions to the ACAS alerts can be investigated further via individual analysis of the occurrences detected via FDM. It usually requires the consideration of additional sources of information and complex assessment activities. In addition, these activities are considered difficult to automatize in current FDM systems.

9) Inappropriate ACAS settings

In general, ACAS systems can be set to different modes. One example besides the regular mode is “Traffic Advisory (TA) Only”. Due to special operational requirements, it might be advisable to change the mode of the ACAS in certain situations. In case information about the used ACAS mode is available, the correctness of the selected mode shall be monitored by FDM. In addition, any further information regarding the operability of the ACAS that might be available in FDM shall be monitored to ensure the correct service of the ACAS.

4 See the list classifying occurrences in civil aviation to be mandatorily reported according to Regulation (EU) No 376/2014 of the European Parliament and of the Council
http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32015R1018&from=EN

VIII.Consolidated Precursors

Based on the previous chapters of this document, the *MAC* recommendations of EOFDM Working Group A are collected in Table 2.

MAC recommendations:

Table 2: Working Group A MAC recommendations

MAC recommendations	
Number	**Name**
MAC01	Incorrect altimeter setting or incorrect transition timing
MAC02	Lateral deviation
MAC03	Level bust
MAC04	High rates of climb / descent
MAC05	Inadequate use of automation
MAC06	Automatic altitude control system off in RVSM conditions
MAC07	Last minute change of SID and STAR
MAC08	ACAS alerts
MAC09	Inappropriate ACAS setting

MAC01 Incorrect altimeter setting or incorrect transition timing: Develop means to detect incorrect altimeter settings and incorrect timing of the transitions, which could lead to situations with an increased *MAC* risk.

MAC02 Lateral deviation: Develop means to detect situations where the actual flight trajectory is deviating from the published, cleared or intended trajectory.

MAC03 Level bust: Develop means to identify level busts, i.e. situations where the cleared and intended altitude or flight level is overshot during climb or undershot during descent.

MAC04 High rates of climb / descent: Develop means to identify climbs and descents with high rates. Due to the trigger logic of ACAS alerts, these high rates can lead to the generation of nuisance alerts (see MAC08).

MAC05 Inadequate use of automation: Develop means to identify situations of inadequate use of automations related to the trajectory [5].

MAC06 Automatic altitude control system off in RVSM conditions: Develop means to identify situations with inappropriate settings of the automatic altitude control system in RVSM conditions.

MAC07 Last minute change of SID and STAR: Develop means to identify last minute changes of the SID or STAR (possibly in combination with MAC02).

MAC08 ACAS alerts: Monitor every safety relevant information with respect to the ACAS that is available within FDM. In particular, resolution advisories shall be identified and further investigated in detail.

MAC09 Inappropriate ACAS setting: Develop means to monitor the settings of the ACAS and to verify their suitability.

5 A similar recommendation exists for LOC-I precursors in EOFDM WGA - Review of Accident precursors for Loss of Control In Flight (LOC-I) document: recommendation LOC29 “Mismanagement of Automation”

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