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SAFETY PROMOTION
Good Practice document

EOFDM WORKING GROUP A

REVIEW OF CONTROLLED FLIGHT INTO TERRAIN (CFIT) PRECURSORS FROM AN FDM PERSPECTIVE

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I. Summary

The scope of this document is to identify relevant precursors of *Controlled Flight Into Terrain (CFIT)* to be monitored through Flight Data Monitoring (FDM) programs. This study is published for the consideration of Operators and aviation communities (e.g. to orient the implementation of FDM events). In addition, it is submitted to EOFDM Working Group B to conduct further actions.

II. Introduction

In the context of this study, the following definition and usage notes for *CFIT* based on the *"Aviation Occurrence Categories"* [1] is used:

In-flight collision or near collision with terrain, water, or obstacle without indication of loss of control.

Usage Notes:

- Use only for occurrences during airborne phases of flight.
- Includes collisions with those objects extending above the surface (for example, towers, trees, power lines, cable car support, transport wires, power cables, telephone lines and aerial masts).
- Can occur during either Instrument Meteorological Conditions (IMC) or Visual Meteorological Conditions (VMC).
- Includes instances when the cockpit crew is affected by visual illusions or degraded visual environment that result in the aircraft being flown under control into terrain, water, or obstacles.
- If control of the aircraft is lost (induced by crew, weather or equipment failure), do not use this category, use Loss of Control - Inflight (LOC - I) instead.
- For an occurrence involving intentional low altitude operations (e.g., crop dusting, aerial work operations close to obstacles, and Search and Rescue (SAR) operations close to water or ground surface) use the Low Altitude Operations (LALT) code instead of CFIT.
- Do not use this category for occurrences involving intentional flight into/toward terrain in manned aircraft or intentional ground impact of unmanned aircraft. Code all collisions with obstacles during takeoff and landing under Collision With Obstacle(s) During Takeoff and Landing (CTOL). Code all suicides under Security Related (SEC) events. Code system, equipment, or command and control failures involving unmanned aircraft under System/Component Failure or Malfunction (Non-Powerplant) (SCFNP) or LOCI as applicable.
- Do not use this category for occurrences involving runway undershoot/overshoot, which are classified as Undershoot/Overshoot (USOS).

The main structure of this document consists of five parts. In chapter III, the applied methodology to develop this document of Working Group A is described. Subsequently, a general introduction to *CFIT* occurrences is given in chapter IV. Any proper *CFIT* analysis requires certain information about the aircraft state and of the underlying and surrounding terrain. In chapter V of this document, this required information is considered and described. Precursors to be observed in FDM for *CFIT* analyses are discussed in chapter VI. Finally, in the last part, the consolidated *CFIT* precursors are summarized in chapter VII.

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

III. Methodology

The objective of WG A analysis is to identify among the precursors of *CFIT* 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 publically 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 FDM best practices 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 *CFIT* precursors based on existing analysis material of *CFIT* scenarios across the industry communities. Indeed, this enables a data driven approach for the identification of *CFIT* precursors as it relies on the existing safety analysis performed by worldwide aviation stakeholders based on official safety investigations or other safety data available. Among the material reviewed, the following two were considered as good references to support this analysis work:

- **Controlled Flight Into Terrain Accident Analysis Report**, published in 2015 by IATA and publically available on IATA website, based on accident data for aircraft with MTOW above 5,7 t that were engaged in commercial operations
- **Controlled Flight Into Terrain Precursors and Defences**, article publically available on SKYbrary Aviation Safety website, based on a broader spectrum of safety data such as: feedback from training sessions (especially simulator), pilots' report, flight data analysis, line observations (e.g. Line Operations Safety Audit, LOSA), survey and audit reports as well as accident and incident investigation.

In a second step, based on the review of this material, the main precursors for *CFIT* scenarios were collected (refer to Annex 1) and the ones most capable of being captured and monitored through FDM programs were identified:

- Poor visibility conditions
- Altimeter errors
- Lateral and/or vertical deviation from intended flight path
- TAWS alerts
- Loss of terrain separation

Each precursor was then analyzed to define the best strategy to monitor/capture them via FDM programs.

IV. CFIT Occurrences and Scenario Analysis

1 Visibility Conditions

The visibility condition plays a vital role in *CFIT* analyses. In various accident scenarios, Instrument Meteorological Conditions (IMC) were present and contributed to the accident progression (e.g. *CFIT* of CA129 [2]). On the other hand, the occurrence of a *CFIT* during a flight maneuver in clear Visual Meteorological Conditions (VMC) being well aware of the surrounding terrain is less likely compared to flying the same maneuver at the same location in IMC.

Considering visibility conditions is therefore beneficial for any *CFIT* analyses. Unfortunately, this information is very hard to assess based on the data that is currently recorded for FDM.

Nevertheless, whilst not today feasible, it seems possible that assuming technology development, there will be the ability to detect prevalent IMC or VMC conditions within FDM robustly in the future. For example, information from Virtual VMC technology (such as Synthetic Vision Systems) might be one data parameter that could be available.

However, today, dependent on the individual FDM capability data fusion with other precursors including sources of meteorological information (e.g., METAR, TAF and en-route weather information) with published approaches and terrain databases, it is possible to determine deviations to requirements (such as MDA(H)) and precursors to potential *CFIT*.

2 Terrain Awareness and Warning System (TAWS) Information

Most aircraft affected by FDM regulations are fitted with Terrain Awareness and Warning Systems (TAWS)[3] such as the Ground Proximity Warning System (GPWS) or the Enhanced Ground Proximity Warning System (EGPWS) onboard. However, the availability of information of these systems that is recorded in FDM data might vary significantly.

In general, the usage and analyses of recorded information from TAWS is beneficial. The purpose of these systems is that alerts are triggered when the aircraft is in a potentially hazardous proximity to terrain. If the most advanced systems (EGPWS) can consider terrain and airport databases, TAWS basically considers specific parameters such as radio altimeter information (or a combination of several parameters) and monitor if these parameters reach defined thresholds. For example, the TAWS can provide indications of excessive rates of descent, excessive closure rate to terrain, negative climb rate or altitude after take-off, flight into terrain when not in landing configuration or excessive downward deviation from an ILS glideslope.

The first information that must be recorded on the aircraft is the triggering of the alert, this helps to detect dangerous situations during flight operations. Most FDM software tools are able to raise events whenever TAWS warnings are detected on the recorded flight data.

However when implementing this parameter in the FDM, the specific characteristics of the particular TAWS system need to be considered (e.g. version terrain data base). For example, protected areas where TAWS alerts may not be triggered, but in some cases, a too low approach could be a precursor to *CFIT*.

A further possibility is to consider not only the triggered events, but also to consider the underlying observed parameters. These parameters are often not directly available in FDM data. One goal of this document is to define values that contain information about the severity of the specific scenario with respect to *CFIT*.

2 Aircraft Accident Report, Controlled Flight Into Terrain Air China International Flight 129, B767-200ER, B2552, Mountain Dotdae, Gimhae, April 15, 2002, Korea Aviation-Accident Investigation Board

3 Regulation (EU) 965/2012, Part CAT (commercial air transport)
CAT.IDE.A.150 Terrain awareness warning system (TAWS)
(a) Turbine-powered aeroplanes having an MCTOM of more than 5 700 kg or an MOPSC of more than nine shall be equipped with a TAWS that meets the requirements for Class A equipment as specified in an acceptable standard.
(b) Reciprocating-engine-powered aeroplanes with an MCTOM of more than 5 700 kg or an MOPSC of more than nine shall be equipped with a TAWS that meets the requirement for Class B equipment as specified in an acceptable standard.

V. Preparations Necessary to Monitor CFIT Risk Through Flight Data Monitoring

1 Reconstruction of Aircraft Parameters

Knowing the position and altitude of the aircraft is important to start *CFIT* precursor monitoring. In the following, all aircraft parameters that are required for the investigations presented within this document are listed:

- Latitude and Longitude of the aircraft position
- Geometrical altitude of the aircraft above mean sea level and above ground
- Three-dimensional speed vector of the aircraft

This list of aircraft parameters can either be given for a specific time point during flight for which the analyses is conducted or alternatively, the aircraft parameters can be given for a specific time period and the analyses carried out for the entire period. For the second option, it is assumed within this document that all parameters are given with the same sampling rate.

The required aircraft parameters can be obtained in various ways. The simplest way is a direct read out of the associated parameters from the flight data recording.

In case there are several parameter values for the same state available (e.g. of different sensors), correlating them could be advantageous.

Another method consists in using a physically motivated model to reconstruct the associated parameters. As an example, the physical equation distance = speed x time holds. It might be the case that the quality of the position and time recording is better than the quality of the (ground) speed recording. Using the physical formula and accurate position and time data, a good speed recording can be reconstructed and used to improve the original recording.

2 Access to Terrain Databases

To investigate the proximity of a scenario regarding a *CFIT* accident, information about the underlying and surrounding terrain is necessary. Combining the aircraft parameters with the relationship to terrain, as well as actual vs. published (SID/STAR etc.) flight paths can help detecting precursors to *CFIT*.

There are various terrain databases publically available and the following are briefly described:

- SRTM
- ASTER GDEM
- GTOPO30
- TanDEM-X

Commercial FDM software (or their add-on packages) might provide access to further or other terrain databases. It is not within the scope of this document to give an overview of all these commercial models.

The terrain databases were investigated based on the following criteria:

- Is the database freely available?
- Is the database well documented?
- Are further resources necessary to use the database?
- When was the release date?

- Which agency or company is responsible for it?
- What percentage of the Earth's surface is covered?
- How fine is the spacing of the underlying grid?
- What is the accuracy of the model?

An overview of the considered terrain databases is given in Table 1.

Data from NASA's SRTM is recorded in accordance with the DTED specification (MIL-PRF-89020B). This is a military standard, originally designed in 1970 and reissued in 1996 in order to include the requirements of the SRTM program. It specifies the contents, format and all assumptions related to the data made available in the scope of the program, including the resolution of the measurements.

Table 1: Overview Terrain Databases

	SRTM	ASTER GDEM	GTOPO30	TanDEM-X
Availability	Freely available	Freely available	Freely available	Free for research purpose, commercial application for purchase
Documentation	On NASA website	On NASA website	On the U.S. Geological Survey website	On DLR website
Required further resources	GIS or other special application	none	none	none
Release date	September 2015	2009	1996	2010
Responsible entity	NASA	Ministry of Economy, Trade, and Industry of Japan and NASA	USGS	DLR
Earth coverage	Between 56 deg South and 60 deg North of equator	Between 83 deg South and 83 deg North of equator	All	All
Grid spacing	30 m / 98 ft pixel spacing	1 x 1 degree in latitude and longitude (Level4Z 60 x 60 NM)	Approx. 1km	12 m
Accuracy	less than 10 m relative vertical height accuracy; less than 20 m absolute horizontal circular accuracy	7 – 14m	30 - 500m	2 m vertical

Given the access to the terrain database is provided via the FDM software, then, in order to derive the vertical distance of the aircraft to the underlying terrain, only the reconstructed position and geometrical altitude is necessary (i.e. no information regarding the speed). The characteristics of the chosen terrain elevation model influences the estimated vertical distance to terrain. Especially in rough terrain or for terrain models with a coarse grid spacing, interpolation between different model points is necessary to obtain good results.

Once the vertical distance to terrain is obtained based on the terrain database data and the aircraft position and geometrical altitude, it can be compared to the recorded radio height (for situations in which this is valid, e.g. below 2500 ft AGL).

Finally, this comparison can be used to assess the plausibility of the terrain database.

VI. Precursors to be Monitored

Precursors describe conditions for which the risk of or the proximity to a potential *CFIT* accident is increased. Within this chapter, a selection of *CFIT* precursors that are relevant for FDM analyses and were identified by Working Group A are presented.

1 Wrong Altimeter Reference Settings

During an aircraft's descent through the transition level during approach, the reference setting of the altimeters is changed from QNE to QNH. Depending on the approach characteristics, an error during the modification of the altimeter reference settings might have fatal consequences (e.g. this was the most probable cause of the *CFIT* of Canada Jet Charters Limited [4]).

Being able to observe the trends of wrong altimeter settings is beneficial and is possible providing suitable information is available. For example, the barometric altimeter recording can be compared to the runway elevation and it can be checked whether the difference is exceeding a certain threshold. Another example is where the published QNH from the associated METAR report is available, it can be used for comparison if the altimeter reference setting of the FDM recording.

Comparison may also be possible using aircraft geometric altitude (e.g. radio altimeter), however this will require additional combination of other sources of data (e.g. terrain databases and aircraft parameters).

2 Flight Below Minimum Sector Altitude (MSA)

According to ICAO definition, the Minimum Sector Altitude (MSA) is the lowest altitude which may be used which will provide a minimum clearance of 300 m (1000 feet) above all objects located in the area contained within a sector of a circle of 46 km (25 NM) radius centered on a radio aid to navigation. Descending below the MSA increases the risk for a *CFIT*, is one precursor that could be observed in a FDM system.

3 Deviation Below Glideslope

In most cases, the 3° glideslope as part of the Instrument Landing System (ILS) offers vertical guidance during approach. Taking into account stabilization of approaches, the deviation above/below glideslopes, and rate of descent, can be identified. Depending on the severity of the deviation and the distance to the runway, the *CFIT* risk is increased. The goal of this precursor is to observe severe deviations below the glideslope that significantly increase the risk.

Note: Similar precursors can be used in defining risks of Runway Excursions.

4 Flight Management System (FMS) Incorrectly Set

The FMS allows a planned route to be pre-programmed, for example Standard Instrument Departures (SID) and Approaches (STAR). This programming can be affected by errors and a wrong target flight path could bring the aircraft into close vicinity to terrain. Cases where standard published approaches are deviated from can lead to possible precursors for *CFIT* risk.

4 Aviation Occurrence Report, Controlled Flight Into Water, Canada Jet Charters Limited Learjet 35 C-GPUN, Masset, British Columbia 8 nm NW, 11 January 1995, Report Number A95P0004, Canada

5 Inadequate Vertical Mode Selections of the Aircraft Flight Control System (AFCS)

Common AFCS provide various settings, so-called modes. Based on the individual approach characteristics, a suitable mode has to be chosen. For *CFIT* analyses, modes for the vertical guidance are of special interest. A setting inappropriate for the given operational scenario, or incorrect use of the modes and deviation from published SOP's should be monitored and flagged by FDM.

6 Incorrect Descent Point

An incorrect descent point can bring the aircraft into close vicinity of terrain and should be investigated by FDM.

This risk can increase during instrument approaches where a descent point is determined based on distance from a fix (e.g. RNAV-GNSS). High workload and human factors can lead to incorrect reading of the approach chart and to an early descent towards the terrain.

The actual descent point vs. the published descent point should be compared, and any impact or deviation caused by NavAids also monitored and flagged by FDM.

The impact of NavAids on *CFIT* precursors should also be monitored, taking into consideration the correct following of the appropriate glide, and any deviation of actual approaches to published/expected approaches.

7 Terrain Awareness and Warning System (TAWS) Alerts and Crew Reactions

The soft and hard warnings of the TAWS should be monitored per fleet and airfield. Also, the TAWS modes activated should be recorded and considered in the FDM systems.

In addition, further to a TAWS alert, not following the correct escape maneuver, or published SOP's, could increase the *CFIT* risk and should be investigated by FDM.

It should be noted that, in some very specific cases, repeated TAWS alerts can be observed for a given airport or a given approach procedure. Such cases must be investigated as they might generate inappropriate crew reactions. External factors that lead to a high rate of such untimely alerts should be monitored and flagged by FDM. They can be linked to TAWS configuration, deviation from SOP, inappropriate SOP design or particular meteorological conditions.

> Note: Mismanagement or deviation from SOP's linked to Escape Maneuvers could be a precursor as well to LOC-I.

8 Inadequate Missed Approach and Go Around Flight Path

This precursor captures the inadequate actions of flight crew during a Missed Approach and Go Around scenario. Where a missed Approach/Go-Around is flown in the vicinity of terrain, this scenario increases *CFIT* risk if the published missed approach procedure is not accurately flown.

In addition to *CFIT* risk, this precursor could also lead to situations of loss of control, which are covered in a separate document also published by EOFDM Working Group A [5].

5 Review of Accident Precursors for Loss of Control in Flight, Revision 1- 2015.12.17, EOFDM Working Group A, LOC12-15+30+32

9 Loss Of Communication

A loss of communication between pilots and the responsible air traffic control service increases the workload for pilots. When combined with proximity to terrain, this distraction could divert their attention away from navigation and monitoring, which could lead to an increased *CFIT* risk. Therefore, loss of communication should be considered as a precursor for *CFIT* when combined with proximity to terrain and their occurrences should be observed by FDM.

10 Low Energy State During Approach / Unstable Approach

Every flight period near terrain incorporates a certain level of risk for *CFIT*. Especially during approach, the pilot's workload is high and an unstable approach could further distract pilots or increase even further their workload. Unstable approaches and incorrect energy management should be monitored by FDM. As such, please refer to recommendation RE26 of WG A "Unstable Approach" in the document **Runway Excursions: 2. Review of Accident Precursors** and the guidance material proposed by WG B under Event RE26 "Unstable Approach" in the document **Runway Excursions: 3. Study for Runway Excursion Precursors,** both available on EASA website.

11 Inadequate Response to Wind Shear Warning

A wind shear is a rapid change of wind speed and/or wind direction. Depending on the flight path and the surrounding terrain, a wind shear and its influence to the flight path could increase *CFIT* risk severely and should be investigated by FDM.

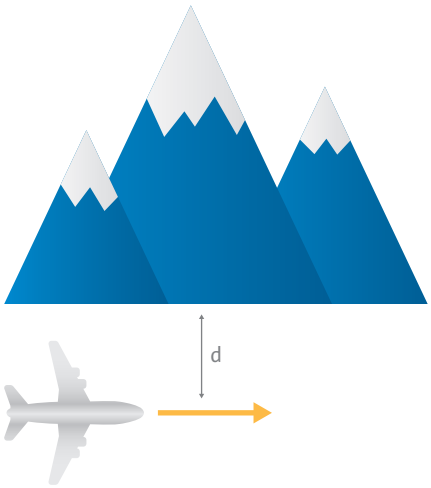
12 Reduced Horizontal Distance to Terrain

Estimate the horizontal distance from the aircraft to the surrounding terrain can be especially beneficial for departures and approaches in mountainous areas in order to capture scenarios where the horizontal distance to terrain is reduced. Compared to the estimation of the *Vertical Distance to Terrain*, the technical implementation of such a measurement is more complex. Again, a meaningful interpolation between the grid points of the terrain elevation model is required. The only required aircraft state is the three-dimensional position. In addition, an adapted threshold has to be defined in order to capture situations of reduced horizontal distance to terrain.

13 Reduced Time to Terrain Impact

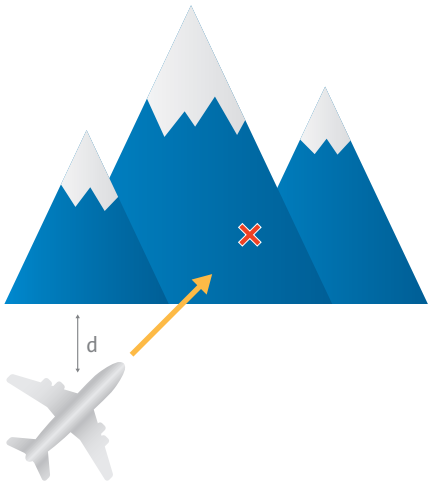
For this precursor, the three-dimensional speed is used in addition to the three-dimensional position. In fact, neither the vertical distance nor the horizontal distance to terrain are crucial for the occurrence of a *CFIT*, but are useful to categorize the scenario. What is important is distance plus the speed and direction vector. Based on the current three-dimensional position of the aircraft together with a three-dimensional speed vector, a "virtual" *Time to Terrain Impact* can be calculated. The underlying assumption for this calculation is that the speed vector stays constant until the *"virtual" CFIT* occurs.

The following scenario is the motivation for this precursor. It is assumed that an aircraft is flying along a mountain range such that the three dimensional speed vector is parallel to the mountain range. Even if the distance between the aircraft and the cliff is small, this implies that the *Time to Terrain Impact* is infinite. Nevertheless, for the same horizontal distance to terrain, the situation becomes more critical if small changes of the speed vector towards the mountain range occur. This situation should be covered by this particular precursor. Also, what it means to significantly reduce time to impact has to be researched in order to define such a precursor and, in particular, a suitable time threshold.



Aircraft trajectory is parallel to terain

=> Time to impact is infinite



Aircraft trajectory converges with terain

=> Time to impact is finite
and can be computed

VII. Consolidated Precursors and Recommendations

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

For each recommendation, levels for the influence of the outcome of the analysis and complexity of the technique are indicated. Possible values for both of them are *High*, *Medium* and *Low*.

Preparatory Actions:

- **Reconstruction of relevant aircraft parameters:** Develop means to obtain accurate position and speed recording of the aircraft (e.g. direct FDM recording readout or reconstruction based on other parameters).
- **Access to terrain database:** Provide access to a (public) terrain database in order to conduct *CFIT* analyses going beyond the analyses of triggered TAWS alerts. Develop means to estimate the vertical distance to terrain based on aircraft position and terrain database in order to validate the plausibility of the terrain database compared to recorded aircraft height.

Table 2: Working Group A CFIT Recommendations

CFIT Recommendations			
Number	**Name**	**Influence**	**Complexity**
CFIT01	Poor visibility condition	Medium	High
CFIT02	Wrong altimeter settings	Medium	Low
CFIT03	Flight below MSA	High	Low
CFIT04	Deviation below glideslope	Medium	Medium
CFIT05	FMS incorrectly set	Medium	High
CFIT06	Inadequate vertical mode selections of AFCS	High	Medium
CFIT07	Incorrect descent point	Medium	Medium
CFIT08	Inadequate TAWS escape maneuver	High	High
CFIT09	Inadequate Missed Approach and Go Around flight path	High	High
CFIT10	Loss of communication	Low	Medium
CFIT11	Low energy state during approach / unstable approach	Medium	Medium
CFIT12	Inadequate response to wind shear warning	Medium	Medium
CFIT13	Reduced horizontal distance to terrain	High	High
CFIT14	Reduced time to terrain impact	High	High

CFIT Recommendations:

CFIT01 Poor visibility condition: Develop means to identify present visibility conditions (e.g. IMC or VMC).

CFIT02 Wrong altimeter settings: Develop means to identify wrong altimeter settings.

CFIT03 Flight below MSA: Develop means to identify situations of aircraft flying below MSA.

CFIT04 Deviation below glideslope: Develop means to identify (severe) deviations below glideslope that increase *CFIT* risk.

CFIT05 FMS incorrectly set: Develop means to identify errors in FMS settings, especially those associated to close to terrain operation (e.g. approach in a mountainous area).

CFIT06 Inadequate vertical mode selections of AFCS: Develop means to identify inadequate vertical mode selections of the aircraft flight control system, especially those associated to close to terrain operation (e.g. approach in a mountainous area).

CFIT07 Incorrect descent point: Develop means to identify incorrect descent points.

CFIT08 Inadequate TAWS escape maneuver: Develop means to identify escape maneuvers after a triggered TAWS alert that are non compliant with the correct maneuver or airline SOPs. And beyond that, approaches with repeated TAWS soft warnings (or just one TAWS warning) should be monitored. Repeated TAWS soft warning during an approach can evidence that either the aircraft was not safe with regards to the terrain potentially due to the approach procedure design, or that the TAWS needs to be adjusted for that particular approach.

CFIT09 Inadequate Missed Approach and Go Around flight path: Develop means to identify Missed Approaches and Go Around flights paths that are non compliant with published information or airline SOPs.

CFIT10 Loss of communication: Develop means to identify loss of communication.

CFIT11 Low energy state during approach / unstable approach: Develop means to identify low energy states during approach and unstable approaches.

CFIT12 Inadequate response to wind shear warning: Develop means to detect inadequate responses to wind shear warnings, especially in situations close to terrain (e.g. approach in a mountainous area).

CFIT13 Reduced horizontal distance to terrain: Develop means to identify scenarios of reduced horizontal distance to terrain.

CFIT14 Reduced time to terrain impact: Develop means to identify scenarios of reduced time to terrain impact assuming the aircraft maintains current track and speed.

VIII. ANNEX 1 - List of Original CFIT Precursors

Based on the review of the available safety analysis studies about *CFIT* scenarios within the industry and the internal discussions of the working group, the following possible precursors of such scenarios were identified:

- GPWS/TAWS alert/warning (genuine, nuisance or false)
- Flight below MSA, MSAW warning
- Deviation below G/S
- Other cases of reduced terrain separation
- Prolonged loss of communication (PLOC) between pilot and controller(s)
- Misunderstood ATC clearance
- Low-energy state during approach
- Land short (runway undershoot) event
- Low altitude pattern following a go-around
- Inappropriate low altitude maneuvering
- Loss of visual reference whilst conducting circling approach
- Loss of situational awareness (incorrect descent point, stepped descents)
- Low-on-fuel condition/fuel starvation
- Aircraft misconfiguration
- Auto-pilot misuse
- Low pitch attitude/shallow flight path/altitude loss after lift-off
- Flight below desired profile path during climb
- Lateral deviation during climb (SID)
- Descent/flight below segment or sector safe altitude
- Altimeter setting error
- FMS incorrectly set
- Failure to check navigation accuracy before approach
- Lateral deviation during approach (STAR)
- Failure to revert to navaids raw data in case of doubts on automation
- Incorrect or inappropriate radar vectoring by ATC (i.e., below minimum vectoring altitude (MVA) and/or toward high terrain)
- Premature descent to the next step-down altitude during a multiple-steps-down non-precision approach
- DME confusion (non-collocated DME versus ILS-DME), in identifying the final descent point
- Premature descent to DA(H) before G/S intercept or premature descent to MDA(H) before final descent-point/FAF
- Premature descent below MDA(H) before reaching the visual descent-point (VDP)
- Flight below desired flight path during initial and/or final approach
- Approach profiles incorrectly flown

- Continued approach, when below DA(H) or MDA(H), after loss of visual references
- Late or inadequate response to GPWS/TAWS alert/warning
- Late or inadequate response to MSAW warning
- Late or inadequate response to wind shear warning
- Unstabilized approach (steep or shallow approach)
- Failure to go-around
- Lack of effective flight path control during go-around
- Failure to follow published missed-approach procedure
- Inadequate fuel management

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