Flight Standards
Air Traffic Management/Air Navigation Services (ATM/ANS) Development

Weather Information to Pilots Strategy Paper

An Outcome of the All Weather Operations Project

19 January 2018

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Conventions:

For clarification, within this document:

1) *"Meteorological information"* is used to describe data that is generated for, distributed to, and used by aviation stakeholders.

2) *"Weather"* and *"severe weather"* are used to describe the manifestation of meteorological phenomenon on the aircraft and its immediate environment.

3) The abbreviation *"WXR"* is used to refer to *"on-board weather radar"*, and is distinct from meteorological ground based weather radar systems. Both systems are specifically designed to identify precipitation and, in some cases, identify phenomenon such as wind-shear through Doppler radar processing.

4) *"CAT"* will refer to *"Clear Air Turbulence"*, whereas the term *"Commercial Air Transport"* will always be used in full.

5) *"Part-MET"* refers to the provisions laid down in Annex V of Regulation (EU) No 2017/373 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight, repealing Regulation (EC) No 482/2008, Implementing Regulations (EU) No 1034/2011, (EU) No 1035/2011 and (EU) 2016/1377 and amending Regulation (EU) No 677/2011[1]

6) *"Education"* refers to the development of understanding or knowledge of a subject, often at a theoretical level. In the context of this Strategy Paper, specialist topics such as meteorology and the use of on-board weather radar are required to be understood. *"Training"* refers to the practice of applying understanding or knowledge in real (or simulated) circumstances to develop proficiency in decision making and the taking of subsequent actions.

[1] EUOJ L62 of 8.3.2017

1 Executive summary

The Weather Information to Pilots project team has, over the last 18 months, carefully considered the meteorological phenomena that contribute to aviation incidents and accidents. The team has reviewed the existing means to mitigate against the effects of the weather, including the use of on-board weather radar, other on-board sensors, the information provided to pilots pre-flight, and the information that is available in-flight. The team has also considered the means available to provide that information to pilots, such as communication systems and the emerging availability of Electronic Flight Bag (EFB) solutions. The human/machine interface should also be considered in the 'holistic' solution(s).

This Strategy Paper, recognises that

- a range of meteorological information – observed and forecast – is already available at high spatial and temporal resolution, though is not always utilized.
- developments continue in the field of on-board weather radar and other on-board sensors.
- there are existing communications systems – sometimes utilising commercial infrastructure – that are available to Commercial Air Transport and could support the uplink and downlink of greater volumes of meteorological information.
- capabilities already exist to display meteorological information in intuitive, interactive ways and exploiting the use of colour and symbols for efficient assimilation of information

Ideally, the above elements can be employed to enhance the situational awareness of pilots, both in the pre-flight and in-flight phases. Accordingly, the project team presents 9 recommendations, listed in section 12.
Yet, there are challenges. New technology, new 'types' of meteorological information, and new 'ways' of displaying information should be implemented in a way that is consistent with safe and efficient practices. On the one hand innovation and early adoption should not be penalised, on the other there are investments in existing long term projects that are also anticipated to deliver improvements to the meteorological information available to pilots. Consideration of standardisation of colour schemes and symbol, consistent with the cockpit environment also needs to be taken into account.

To appropriately implement the recommendations above, a further body of work is anticipated through a series of related Actions. The actions are listed in Appendix A.

In certain cases, such as the revision of guidance for EFBs, actions have already commenced with outcomes expected in the next 6 months. In other cases, further activities expected to take 12, 24 or 36 months will lead to more 'directed' guidance and outcomes. In the latter case, it is intended to draw upon existing expertise from relevant groups, and to harmonise with other regulatory authorities and standardisation organisations. This approach is considered to be cost effective and time efficient.
The timescales are consistent with existing programmes of work such as ICAO Annex amendment cycles; the regular update and maintenance of EU regulations relating to aviation; and SESAR and NextGen development/deployment activities.

2 Introduction

Aircraft operations have always been influenced by the weather. Whilst modern aircraft design and the availability of weather observations and forecasts contribute to a predominantly very safe flying environment, there remain occasions where severe weather events have been identified as being a contributing factor in the causal chain of accidents and incidents. Such events remain of concern within the aviation community and corresponding safety recommendations have been addressed to EASA by investigating authorities.

Since 2015, the Agency has increased its focus on weather related challenges and, as part of that work, has sought to identify if the meteorological information available to pilots could be enhanced. Accordingly, EASA organised a first workshop dedicated to "Weather information provided to pilots"[2]. Following the workshop and the recognised need to take further action, the Agency integrated the 'Weather Information to Pilots' project within the 'All Weather Operations' activities[3]. The project team launched its work in April 2016. After an initial assessment of the situation, the Agency organised four technical meetings[4] involving representatives from international organisations, associations and industry[5].

This EASA Strategy Paper (the 'Strategy Paper') focuses on the weather phenomena that introduce risk to aviation, describes the current mitigation measures, the deficiencies and how to overcome them.

The recommendations proposed by the project are intended to improve the situational awareness of pilots through improved access to meteorological information during all phases of flight. They also take into account the considerable research and development activities that have been undertaken in the preceding decades to mitigate against the effects of severe weather phenomena. However the project identifies that further improvement to the situational awareness and decision making process of pilots should be implemented through the application of current technologies, and the development and deployment of new technologies in order to make the aviation system less vulnerable to weather events.

3 The WIP project

3.1 Scope and objective

The objective of the project is to propose means to maximise in-flight safety through enhanced meteorological situational awareness in the cockpit and, therefore, to reduce the risk of flying in severe weather conditions.

Whilst the scope extends to the take-off and landing phases of flight, the Strategy Paper does not consider the effects of weather on the aerodrome itself (i.e. airport infrastructure, ground movements, airside staff etc).

It should also be noted that the pilot is continuously assessing the weather through the human senses – particularly with regard to sight and the view through the cockpit windows. Even at night, the visual sense is

[2] This workshop, held in October 2015, was intended to assess the potential for aviation safety benefits that could result from providing enhanced weather information essentially to pilots in the cockpit. For more information: http://www.easa.europa.eu/newsroom-and-events/events/workshop-%E2%80%9Cweather-information-provided-pilots%E2%80%9D

[3] All Weather Operations (AWO), RMT.0379

[4] 18-19 October 2016, 13-14 December 2016, 7-8 June 2017, 14 September 2017

[5] The following organisation participated to the overall coordination and meetings: SESAR Joint Undertaking, EUROCONTROL, Meteorological and Satellite services providers, pilot's associations and Industry (Thales, Honeywell and Airbus).

important for assessing the weather situation. Whilst this document concentrates on technology, information, communication, and means of presentation; the pilot is continuously assessing the situation through their senses.

To reach this objective, the overall approach of the project is to enable:

Who	Flight crew members of European operators
What	to use timely, accurate, relevant and consistent meteorological information in an easy to access, easy to interpret format
How	provided during flight briefing and in-flight by modern airborne weather radars and uplinked weather information, underpinned with the necessary training to fully understand and interpret this information
For	for flight-planning and in-flight strategic and tactical decisions covering each phase of the flight
When	Actions proposed to commence 2018, with main deliverables by 2020.

3.2 An enabler for future weather activities

The project is not limited to the delivery of this Strategy Paper but is meant to be an enabler to contribute to further weather related activities initiated by the Agency. Therefore, this paper will be updated as necessary. In this first version, the Strategy Paper is structured into 14 sections and outlines why meteorological information is important for aviation safety, the objectives of the actions proposed and the way forward in the short and long term.

Currently, the scope of the strategy paper is limited to commercial air transport operations and non-commercial operations with complex motor-powered aircraft (NCC). In the future, the scope is expected to be extended to consider non-commercial operations with non-complex aircraft (NCO) as well as to helicopter operations.

4 Severe weather: a contributor to accidents and incidents

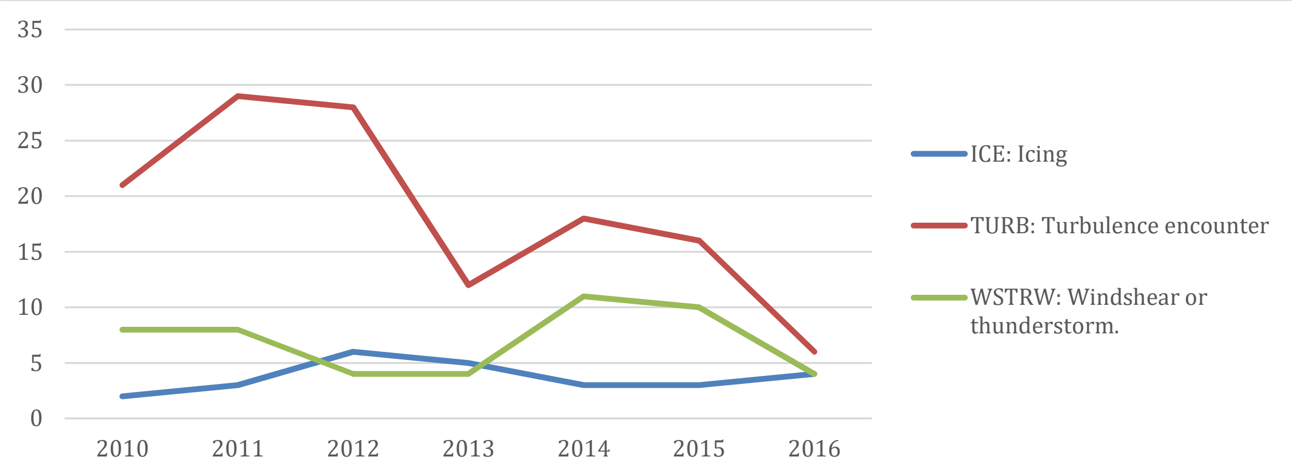
The International Air Transport Association (IATA), in its 2016 Safety Report[6], identifies weather as the first threat contributing to aircraft accidents.

- Adverse weather is present in 31% of the accidents in the 2012-2016 period and thunderstorms present in 8% of the accidents.
- In 57% of the accidents in the cruise phase of flight, weather was considered a contributing factor
- Weather is also a key contributor to loss of control in-flight (LOC-I) accidents over the last decade, with 36% of LOC-I accidents having occurred in degraded meteorological condition, in most of the cases involving thunderstorms and icing.
- Unnecessary penetration of adverse weather was a factor in 7% of the accidents in 2016.
- Poor weather conditions (present in 49% of the accidents) and airport facilities (37%) still represent the largest components for environmental factors, while errors in the manual handling of the aircraft were noted to have contributed to 48% of runway excursions.

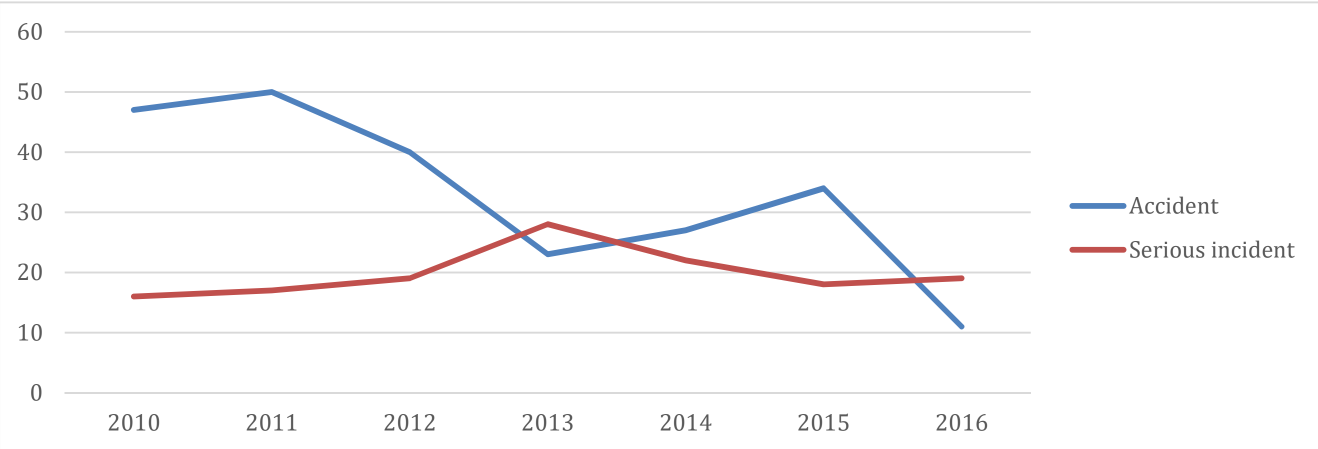
[6] IATA Safety Report 2016, issued April 2017 – 53rd edition. The IATA Safety Report is the flagship safety document produced by IATA since 1964. It provides the industry with critical information derived from the analysis of aviation accidents to understand safety risks in the industry and propose mitigation strategies.

The EASA accident/serious incident repository and the global accident/serious incident figures show a decreasing trend, and further enhancement to the pilot's situational awareness of the meteorological 'picture' can only contribute to the continuation of that trend.

The graph below shows the evolution of the global figures for those accidents/serious incidents related to the identified 3 major weather phenomena in the period 2010-2016. They follow the same decreasing trend.



The graph below shows the number of accidents and serious incidents related to weather events during the period 2010-2016.



Extracted from the EASA occurrence database, the table below provides a summary categorised by weather hazard and by class (fatal accident, non-fatal accident, serious incident and other incidents) in the period 2010-2016. The statistics relate to European operators operating worldwide.

	Period 2010-2016 – CAT Aeroplane MTOW>5700kg			
Hazard	**Fatal Accidents**	**Non-Fatal Accidents**	**Serious Incidents**	**Other Occurrences**
Clear air/Cloud induced turbulence	0	24	6	16
Lightning	0	0	1	25
Hail	0	2	2	2
Icing	2	2	9	17
Windshear	0	8	3	3

Volcanic ash	0	0	0	3
Bird strike	0	0	5	68
Sandstorm	0	0	0	0
Snow	0	2	4	4

Although the number of accidents and serious incidents in which weather was considered contributory has shown a decreasing trend over the last 5 years or so, this project is still considered to be highly relevant since:

- Any accident or serious incident that can be avoided, should be avoided;
- Increased capacity and more flexible routing requires enhanced situational awareness to maximise usage safely and efficiently;
- Several studies have indicated the likely increase in frequency and intensity of severe weather events[7]. The deliverables of this project will mitigate against any consequential increase in the number of accidents/serious incidents that might follow from such changes to the climate.

4.1 Meteorological information currently available to pilots

The process of providing meteorological information to pilots can be separated into two main phases. The pre-flight briefing phase, and the in-flight phase.
During the pre-flight phase, pilots are provided with meteorological information for the route they will fly including en-route and destination alternates. The minimum requirements relating to the meteorological information to be provided are set out in ICAO Annex 3 – *Meteorological Service for International Air Navigation*, and in *EU Implementing Regulation 2017/373 Annex V Part-MET*. This information is taken on-board in either paper or electronic flight bag (EFB) formats.

During the in-flight phase, the availability of updates to the original briefing material varies and is often limited. For example, updates via the Aircraft Communications Addressing and Reporting System (ACARS) or VOLMET broadcasts on the High Frequency (HF) radio are possible but are subject to limitations of availability, and of content and format. This is particularly relevant for longer-haul flights where updates to the meteorological information may render the original version obsolete, for example in fast developing convective situations.

It is also appropriate to classify the meteorological information available to the pilot as that information from external sources, and that information available from aircraft sensors. In the latter case, the aircraft's 'on-board weather radar' (WXR) is of particular importance to the pilot's situational awareness. Aircraft WXR are designed to produce radar information relevant to the aircraft. Pilots' base their routing decisions, in part, on the indications of the WXR radar as this is the most reliable source with almost zero latency. As Air Traffic Control (ATC) does not have access to the WXR picture at present, pilots coordinate their intended flight-path with ATC.

The WIP project notes that meteorological information relevant to pilots and the way this information is communicated and/or displayed for easy interpretation has advanced. Indeed, it is recognised that EFBs are in use today, and may include applications for the display of meteorological information. A coherent

[7] Studies such as the Intergovernmental Panel on Climate Change (http://ipcc.ch/report/ar5/wg2/), and EUROCONTROL's 'Challenges of Growth 2013' (http://www.eurocontrol.int/sites/default/files/article/content/documents/official-documents/reports/201303-challenges-of-growth-2013-task-8.pdf) and 2010 http://publish.eurocontrol.int/sites/default/files/content/documents/official-documents/facts-and-figures/statfor/challenges-of-growth-climate-adaptation-march-2010.pdf identify scenarios where the intensity, frequency and location of severe weather events are, on balance, expected to change based on anticipated future climatological changes. Whilst categorical predictions are not yet possible, on balance, there is an expectation with low to moderate confidence of an overall increasing frequency and intensity of severe weather events.

approach to how this is applied in a European context would serve to ensure a consistency within the network.

The project also notes the advancements in WXR technology.

5 The weather threats

This section describes the main weather threats for aviation.

5.1 Cumulonimbus Cloud (CB cloud)

Cumulonimbus Cloud (CB cloud), and often referred to as a thunderstorm cloud, is a convective cloud of significant vertical development. CB cloud is particularly important to aviation since it is associated with several phenomena hazardous to flight. Hazards associated with CB cloud are listed below, and any combination (or all) of the listed phenomena may be experienced in relation to a single CB cloud:

- Severe turbulence (convectively induced turbulence)
- Severe icing (super-cooled water icing conditions)
- High altitude ice crystals
- Low level wind shear (microburst)
- Hail
- Lightning
- Tornadoes, funnel clouds and waterspouts
- Reduced cloud base and visibility at the airport during thunderstorm/heavy shower events.

More details regarding the specific phenomena that may accompany the presence of CB cloud are given below. All pilots are taught the importance of CB cloud with regard to aviation, and the hazardous phenomena that may be present.

5.2 Turbulence

Turbulence is the leading[8] cause of in-flight injuries. Three meteorological phenomena generate turbulence:

- Convective Induced Turbulence (CIT) is due to thermally induced upward and downward moving air in and around convective cells;
- Clear Air Turbulence (CAT) is due to the horizontal or vertical shear effect between wind layers. CAT may generated in association with very strong, high altitude winds – jet streams; or in association with mountain waves;
- Orographic/low level turbulence is due to the disruption of the airflow close to the surface in the vicinity of obstacles (hills, mountains, significant structures).

Turbulence cannot normally be detected by the naked eye and may be encountered unexpectedly. Although forecasts of general areas of turbulence are quite good, forecasting precise locations is difficult. WXR cannot detect CAT whereas they can detect CIT.

It should be noted that a contributing factor to the number of in-flight injuries due to turbulence is that passengers and crew, particularly cabin crew carrying out their duties, may be moving around the cabin. Improvements to the availability of information to pilots regarding turbulence would assist in ensuring occupants were seated and wearing seatbelts.

[8] FAA Information for Operators (InFO)
https://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/info/all_infos/media/2011/InFO11001.pdf

5.3 Icing conditions

5.3.1 Super-cooled water icing conditions

Ice accretion on airframe cold surfaces occurs when the aircraft encounters super-cooled water droplets/drops. A super-cooled drop is a drop of liquid water with a temperature below the freezing point of water. This is an unstable state for water, and impact with a sub-zero airframe will result in the water turning to ice. Consequences of ice accretion may be diverse including:

- reduction of visibility
- damage due to ice shedding
- blockage of pitot tubes and static vents
- reduced flight performance
- adverse aero-dynamic effects
- increased weight

Super-cooled icing conditions can be detected by in-situ detection systems or WXR. Research is on-going to develop capability to discriminate and characterize the super-cooled icing conditions (small droplets vs. large drops).

5.3.2 High altitude ice crystals (HAIC)/Ice Crystal Icing (ICI)

Ice accretion on airframe hot surfaces (engines and heated sensors) may occur when the aircraft encounters high altitude ice crystals (HAIC) with high ice water concentrations. Such events are known as ice crystal icing (ICI) conditions. Parts of the aircraft susceptible to ice accretion under severe ICI conditions are engines and air data probes. ICI encounters have been connected to a number of jet engine power-loss and damage events in recent years.

A number of indicative factors have been identified that are associated with ICI (see paragraph 6.2.2) but it remains possible that the phenomenon may not be detected by the flight crew.

5.4 Low Level Wind Shear

Low-level wind shear represents a serious hazard for the operation of aeroplanes during the approach and departure phases. Low-level wind shear incidents are compounded by the fact that pilots may have less time to handle abnormal situations and recover the aircraft from sudden loss/gain of lift.

Low-level wind shear is often associated with convective activity, and in particular when convective downdraughts spread out horizontally after striking the ground. Such occurrences are known as microbursts. Low-level wind shear may also occur when strong temperature inversions exist near the surface. The wind direction and speed above and below the inversion may be very different, resulting in wind shear.

5.5 Hail

Depending upon the size of the hailstones, encounters with hail may result in damage to aircraft structures (e.g. radome, windshields, etc.). Formed within deep convection, hail may be encountered at all levels up to and including cruise altitudes - especially in severe thunderstorms.

5.6 Lightning

A lightning[9] strike, which is an atmospheric discharge of electricity, encompassed in thunderstorm cells, can be very distressing to passengers and crew. Aircraft damage is usually confined to aerials, compasses, avionics, and the burning of small holes in the fuselage. Nearby lightning can blind the flight crew rendering them momentarily unable to navigate either by instrument or by visual reference. Lightning discharges may disrupt radio communications on low and medium frequencies and damage electronic navigational equipment. Commercial planes are hit about once a year[10], and most events occur during the climb or descent and when the plane is flying in a cloud.

Lightning strikes may also impart an unknown amount of electromagnetic radiation on electronics and humans on board the aircraft. The flight crew does not have an indication of the status and movement of CB cloud in the vicinity of an airport. Lightning strikes on the ground can lead to airplane damage and injury to personnel.

5.7 Volcanic Ash

Volcanic ash clouds, and in particular those with high concentrations of volcanic ash, can adversely impact the continued airworthiness of aircraft. Several severe incidents have occurred in recent decades that resulted in temporary multiple engine failures to commercial airliners. In each of those cases the crew were able to restart a sufficient number of engines to permit safe landings, and to date there has been no aircraft loss or fatality attributed to flight in volcanic ash clouds. A database of 83 encounters between aircraft and ash clouds, provided by the United States Geological Survey, is referenced in ICAO Doc 9691 – *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds* (Appendix F). This information was updated in 2010 by the United States Geological Survey's (USGS) "List of aircraft encounters with volcanic ash clouds: A Compilation of Known Incidents, 1953–2009"[11].

With the eruption of the Eyjafjallajökull volcano in Iceland in April 2010 the aviation community was confronted with an unexpected and unprecedented disruption of the aviation transport system in Europe. To manage this extremely significant event volcanic ash concentration charts were introduced, and these are now a component of the *Volcanic Ash Contingency Plan – European and North Atlantic Regions* (EUR Doc 019/NAT Doc 006, Part II). Currently, there is no certified on-board technology available to alert the crew to the presence of volcanic ash around or ahead of the aircraft. Secondary clues, e.g. St. Elmo's fire, dust coming into the cockpit, and engines operating abnormally may alert the crew to the presence of volcanic ash.

5.8 Tornadoes, Funnel Clouds and Waterspouts

Tornadoes are associated with the most violent CB clouds. A tornado is an extremely concentrated vortex that extends from the base of the CB cloud to the surface. Meteorologists have estimated that wind in such vortices can exceed 260 kts. An aircraft entering a tornado is almost certain to suffer loss of control and structural damage due not only to the shear forces, but also from debris picked up from the ground. In-flight encounters between aircraft and tornadoes are rare, however fatal accidents have been recorded[12].

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[9] Lightning occurs as a result of a build-up of static charges within a Cumulonimbus cloud, often associated with the vertical movement and collision of ice particles (Hail), which result in a negative charge at the base of the cloud and a positive charge at the top of the cloud. Beneath the cloud, a "shadow" positive charge is created on the ground and, as the charge builds, eventually a circuit is created and discharges takes place between the cloud and the ground, or between the cloud and another cloud. An aircraft passing close to an area of charge can initiate a discharge and this may occur some distance from a Thunderstorm.

[10] Source: European Central Repository (ECR).

[11] Guffanti, Marianne, Casadevall, T.J., and Budding, Karin, 2010, Encounters of aircraft with volcanic ash clouds; A compilation of known incidents, 1953–2009: U.S. Geological Survey Data Series 545, ver. 1.0, 12 p., plus 4 appendixes including the compilation database [https://pubs.usgs.gov/ds/545/]

[12] On 6 October 1981, a Fokker F-28-4000 operated by KLM Cityhopper on a passenger flight from Rotterdam to Eindhoven in the Netherlands was destroyed due to a tornado encounter. The aircraft had encountered sudden vertical acceleration reaching 6g which had resulted in one wing being detached from the aircraft and consequent terminal loss of control.

5.9 Low cloud and reduced visibility in thunderstorms and heavy showers

The nature of thunderstorms and heavy showers, and their associated CB cloud formations, can result in rapid and marked deteriorations of cloud base and visibility. Low cloud base and reduced visibility, may develop very quickly. Even if the most severe of the effects may be over limited geographical areas, the relevance of low cloud and reduced visibility is significant when at, or in the vicinity, of the aerodrome.

6 Current mitigations measures

This section describes the existing sources of weather information that may be available to the pilots and contribute to the mitigation of the weather threats.

Circumnavigating areas where hazardous weather phenomena are present is the main mitigation to the safety risks they present. To support their decisions, pilots have to build a mental representation of weather phenomena based on information from the WXR, meteorological information gathered or provided during pre-flight briefing, visual observation from the flight deck, including instrument displays, in-flight updates as available, and local weather information provided by Air Traffic Services (ATS).

6.1 Pre-flight meteorological information

Pre-flight briefing ensures that relevant meteorological information, available at the time of the briefing, is provided to the pilot prior to departure. The briefing package contains specific meteorological information to be provided by meteorological services providers in accordance with MET.OR.240[13] of Part-MET[14]. Appendix B specifies the list of meteorological elements to be provided. Meteorological information required to be on board is expressed in Air Ops CAT.GEN.MPA.180.[15]. In light of emerging technology with regard to EFBs it is proposed to review both implementing regulations.

In addition to the ICAO regulated information, the Volcanic Ash Advisory Centres London and Toulouse issue supplementary volcanic ash concentration charts for consideration during flight planning. Also, real time satellite imagery of ash, such as the ´annotated satellite imagery´ provided by VAAC London, is not part of the normal briefing package.

6.2 In-flight meteorological information

During the flight, pilots, in addition to the human senses, particularly sight, can receive meteorological information through three different means:

1. On-board weather radar (WXR)
2. Other weather detection equipment
3. Weather updates communications

6.2.1 On-board weather radar

On-board weather radars (WXR) are the primary source of information available to the pilot relating to precipitation, and by inference areas of convective activity such as CB cloud, ahead of the aircraft. They scan ahead and, from reflected radar returns, provide pilots with a real-time view of the intensity and rate of precipitation ahead of the aircraft to support tactical decisions. They are of particular benefit with regard to

[13] MET.OR.240 includes: WAFS upper air wind/temperature forecasts, WAFS SIGWX, METAR or SPECI, TREND, TAF, SIGMET and special air-reports, volcanic ash and tropical cyclone advisory information, aerodrome warnings, meteorological satellite images, ground-based weather radar information. For more specific information, please see Appendix B of this document.

[14] Annex V of Regulation (EU) No 2017/373 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight, repealing Regulation (EC) No 482/2008, Implementing Regulations (EU) No 1034/2011, (EU) No 1035/2011 and (EU) 2016/1377 and amending Regulation (EU) No 677/2011

[15] Commission Regulation (EU) No 965/2012 on Air operations.

identifying areas of deep convection, and – as noted below – can identify wind shear in certain situations. WXR technology is continuously being improved to better detect precipitation in its liquid and solid states, and additional capabilities have been developed such as the inference of hail, and lightning areas.

With regard to hail, it should be noted that depending on the characteristics of the hailstones and on the presence of liquid water, WXR returns may be very different. In such instances, a good analysis of the environment is needed to ensure avoidance of these conditions.

WXR provides the pilot with a 'weather picture' in the cockpit permitting identification and avoidance of specific, undesirable 'weather' formations. Common ranges selected by pilots are from 30Nm to 80Nm but the maximum range of detection is up to 320Nm with the latest generation of WXR. The precise functionality is dependent on the aircraft radar set and the situation of the aircraft. WXR is complemented with meteorological reports and forecasts provided during the pre-flight briefing (e.g. SIGMET or SIGWX) or updated in-flight (VOLMET, ATIS, ACARS).
Some WXR systems include predictive wind shear (PWS) capability. PWS provides an early indication of the presence of wind shear ahead of the aircraft though is currently limited to the take-off and landing phases of flight. PWS systems are installed in many, but not all, of the large aeroplanes in service today.

6.2.2 Other weather detection equipment

Some aircraft have equipment permitting the detection of other hazardous weather conditions. Over the years, a wide variety of weather detection systems have been developed, and some examples are listed below:

Icing: systems are available to detect icing conditions in-flight and provide the crew with the related ice indication or automatically activate de/anti-icing systems whenever the aircraft is flying in icing conditions. Ice protection systems are used to protect aircraft surfaces from ice accumulation in flight or on the ground[16]. With regard to as ice crystal icing (ICI) conditions, new icing detectors able to detect ice crystals are under development as part of research activities. Even if ice crystals themselves are not detected by current weather radars, the convective weather systems which generate severe concentrations of HAIC are identified by WXR. Therefore, current WXR systems remain a significant and useful means for the detection and avoidance of the conditions associated with ICI. Moreover, a number of indicative factors are reported by pilots during encounters with ICI. These are usually associated with visible moisture, and can include one or more of the following:

- Appearance of rain on the windshield at temperatures too low for rain to exist. This 'rain' is usually associated with a "shhhh" noise;
- Small deposits of ice particles on wipers;
- Smell of ozone;
- St Elmo's fire;
- Aircraft Total Air Temperature indication that remains near 0 °C;
- Light to moderate turbulence in Instrument Meteorological Conditions.

Wind shear[17]: reactive wind shear systems (RWS) use algorithms that rely on actual air-data measurements from sensors on the aircraft to detect the presence of wind shear when the aircraft is very close to or in the phenomena. In addition, some airports have ground based wind shear detection warning systems which will alert ATS (for passing to the pilot) of its occurrence on approach and departure.

[16] De-icing systems remove ice from the contaminated surface and are activated after icing conditions have been encountered, while anti-icing systems provide a protection from icing, and are usually activated just before or immediately after entering icing conditions.
[17] Prediction of wind shear for aeroplanes performing commercial air transport operations is addressed by NPA 2016-18 (https://www.easa.europa.eu/system/files/dfu/NPA%202016-18.pdf)

Lightning Sensor Systems: lightning sensor systems help identify areas of lightning. The sensor detects electromagnetic discharges resulting from lightning activity. Some of the severest turbulence occurs during the growth stage of a CB cloud before WXR returns intensify. A Lightning sensor system can therefore complement the on-board weather radar. The system is designed to detect electrical discharge activity that the on-board weather radar cannot see.

6.2.3 Weather updates communications

The basic communication method used by pilots to receive weather information in-flight is voice. The pilots receive meteorological information directly through the communication broadcasts, such as VOLMET[18] or ATIS. VOLMET and ATIS are services that require the flight crew listening to the transmissions, and writing the information on paper. They may be received via data-link (D-VOLMET / D-ATIS).

Meteorological information may also be made available within the cockpit in-flight via ACARS. The flight dispatch or Flight Operations Centre (FOC)[19] ACARS applications can also transmit some limited data about the expected meteorological conditions. ACARS character-based messages are transmitted primarily via VHF radio signals, or sometimes via satellite communication depending on the operator's policy.

Special air-reports[20] are essential sources of weather information as pilots report the encountered weather conditions experienced in near real-time via voice to the Air Traffic Control (ATC) and in some cases via ACARS to the FOC.

7 Areas for improving meteorological information in the cockpit

Pilots, who have the ultimate responsibility of the operations and the safety of the passengers and crew, sometimes consider that they are not always provided with the most relevant up-to-date weather information[21] from the time they prepare for the flight until they land at the destination. In some instances this may be due to the limitations of the available meteorological information (observations and forecasts) at the pre-flight stage, but also of the awareness of all actors involved in the provision and/or management of meteorological information in-flight, and of course the variability of communications capability. The latter may reflect limitations in aircraft equipage and/or ground and satellite based communication systems.

WXR, as an aircraft system, is not of itself dependent upon external sources. However, analysis of accidents and incidents[22] has shown that in many cases pilots did not operate the radar correctly. The information was available, but improper use of the system and/or not understanding system limitations compromised the overall situational awareness.

It is also appropriate to consider ICAO's own reference to the display of Meteorological Information in the Cockpit, as outlined in Appendix 9 of ICAO Doc 8896 – *Manual of Aeronautical Meteorological Practice*.

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[18] VOLMET provides pilots with information on the weather conditions (only METAR, TAF & SIGMET) at the surrounding main airports of their destination. The purpose is to allow the pilot to decide in time on deviating the aircraft to an adjacent airport in case of unexpected bad weather conditions at the destination airport. ATIS provides local weather reports for the airport concerned.

[19] FOC used within SESAR, may also be referred to as Airline Operations Centre (AOC), or Operations Control Centre (OCC)

[20] Special air-reports are reports of meteorological, and other phenomena, as specified in ICAO Document 4444 Procedures for Air Navigation Services (PANS-4444), Chapter 4, 4.12.3 and Appendix 1 of same.

[21] Khatwa R. An Analysis of the Operation and Interpretation of Weather Radar by Flight Crews, Flight Safety Foundation International Air Safety Seminar, Seoul, Korea, October 2007

[22] Honeywell reference with detailed analysis: Khatwa R. An Analysis of the Operation and Interpretation of Weather Radar by Flight Crews, Flight Safety Foundation International Air Safety Seminar, Seoul, Korea, October 2007).

In section 2.3 of Appendix 9 to Doc 8896, it is noted that apart from the standard products specified in ICAO Annex 3, the following products are useful for enhancing situational awareness in the cockpit, and could be provided subject to agreement with the operator concerned;

- wind profile derived from automatic downlink meteorological data;
- weather radar images;
- satellite images;
- lightning location display;
- short term forecasts (nowcasts);
- terminal movement area weather products for “tailored approaches”; and
- three dimensional (3D) displays (e.g. radar and volcanic ash).

Whilst it may not be feasible to provide all of the above in the near future, it does provide an overview of a range of products/services that would assist situational awareness. In any event, and as noted in ICAO Annex 3, certain data types (such as satellite imagery) do require specialist knowledge and so the provision of such information should be supported by a combination of documentation, training and appropriate ‘visualisation’ of the data.

It should be noted that there are, already, EFBs with applications to display meteorological information.

7.1 Weather information for flight planning

Today, meteorological information for flight planning is based on the most up-to-date information available at the time of the briefing. However, in some cases, this information may have long intervals between update and distribution compared to the evolution of the phenomena. Forecasts of severe hazards such as thunderstorms, turbulence or icing, may be outdated after several hours of flight, and may provide only a rough estimate of the phenomenon.

Indeed, the meteorological information available at the original briefing might be superseded by previously unexpected or revised developments (e.g. areas of CAT that had not been predicted in the planning phase). Synoptic charts and satellite images may be provided in the pre-flight documentation but, especially for long-haul flights, this information may be outdated and using it for adopting a decision could lead to errors or to taking excessively inefficient deviations.

Additionally, meteorological information is often presented in black and white with a fixed pre-defined format. This may have been an appropriate standard in past years, but today, it is feasible to use data formats that enable meteorological information to be presented in more dynamic and intuitive ways through the use of colour and appropriate overlays with other information.

7.2 On-board weather radar

The ability of WXR to detect weather phenomena is limited in both direction and range. Additionally, WXR can only detect precipitation and certain hazards associated with precipitation. The efficiency of detection depends upon the size, composition, phase (liquid/solid) and concentration of the droplets (water) or particles (ice). For aircraft equipped with WXR, pilots should be familiar with the operating techniques (settings and display analysis) and limitations of the specific system.

When flying in regions affected by convective weather, pilots use the information provided by the WXR - as well as their experience - to safely navigate the aircraft to avoid the most active areas of turbulence, hail, icing and lightning that may compromise the safety of the flight. Finding the optimum route to traverse large areas of convective activity can be difficult due to the limitations of on-board weather radars, especially when using the traditional ones.

There are many different generations of WXR in use today. Of these, older systems are limited in their performance and/or require appropriate training to properly use (e.g. manual selection of tilt and gain). Heavy precipitation may also conceal weather behind a cell depicted on the radar display (attenuation) and the image does not always provide the pilot with the information needed to safely navigate the aircraft through large areas of convective activity. For example, the radar display may show gaps in the first line of convective cells, but due to the attenuation of the radar signal, the returns do not always provide a full image of the situation behind the strongest cells.

Even if more and more operators equip their aircraft with automatic WXR, due to the radar technology, some limitations will still exist: weather radars are not able to detect ‘dry’ phenomena such as CAT or volcanic ash.

7.3 Weather detection equipment

Ice detection sensors in airplanes have a long history of reliable operation. The more recently recognised phenomenon of ´Ice Crystal Icing´ (ICI) is, however, not detectable by presently installed equipment. Systems that actually detect and identify ice crystals are being developed, however, they provide no look-ahead capability.

Some older aeroplane types not equipped with PWS Weather Radar function may only be equipped with reactive wind shear system (RWS). Although this should provide an alert to the flight crew, it may come too late as the aeroplane is already experiencing the effects of the wind shear. PWS is only available during the landing and take-off phases, and is dependent upon precipitation for identification of wind-shear through Doppler effects.

Most commercial aircraft have basic capability to measure (or derive) routine weather parameters such as wind speed, wind direction and temperature and this can be relayed to the ground either via ACARS or through Mode-S interrogation (along with aircraft position and time). In addition, a few European based aircraft are equipped with bespoke and more accurate dedicated MET sensors for recording these parameter; and fewer still have the added capability of measuring humidity. The primary purpose of these observations is to improve the quality of weather forecasts.

7.4 Meteorological information updates

When using voice communications, updates to meteorological information is one-way communication. The pilots can only listen to the communication. METAR/TAF information related to the airport are also available to the flight crew through VOLMET or included in the ATIS.

Through ACARS, operators arrange for the information to be made available on demand, or via a push-service for SIGMET, for example. Meteorological information in alphanumeric form (e.g. SIGMET) can be provided via ACARS, however, the geographical coverage is not global. The streaming of high volumes of information through ACARS is challenging because of the limited bandwidth/performances and costs. Many operators are dealing with connection speeds that are – by modern standards - very limiting. VHF connections providing up to 31, 5 Kbps or legacy SATCOM with 3 to 4 Kbps are typical. It should be noted that ACARS is not mandatory on an aircraft, although increasing numbers of operators are implementing ACARS on their aircraft.

Recent and evolving data link technologies could be used to uplink more meteorological information to the cockpit than is currently possible via ACARS. However, these technologies are not widely implemented in Europe[23].

Some operators use Internet Protocol (IP) satellite communications that have near-global coverage mainly to support both cockpit, cabin and passenger applications. The greater bandwidth available via this technology would facilitate the transmission of meteorological information to the cockpit. Such information need not be limited to updates of existing data, and would permit the more elaborate meteorological information to be transmitted. Currently, only a few operators are understood to have implemented such connectivity for flight crew operations.

7.5 Meteorological information provision

Currently, according to Part-MET, certified meteorological services providers provide regulated meteorological information as specified for pre-flight briefing. The provision of these meteorological information services could be cost recovered and are therefore free at point of use by any aviation stakeholder. Outside this regulatory context, additional meteorological information can be provided on a commercial basis and this is a business decision of the operator. It is necessary to recognise that these non-regulated services can also provide relevant meteorological information, and that these providers should adhere to a minimum set of requirements. It is important to ensure that meteorological information delivered by these service providers match the quality requirements of end-users for use in flight operations, and that information is consistently available to all stakeholders (in the cockpit and on the ground).

7.6 Pilot education and training relating to meteorology

Interpretation of meteorological information requires specific education relating to weather phenomena and an appropriate level of initial and recurrent training.

With regard to the use of WXR, the emphasis in training should be on flight in convective situations. Pilots may not always be aware of the limitations of the aircraft radar and may not know how to properly set the appropriate radar due to insufficient training and/or knowledge of the meteorological phenomena. Radar image colours indicate a reflectivity level but not a hazard level. Adequate knowledge/skills and training are needed in order to know how the WXR works and its limitations, such as proper tilt management techniques being an example. The WXR radar, if not correctly used or interpreted, may mislead the flight crew:

- when an area of strong activity is hidden behind heavy rain
- to determine if an elected trajectory between clouds is blocked by adverse weather further ahead or
- if the antenna tilt is not correctly adjusted.

Using a WXR in manual mode, pilots must select adequate tilt and gain settings to obtain the relevant information. If the tilt is too low, ground echo may be displayed on the radar image and make interpretation difficult. On the contrary, high tilt settings may induce the risk of not detecting CB cloud in front of the aircraft. Tilt setting has to be tuned according to the flight phase and the topology of the terrain.

Specific education and sufficient training will also be required to correctly interpret and use any new meteorological information used in the cockpit, such as satellite imagery, or high resolution ‘nowcasts’.

[23] An example is the Automatic Dependent Surveillance-Broadcast (ADS-B). If it is purposed to transmit information to ADS-B receivers (on ground and in flight), the transmission of weather information on 1090ES (major aviation users) is not foreseen yet (for bandwidth capacity reasons).

8 Approach to improve weather awareness in the cockpit

The approach of the Agency to improve the awareness of the meteorological situation in the cockpit covers the following areas for which the Agency proposes specific recommendations in Section 12.

This section details the Agency's approach with regard to basic meteorological information, WXR and related pilot training, pre-flight and in-flight meteorological information, the accessibility (through EFBs) of the information, connectivity to facilitate access to updates of the information, and the source of meteorological information.

8.1 Pilot training for on-board weather radars and basic weather training for pilots

Based on safety investigation reports that identified some shortfall in the area of pilot training on the use of WXR[24], the Agency proposes requirements to enhance pilot training in this regard. The effective use of the WXR requires a good knowledge of the structure of cumulonimbus cloud and its associated phenomena combined with an understanding of the operating principle of radar as well as its limitations. Pilots should actively monitor and constantly interpret the images displayed and understand that appropriate management of tilt and gain is essential in order to fully estimate and assess the vertical development of cumulonimbus clouds. Incorrect adjustment can lead to non-detection of such developments. The Agency proposes that:

- Operators should provide formal initial and recurrent weather radar training.
- Operators should ensure that the Aircraft Operations Manual provides a clear description of the recommended techniques for operating the WXR for weather avoidance

Enhanced training is expected to be provided for pilots using all types of WXR even if automatic features in the most recent generation of models will facilitate the pilots' task in the tilt and range manipulation. The limitations of the systems should always be clearly highlighted and understood.

8.1.1 On-board weather radars

Because the latest generation of WXR already enhance the detection of precipitation (especially with regard to convection and its associated hazards) at a longer range and more accurately, the Agency proposes to promote the installation of such WXR. This may support the pilots' task to identify and avoid adverse weather in a tactical manner[25].

The following available advanced functionalities with regard to performance and reliability are:

- convective hazards prediction (hail, lightning);
- predictive wind shear;
- enhanced turbulence detection;
- extended range for reflectivity (e.g. up to 320 NM);
- ground clutter reduction;
- radar attenuation depiction.

It should be noted that other new WXR features also enhance the pilots' situational awareness and should be promoted:

- vertical Situation Display with weather (along-track, selected azimuth or along unwound Flight Management System (FMS) flight plan)

[24] Khatwa R. An Analysis of the Operation and Interpretation of Weather Radar by Flight Crews, Flight Safety Foundation International Air Safety Seminar, Seoul, Korea, October 2007

[25] Although the most recent generations of WXR systems include algorithms correcting/reducing the effect of the Earth's curvature, it is acknowledged that intrinsic limitations such as the curvature of the Earth and cloud masking issues will remain. WXR will, for the foreseeable future, l be limited in range for the support of short term pilot decisions, but not a strategic view.

- automatic tilt and automatic scan features
- Earth curvature corrections;
- independent left side / right side range settings.

Generally speaking, any feature/ functionality providing more accurate or additional pertinent weather information which can enhance the crew awareness of the weather ahead of the aircraft should be promoted. In the meantime, it is expected that increasing numbers of aircraft (new orders as well as retrofit of existing fleets) will be equipped with the latest generation of WXR as technology progresses.

8.2 Graphical representation of meteorological information

It is considered that the pilot's workload would be reduced if the information provided led directly to decisions rather than requiring interpretation and inference to make decisions. However, the processes employed (filters/colours/symbols) to derive decision support information should allow the pilot access to the underpinning meteorological information – i.e. an aerodrome may be highlighted 'red' to indicate that one or more thresholds have been exceeded, but the pilot should be able to interrogate to determine the reason for the 'red' highlight,

The Agency recommends that meteorological information should be provided, at the pre-flight briefing and in-flight updates, in a format that facilitates the:

- Display the information graphically, and in an intuitive manner
- Display of the information using appropriate colour schemes to identify, for example the severity/intensity of phenomenon
- Overlay of the information with other meteorological and/or non-meteorological information (such as the aircraft's route)
- Display information relating to validity of forecasts and the time of observations (including remotely sensed observations)
- Accessing of clear legends describing the meaning of symbols/colours/abbreviations

8.3 Meteorological information below FL 100

Currently, the provision of low-level charts for SIGWX are not required to be made available to pilots of commercial air transport operations. Under current ICAO Annex 3 requirements, the provision of a graphical low level area forecast (or low level SIGWX) is a State decision and responsibility. Under Part-MET, it is similarly a State decision and responsibility. There is no requirement to distribute low-level charts for SIGWX internationally[26]. Whilst recognising the potential utility of these products, they are not of themselves directly targeted at commercial air transport and there are a number of issues with regard to consistency of information provided, and the manner in which that data is made available.

It is also noted that work is underway (SESAR Deployment Manager (DM) with regard to the provision of pan-European high resolution data for hazardous phenomena (CAT, icing, CB cloud, winter weather), and this may be a more appropriate approach to shared situational awareness (pilot, ATS, NM) in contrast to the use of multiple sources of data in different styles and using 'static' image formats.

As noted in the 'Further considerations' section, the eGAFOR project aims to address the issues of fragmentation and inconsistency of MET products as support for low-level SIGWX. When successfully implemented, it will provide uniform information on meteorological conditions along the flight route across 8 neighbouring EU and non-EU member States. The project shall be completed by December 2020 and

[26] Note, a trial of the provision of low level area forecasts in graphical format is currently being undertaken on the Secure Aviation Data Information Service (SADIS). This will report to the ICAO EUR METG/27 meeting (September 2017), and to the Meteorological Panel's Working Group - Meteorological Operations Group (WG-MOG) provisionally in April/May 2018.

supports essential operational changes identified in the European ATM Master Plan. It also falls into the priority area of SESAR "other projects" (deployment of ATM functionalities defined in the European ATM Master Plan) in the Connecting Europe Facility (CEF) Work Programme.

Accordingly, for the development of such requirement, the WIP will continue to monitor such developments and coordinate with the MET providers.

8.4 Access to in-flight updates to meteorological information on EFBs

Acknowledging the very fast development of EFB applications and the fact that many airlines have equipped their pilots with EFBs, the Agency proposes to promote and facilitate the access to in-flight meteorological information, including in-flight updates, on EFBs and recommends operators to take advantage of these technologies to bring up-to-date meteorological information to the cockpit. The Agency considers essential that the display capabilities of modern EFBs are utilized to their best, for example through the use of colour and standard symbols for better visualization and interpretation of meteorological information.

This recommendation supports the current EASA proposed regulatory framework on EFBs[27], which also provides benefits with regard to the provision of meteorological information to pilots. The WIP project will make use of this regulatory framework to continue improving existing requirements or means of compliance and introduce safety promotion when needed.

The Agency will encourage the use of newest technologies through safety promotion leaflets, briefings, information sessions, etc. The project will continue contributing to the current EASA activity on EFBs and more generally to any task related to EFBs within the Agency and other organisations, e.g. EUROCAE working group dealing with EFB applications (WG106 for EFB applications).

8.5 Connectivity solutions supporting uplink meteorological information

The Agency encourages the aviation community to expand the use of live uplink into the cockpit to facilitate the update of meteorological information. Uplink solutions should be quickly deployable since mature solutions do exist today. Although it is expected that increasing numbers of aircraft will be equipped with broadband SATCOM and in-flight Wi-Fi connectivity solutions, such solutions should still be promoted for the benefits they can bring to the cockpit.

The in-flight weather (IFW) proposed provisions in NPA 2016-12 do not preclude the use of any particular connectivity means provided that operators ensure compliance of their own solution to the applicable data connectivity and security provisions.

8.6 Provision of Meteorological information

The availability of weather applications from multiple sources and from a range of providers means that pilots and those operating in the aviation environment have 'easy' access to a vast amount of meteorological information. However, not all of that information is suitable for, nor intended to be used by the aviation community.

As such, three 'tiers' of meteorological information are proposed for consideration as a suitable framework for the formulation of proportionate oversight for the provision of such information.

The 'tier' approach can be considered as different classifications of meteorological information. The highest tier of information is that required essential for safe and efficient flight, and is only to be provided by certified

[27] Notice of Proposed Amendment 2016-12. This NPA addresses the transposition of the ICAO Annex 6 provisions on electronic flight bags (EFBs), applicable since November 2014, into Regulation (EU) No 965/2012 (the Air Operations Regulation).

providers. The second tier recognises that additional meteorological information is available, and that – with yet to be determined – the application of appropriate standards, can supplement and assist with regard to situational awareness. The lowest, third tier, identifies that certain information is not appropriate for aviation purposes.

Tier 1:

At the highest level, international air navigation is overseen by ICAO globally, and by EASA within Europe. Standards and Recommended Practices (ICAO) and Implementing Regulations supported by Acceptable Means of Compliance and Guidance Material (Europe) are in place to ensure that for specific data that is considered to be of fundamental importance to the safety of aircraft, the data and the providers of that data meet minimum operational standards. There is no intention to change those requirements.

For example, products and services explicitly referred to in ICAO Annex 3 and/or EASA Part-MET such as METAR, TAF, SIGMET, WAFS, VAA are regulated.

The providers of such information will be certified meteorological information services providers and will be required to meet the necessary oversight and certification requirements as specified by ICAO Annex 3 and/or EASA Part-MET.

Tier 2:

There is also a set of meteorological information that is mature and – with appropriate underpinning quality management and training on its use - is seen as being beneficial to pilot situational awareness through an appropriate uplink to EFBs:
For example, the provision of supplementary meteorological information such as meteorological satellite data, ground-based radar data etc.

The providers of such information would be expected to meet the necessary oversight and approval requirements (mechanism to be defined) with, for example:

- Organisational culture
- Organisational robustness
- User manuals/instructions
- Underpinning training with regard to the information
- Underpinning research

The above elements may be incorporated into an operator's own safety risk assessment process, as currently proposed with regard to the addition of GM to the AMCs on the use of EFB and in-flight weather applications (SPA.EFB.100 and NCC.GEN.131) with regard to 'reliable sources'.

In such cases, access to Tier 1 information should always be assured in the event of non-availability of Tier 2 information.

Tier 3:

The third tier of meteorological information would be that for which there is no intention for it to be used for aviation purposes and/or there is insufficient quality management/training material. For example, weather application for tourism purposes; weather data with no auditable/assignable authenticity/source etc.)

Whilst recognising that such applications/information may be perfectly suitable for their target audience/customer base, such applications/information are not deemed to be appropriate for flight related purposes.

9 Benefits

The primary outcome of the project will be to ensure that, with current and emerging technology, meteorological information is available to the pilot in order to enhance situational awareness and this in turn can only increase safety.

The outcomes of the project will bring additional benefits to pilots, crew operators and ultimately the passenger during all phases of flight through greater efficiencies as a consequence of enhanced, relevant meteorological information updated more frequently. All the recommendations stemming from this project will facilitate uninterrupted access to meteorological information and consistent use of the information, from pre-flight planning until the completion of the flight.

9.1 Improved weather information

The project intends to facilitate access for pilots to have the right information at the right time through continuous access to meteorological information. If pilots know sooner about problems ahead (thunderstorm cells, airports expected to be below minimums, etc.), they can plan appropriate strategic avoidance to avoid potential safety issues.

The idea is to facilitate operators' choice to have enhanced meteorological information supporting their flight operations.

This enhancement will be facilitated by meteorological service providers using observation downlinked from the aircraft (i.e. using the aircraft as a sensor). The key features of this process are

- integrating the observations (wind speed, direction and humidity) into the initialisation field of numerical weather prediction models (i.e. global models, regional models, mesoscale models, nowcasts, high resolution etc.), and
- use the observations in the verification of forecasts, to constantly improve and enhance the quality of the forecasts at altitude. The addition of humidity observations also provides added detail on cloud and icing, thereby maximising forecast accuracy of these parameters.
- it is also possible to downlink data from the on-board weather radar for integration into ground based weather radar, to generate a more comprehensive overview of adverse weather along a trajectory.

9.2 Improved tactical decisions by using on-board weather radar latest technologies

By encouraging operators to install the most recent WXR, including turbulence and wind shear warning functions, in their aircraft, the Agency wants to ensure that the decisions of pilots, at a tactical level, is based on reliable information from the best equipment for detecting and indicating to the crew where dangerous weather conditions are possible. The latest generation of such weather radar is also able to infer weather phenomena such as lightning and hail, and notify pilots of the areas where the radar signal is attenuated. Other features are also available such as display of convective areas, and identification of 2 levels of turbulence (moderate and severe). In addition the data can be corrected for Earth curvature effects. Pilots are also able to view weather on a Vertical Situation Display (VSD). These features enhance the pilot's situational awareness.

9.3 Improved access to weather information by uplink

By promoting the use of best technological solutions to bring meteorological information to the cockpit, the project sees benefits for pilots and operators. Long-haul flights are anticipated to benefit in particular since the weather can evolve significantly between departure and arrival. The added-value of promoting connectivity on-board is multi-fold:

- Obtain meteorological information relating to phenomena that cannot be detected by on-board systems (outside the range of, or not detectable by, the on-board weather radar) and/or to be used in conjunction with the on-board detections systems;
- Update meteorological observations and forecasts;
- Facilitate the depiction of meteorological information in graphical formats using intuitive symbols and colours to assist in the assimilation of information;
- Facilitate the overlay of meteorological information with other data relevant to the flight;
- Opportunity to implement added value functions using uplink weather data and flight planning;
- Continue encouraging affordable communication costs (IP).

This global connectivity benefits the flight crew. Beyond the automatic reporting that some aircraft employ to collect and transfer flight data, the global connectivity provides large scale of communications plus access to text and graphic weather information, including Doppler digital radar images beyond the range of on-board weather radar.

The EFBs' in-flight weather applications will enable the update of near real-time meteorological information based on data from satellite or ground stations and to provide the pilots with a more precise and up to date image of the environment in which they are operating.

9.4 Improved integration with EFB functions

The promotion by the Agency of advanced uplinked meteorological information, including data from meteorological satellites, is expected to improve decision making in the strategic and tactical time frame.

EFBs reduce, and in some cases eliminate, the need for paper copy in the cockpit. They provide faster access to relevant information, increasing pilot's efficiency in adverse weather situations. EFBs optimize the exchange of information, enabling improvement of routing decisions. Weather applications on EFBs can improve weather situational awareness by giving an improved perception of the meteorological situation.

TOPLINK, a SESAR project, performed large scale demonstrations of deployment of new Meteorological Services based on System Wide Information Services for ANSPs, Airlines, Commercial and General Aviation Pilots, Airport operators. The following benefits were demonstrated:

- Improved situational awareness bringing safety benefits;
- Accelerated decision making (fuel strategies, rerouting/deviations and arrival conditions);
- Better anticipation of weather impacts on the route and resulting ATC re-routing requests;
- Improved passenger comfort;
- Facilitating more effective use of onboard weather radar;

Enhanced coordination with airline operations.

10 Potential risks or limitations

The implementation of regulations, recommendations or safety promotion activities by Agency is based on a non-risk based approach principle. Enabling pilots to have access to relevant meteorological information before departure as well as real-time and necessary updated meteorological information in-flight can only bring benefit to the safety of the flight.

Yet, the Agency recognises some potential risks or technological limitations with regard to enhanced weather information that are described below.

10.1 Non-detection of clear-air turbulence by on-board weather radars

Clear-air turbulence occurs independently of the presence of cloud, making it impossible to detect visually and very difficult to measure with on-board sensors. Conventional WXR cannot currently detect such phenomena.

As a mitigation it is suggested to continue the on-going progress of research and flight test in that domain by industry

10.2 Overload of weather information

There is still a need to consider the implications when allowing Tier 2 (non-regulated), information (as described in section 8.6) into the cockpit for the purpose of situational awareness, and in-flight decision making.

There is a potential risk that pilots may be overloaded with too much information, some of which may be irrelevant, conflicting or incorrect. Pilots may need to quickly interpret large volumes of complex weather information to identify what is relevant for their flight. This can divert the pilots' attention from the primary task of flying the aircraft.

Although the risk is low, this consideration needs to be highlighted. Having to deal with too much information could make it more time consuming to identify the relevant safety-critical weather information.

As a mitigation it is proposed to have provision of sets of weather information (see 9.1), that would give structure and purpose to meteorological information handling by the flight crew.

This should be covered during EFB application operational approval process (for example, Human Factors evaluation).

10.3 Potential for misinterpretation of meteorological information

Meteorological satellite images and ground-based radar information have limitations, and as such require specialist interpretation. In consideration, the advantage of remotely sensed observational data of high spatial resolution and high update frequency would be advantageous over otherwise data sparse areas.

When provided for pre-flight and in-flight situational awareness, care must be taken to ensure that the meteorological information is presented so that the important items are highlighted. Furthermore, the provision of such data should be undertaken in such a way to minimise as far as practicable any possibility of misinterpretation e.g. by using standard colour schemes and symbols.

As further mitigation, it is proposed to ensure that any such applications are provided with sufficient documentation, initial training and recurrent training on their use – including limitations thereof. As far as is practicable, the displays should be standardised.

11 Contribution to regulatory and safety promotion activities

This section identifies the needs for amendments to current or forthcoming European standards and rules. In particular, Regulation (EU) No 965/2012 (OPS), Regulation (EU) No 1178/2011 (Air Crew) and Regulation

(EU) No 2016/1377 (Part-MET). In the future, it shall also analyse the needs to contribute to any amendments to the related ICAO documents, in particular Annex 3, Annex 15, PANS-ATM, PANS-AIM, PANS-MET[28].

11.1 Contribution to Regulation (EU) No 2017/373 (Part-MET)

- Consider the necessary revision to Part-MET, including the proportionate oversight mechanism, to enable non-regulated meteorological information to be provided to pilots;
- Consider amending the provisions addressing the representation of meteorological information at pre-flight planning whilst considering issues surrounding continuity and consistency;
- Add, if necessary, new weather products for the provision of weather information, particularly in respect of SESAR deployment initiatives.

11.2 Contribution to Regulation (EU) No 965/2012 (Air-Ops)

- Consider amendments to the necessary provisions related to the airborne weather detecting equipment in Part-CATand Part-NCC, for both on-board weather radar and other weather detection equipment.
- Consider amendments to the CAT.GEN.MPA.180 to reflect different tiers of meteorological information to be used in flight.

11.3 Contribution to RMT.0601 on Electronic Flight Bags

- Add a GM to the AMCs on the use of EFB and in-flight weather applications (in SPA.EFB.100 and NCC.GEN.131) to clarify what is meant by the term 'reliable sources'. Proposal:

GMX XXXX Use of electronic flight bags (EFBs) — operational approval
IN-FLIGHT WEATHER APPLICATIONS
"Reliable sources" of data used by IFW applications are the organisations evaluated by the operator as being able to provide an appropriate level of data assurance in terms of accuracy and integrity. It is recommended that the following aspects be considered during that evaluation:
- The organisation should have a quality assurance system in place, which covers the data source selection, acquisition/import, processing, validity period check, and distribution phases;
- Any meteorological product provided by the organisation and which is in the scope of meteorological information included in the flight documentation as defined in MET.TR.215 (e) (Annex V of Commission Regulation (EU) No 1377/2016) should originate only from authoritative sources or certified providers and not be transformed or altered, except for the purpose of packaging the data in the correct format. The organisation's process should provide assurance that the integrity of those products is preserved in the data for use by the IFW application.

11.4 Safety promotion actions

Regulatory action is not always the only or best way to ensure that safety is improved. By promoting safety, the Agency also wants to address important safety risk in the meteorological information domain. For each type of weather threats, complementary material should describe subject importance and various non-regulatory materials should provide guidance to mitigate the risk.

Such material may include weather safety leaflets, briefings and brochures, Safety Information Bulletins (SIBs), developed by EASA, National Aviation Authorities (NAA), associations, industry and other stakeholders. Acquaintance and familiarity with this material will contribute to promote safety.

[28] PANS-MET is currently in development

The project focuses on promoting automatic weather radar and in-flight connectivity solutions supporting access to meteorological information including the portrayal thereof. Aircraft connectivity can deliver a wide range of benefits, in particular for flight crews and operators. New technologies are emerging that will provide enough bandwidth to meet operators' needs and give passengers and pilots the Wi-Fi connection they need to for their own purposes. The vision of the connected aircraft is becoming concrete and the WIP project will encourage, whenever possible, the use of wider technology trends and in particular more storage capacity and expanding communications bandwidth.

The WIP project recognises the fact that the application of high-bandwidth is become an increasing part of the operators' focus for providing superior on-board experience and to choose from the range of new high-throughput satellite technologies such as Ka-band and Ku-band for continuous in-flight connectivity. This constant innovation is encouraged in order to enhance pilots' operational communications.

Because better weather situational awareness significantly improve Air Traffic Management flow, other organizations like SESAR and SESAR DM should join EASA effort and participate to the promotion, development and deployment of improved and new weather solutions.

12 EASA Recommendations

The Agency proposes 9 recommendations listed below. It should be noted that they are in no particular order of priority:

12.1 Recommendation #1: Education and training; weather hazards, mitigation, and use of on-board weather radar

Require specific education and training on weather hazards and associated mitigation means, including optimum use of on-board weather radars and new services.

12.2 Recommendation #2: Improved weather briefing presentation

Promote improvements to the presentation of weather information in flight briefing packages by promoting use of intuitive, interactive displays, appropriate use of standardised colour graphics and symbols, and intelligent filtering of information.

12.3 Recommendation #3: Promotion of in-flight weather information updates

Promote the use of the latest information available – what is available is as – *if not more* – valuable in the cockpit to ensure up to date situational awareness. Encourage the development and introduction of in-flight weather information applications on EFBs.

12.4 Recommendation #4: Pan-European high resolution forecasts

Support the pan-European developments regarding the provision of high resolution forecasts for aviation hazards (eg, CAT, icing, surface winds, CB, winter weather).

12.5 Recommendation #5: Use of supplementary, 'Tier 2' weather sources for aviation purposes

Develop the necessary provisions to support the use of supplementary' 'Tier 2' meteorological information by pilots.

12.6 Recommendation #6: Development and enhancement of aircraft sensors/solutions

Promote the development of intrinsic aircraft capabilities to facilitate the recognition and, if required, the avoidance of hazardous weather. (e.g.on-board sensors for turbulence, sand / dust / volcanic ash, ice crystals).

12.7 Recommendation #7: Connectivity to support in-flight updates of meteorological information

Promote deployment of connectivity solutions (uplink and downlink) to support the distribution of meteorological information to pilots.

12.8 Recommendation #8: Provision of enhanced meteorological information

Promote provision of high resolution observed and forecast meteorological information, particularly data with high spatial and temporal resolution such as imagery derived from satellite and ground weather radar sources.

12.9 Recommendation #9: On-board weather radar, installation of latest generation equipment

Promote the installation of the latest generation of on-board weather radars, with emphasis on including capability for wind shear and turbulence detection.

13 Further considerations

13.1 Research projects on meteorological information

New technologies ‘for the cockpit’ are continuously emerging based on numerous national and EU funded research projects, promising projection for advanced technologies and operation to deliver actual and near real-time meteorological information to the pilots and all relevant stakeholders for strategic and tactical flight planning.

FLYSAFE[29] is a good example of experimental approach to airborne integrated systems for safety improvement, flight hazard protection and all-weather operations. With regard to adverse weather conditions, FLYSAFE has developed solutions to enable aircraft to retrieve timely, dedicated, improved weather information, by means of a set of weather information management systems presenting information to the crew to allow a better management of the thunderstorm risk.

The EUMETNET[30] Consortium looks at the consolidation of multiple sources of meteorological data including radar composites, aircraft derived information, forecasts/ensemble forecasts; the translation of consolidated weather information into aviation constraints or threshold values, including convection warnings, diagnostics of icing conditions or diagnostics of CAT; the conversion of translated weather information into operational impacts on ATM leading to improved decision making. Pilot briefings using digital MET information, flight

[29] FLYSAFE was an Integrated Project funded by the European Commission as part of the 6th Framework Programme. FLYSAFE aimed to design, develop, implement, test and validate new systems and functions able to improve situation awareness, advance warning, alert prioritisation, anticipate adverse atmospheric conditions, etc.

[30] EUMETNET is a network of 31 European National Meteorological Services providing a framework to organise co-operative programmes between the members in fields of meteorology, data processing and forecasting products.

planning using global forecasts and support to airport collaborative decision making are areas identified as important for this project.

Building on the above capabilities and expertise, EUMETNET was involved in the SESAR1 research project. This research project concluded in Sept 2016, and much of its validations and demonstration are now being taken forward into deployment phase, in partnership with SESAR Deployment Manager. The project is expected to result in new high resolution and harmonised MET forecasts for the European domain, most of which will be directly applicable to cockpit operations.

The High Altitude Ice Crystal (HAIC) project is another good example of a European research program which has resulted in better understanding of a complex weather phenomena, and better understanding of its impact on aircraft. The HAIC project has been able to, mature and validate technologies for detection and long range detection of multiple HAIC conditions (weather radar upgrade, models).

eGAFOR project: It should also be noted that separate activities are being undertaken in European and non-European States, such as the eGAFOR project. The eGAFOR project aims to address the issues of fragmentation and inconsistency of MET products as support for low-level SIGWX. The project is based on cooperation between Meteorological Service Providers (METSPs) in Central and Southeast Europe and industry partners. The ultimate goal is to provide a consolidated and harmonized MET product as support for low-level SIGWX over several states covering a large area of Europe.

When successfully implemented, eGAFOR will provide uniform information on meteorological conditions along the flight route. The eGAFOR project includes 8 different States (some of them are EU member states and some are neighbouring non-EU States METSPs is aimed at increasing safety and efficiency in the area covered in the lower air space and has the potential to be extended to more countries in the future.

The project was selected for funding by INEA- 2016 CEF Transport Calls for Proposal[31].

13.2 The MET-portal for Europe

The System Wide Information Management (SWIM) should enable easy access to a consolidated and harmonised meteorological information through a pan-European portal. A one stop shop point of access to meteorological information would ease the deployment and use of meteorological information by all stakeholders, and this is what is planned through the Deployment of MET-GATE.

13.3 Global harmonisation

Through the Aviation System Block Upgrades (ASBU) methodology described in ICAO's Global Air Navigation Plan (GANP)[32], ICAO Block 1-AMET (2019-2024) module promotes the establishment of Standards for global exchange of information.

> B1-AMET
> **Enhanced operational decisions through integrated meteorological information (planning and near-term service)**
> Meteorological information supporting automated decision process or aids, involving meteorological information, meteorological information translation, ATM impact conversion and ATM decision support.

[31] https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport/apply-funding/2016-cef-transport-calls-proposals
[32] ICAO Doc 9750 *Global Air Navigation Plan*, Fifth edition, 2016-2030

These standards are essential to ensure that pilots can share the same information distributed through the ground networks.

The ICAO Block 3-AMET (2031 onward) identifies the meteorological information used in the cockpit.

> B3-AMET
> **Enhanced operational decisions through integrated meteorological information (near-term and immediate service)**
> Meteorological information supporting both air and ground automated decision support aids for implementing immediate weather mitigation strategies.
> *Note: There is currently no B2-AMET in the GANP.*

The WIP project will monitor and follow-up the developments regarding the GANP and coordinate internally in order to raise awareness that ICAO provisions should keep up with technological advancements to ensure that enhanced products and services are made available. With regard to the FLTOPS Panel, the project will ensure coordination for relevant contribution to the EFB-SG working on rules for weather applications on EFBs. With regard to the MET Panel, the WIP project will ensure that any current and future recommendations are consistent with the provisions of ICAO Annex 3.

14 Conclusion

There is no doubt that weather phenomena can have a great impact on aviation safety as identified in recent incident and accident investigation reports. Current technological developments are helping to mitigate the situation such as improved ground radar infrastructure, meteorological satellites and advanced on-board weather radar. However, there are still gaps and room for further improvements.

Particularly, the pilot community is demanding more near real-time meteorological information in the cockpit since it has been demonstrated that today’s technology already has a great potential to deliver what is needed to pilots as well as to operators and ATC. A first area is the promotion of improvements to on-board weather radar. However due to technology constraints, it will not be sufficient to cover all needs. Therefore a complementary option is the uplink of meteorological information assimilated from various sources such as ground radar, meteorological satellites, and observations disseminated as graphical and textual forecast. Although there are means to present the information via the on-board avionics it is/will be very common in the future to use EFB applications.

Also, guidance and training for flight crews is necessary, to minimise the risks of misinterpretation of weather information.

Considering the effects of climate change, which may produce more cases of severe weather every year around the globe, there is a need to improve upon the weather information currently provided to pilots.

The recommendations provided in section 12 of this Strategy Paper and the consequential actions provided in Appendix A are considered to be an appropriate response to facilitate the enhancement of weather information to pilots.

Attachment A: Action Plan

This action plan provides a synthesis of all the foreseen actions that follow from the recommendations identified in the framework of the Strategy paper.

1 WIP project management

The management and overall coordination of this project is ensured by FS4.2 (ATM/ANS section).

The WIP project manager (PM) ensures that the implementation of the recommendations are timely followed-up and coordinated internally and with the relevant stakeholders. The WIP PM may organise technical meetings if deemed necessary for the implementation of the actions.

2 Action plan

The Recommendations from the WIP Strategy Paper are presented below. Consequential actions are also described.

Several of the consequential actions are considered transversal, and it is proposed to incorporate those actions into a Focussed Study Group/Pilot Project (Action 8.1) with an early adopter operator of In-Flight Weather Applications on Electronic Flight Bag in order to address those actions in the most efficient, realistic and relevant manner.

Recommendation #1: Education and training; weather hazards, mitigation, and use of on-board weather radar

Require specific education and training on weather hazards and associated mitigation means, including optimum use of on-board weather radars and new services.

Action	Affected area	Start date	End date	Expected outcome
1.1 EASA to involve Flight crew-training group. FS.3.4	1.1 Regulation (EU) No 1178/2011	1.1 Q1 2018	1.1 Q4 2018 report Implement by Q4 2020	Pilots will have the necessary knowledge, skills and training in order to manage the on-board weather radar and to interpret the information displayed.
1.2 Require, in all initial and recurrent weather radar training material, inclusion of clear information relating to system limitations (such as attenuation and significance of green radar echoes at high altitude);	1.2 Operators, training organisations	1.2 Q1 2019	1.2 Q4 2019 report Implement by Q4 2020	
1.3 Require the insertion and emphasis in the crew training syllabi, the significance of precision tilt management for detection, analysis, and avoidance of hazardous convective weather; and the pitfalls of over-scanning storm cells.	1.3 Operators, training organisations	1.3 Q1 2019	1.3 Q4 2019 report Implement by Q4 2020	

Recommendation #2: Improved weather briefing presentation

Promote improvements to the presentation of weather information in flight briefing packages by promoting use of intuitive, interactive displays, appropriate use of standardised colour graphics and symbols, and intelligent filtering of information.

Action	Affected area	Start date	End date	Expected outcome
2.1 Identify and review the applicable industry guidance with regard to the use of standardised colour and symbols for weather applications in the cockpit. 2.2 Consider revision of AMC/GM, and possibly IR following action 2.1. 2.3 Identify existing and emerging data formats suitable for graphical display of meteorological information in the cockpit (ie, SWIM compliant). 2.4 Promote the Human Factors benefits of the use of intuitive graphical displays of meteorological information, including the use of standardised colours and symbols. *To be incorporated into the Focussed Study Group/Pilot Project with early adopter operator (8.1)*	2.1 Annex V (Part-MET) of Reg. 2017/373 2.2 Annex V (Part-MET) of Reg. 2017/373 2.3 ATM/ANS 2.4 Transversal (ATM/ANS, SM, etc.)	2.1 Q1 2018 2.2 Q1 2019 2.3 Q1 2018 2.4 Q1 2018	2.1 Q4 2018 2.2 Q4 2019 2.3 Q4 2018 2.4 Progress check Q4 2018, and at Q3 2019 (ongoing in principle.	Increased meteorological information displayed to the pilot in graphical format for enhanced and more efficient situational awareness.

Recommendation #3: Promotion of in-flight weather information updates

Promote the use of the latest information available – what is available is as – *if not more* – valuable in the cockpit to ensure up to date situational awareness. Encourage the development and introduction of in-flight weather information applications on EFBs.

Action(s)	Affected area	Start date	End date	Expected outcome
3.1 Provide AMCs and guidance material on the use of EFB and in-flight weather through NPA 2016-12.	3.1 SPA.EFB.100 and NCC.GEN.131 on in-flight weather applications for EFBs.	3.1 Already in progress	3.1 Opinion No 10/2017 with CRD 2016-12 as appendix Q4 2017 Decision Q3 2018	Operators to implement EFB programs for in-flight weather applications (as per CRD 2016-12) Clarification and guidance on of what “appropriate meteorological information” means in light of emerging technology with regard to EFBs.
3.2 Identify means to promote the safety benefit of using in-flight weather applications on EFB *To be incorporated into the Focussed Study Group/Pilot Project with early adopter operator (8.1)*	3.2 Safety promotion activities.	3.2 Q1 2018	3.2 Q4 2018	
3.3 Consider revision of AMC/GM and possibly IR for carrying of appropriate meteorological information on-board To be incorporated into the Focussed Study Group/Pilot Project with early adopter operator (8.1)	3.3 CAT.GEN.MPA.180	3.3 Q1 2018	3.3 Q4 2018	

Recommendation #4: Pan-European high resolution forecasts

Support the pan-European developments regarding the provision of high resolution forecasts for aviation hazards (eg, CAT, icing, surface winds, CB, winter weather).

Action	Affected area	Start date	End date	Expected outcome
4.1 Identify the opportunities and challenges with regard to the provision of high resolution nowcasts and forecasts for aviation hazards below FL100. 4.2 Coordinate with the MET providers/community, SESAR (EUROCONTROL, EUMETNET) Review and clarify the policies regarding access to SESAR DM datasets via EFB applications 4.3 Identify the opportunities and challenges with regard to the provision of common digital representations of meteorological hazards with regard to collaborative decision making and the contribution to enhanced safety and efficiency. *To be incorporated into the Focussed Study Group/Pilot Project with early adopter operator (8.1)*	4.1 Annex V (Part-MET) of Reg. 2017/373 4.2 ATM/ANS 4.3 ATM/ANS, SM	4.1 Q1 2018 4.2 Q1 2018 4.3 Q1 2018	4.1 Q4 2018 4.2 Q4 2018 4.3 Q4 2018	Provide pilots and stakeholders with a common, digital representation of meteorological hazards below FL100. Feed into SESAR/CEF

Recommendation #5: Use of supplementary, 'Tier 2' weather sources for aviation purposes

Develop the necessary provisions to support the use of supplementary 'Tier 2' meteorological information by pilots

Action(s)	Affected area	Start date	End date	Expected outcome
5.1 Focussed study on the adoption of a three tier approach to define meteorological information in the context of aviation.	5.1 Annex V (Part-MET) of Reg. 2017/373	5.1 Q1 2018	5.1 Q4 2018	The term 'reliable sources' and ;Tier 2 meteorological information is clarified, in particular regarding the level of data quality assurance and the origination of the meteorological product provided by such organisations.
5.2 Identify and specify appropriate means to reflect the use of meteorological information not currently recognised under Part-MET (or ICAO Annex 3) or Part-OPS. Consider amend proposals for Part- MET and/or Part-OPS, if necessary. *To be incorporated into the Focussed Study Group/Pilot Project with early adopter operator (8.1)*	5.2 ATM/ANS	5.2 Q1 2018	5.2 Q4 2019	Formal recognition of providers of supplementary meteorological information of sufficient quality for flight purposes.

Recommendation #6: Development and enhancement of aircraft sensors/solutions

Promote the development of intrinsic aircraft capabilities to facilitate the recognition and, if required, the avoidance of hazardous weather. (e.g.on-board sensors for turbulence, sand / dust / volcanic ash, ice crystals).

Action(s)	Affected area	Start date	End date	Expected outcome
6.1 Coordinate with the Commercial Air Transport Collaborative Analysis Group	6.1 SM	6.1 Q1 2018	6.1 Progress report Q2 2019 and Q4 2020	Research Area that need to be reinforced
6.2 Update the analysis on the statistics to identify the main weather threats (icing, ash etc) for aviation.	6.2 SM, ATM/ANS	6.2 Q1 2018	6.2 Progress report Q2 2019 and Q4 2020	
6.3 Prioritise the areas of research to drive the appropriate Roadmap relating to development of intrinsic aircraft capabilities (for example, the WEZARD project).	6.3 SM, ATM/ANS	6.3 Q1 2018	6.3 Progress report Q2 2019 and Q4 2020	

Recommendation #7: Connectivity to support in-flight updates of meteorological information

Promote deployment of connectivity solutions (uplink and downlink) to support the distribution of meteorological information to pilots.

Action	Affected area	Start date	End date	Expected outcome
7.1 Identify the opportunities and challenges with regard to existing and emerging technological developments with regard to aircraft connectivity.	7.1 Aircraft uplink technologies	7.1 Q1 2018	7.1 Q4 2018	EASA and stakeholders to define recommendations and guidance on aircraft connectivity solutions supporting uplink and downlink of meteorological information.
7.2 Identify means to promote connectivity solutions supporting distribution of meteorological information, particularly, but not only, with regard to European implementations of System Wide Information Management (i.e. SESAR).	7.2 SM, CT	7.2 Q1 2018	7.2 Q4 2018	Increased access to relevant meteorological information relating to phenomena that cannot be detected by on-board systems;

Recommendation #8: Provision of enhanced meteorological information

Promote provision of high resolution observed and forecast meteorological information, particularly data with high spatial and temporal resolution such as imagery derived from satellite and ground weather radar sources.

Action	Affected area	Start date	End date	Expected outcome
8.1 A Focussed Study Group/Pilot Project with an early adopter air operator to assess the opportunities and challenges with regard to the use of high resolution observed and forecast meteorological information, and to identify any challenges with regard to the use and interpretation of such data. 8.2 Following the outcome of 8.1, Focussed Study Group/Pilot Project to provide the necessary guidance with regard to the development of manuals and training to underpin the provision and use of high resolution observed and forecast meteorological information.	8.1 ATM/ANS 8.2 ATM/ANS, SM (training)	8.1 Q1 2018 8.2 Q1 2019	8.1 Q4 2018 8.2 Q4 2019	To ensure a minimum level of standardisation and to ensure that the display of more complex meteorological information is correctly interpreted.

Recommendation #9: On-board weather radar

Promote the installation of the latest generation of on-board weather radars, with emphasis on including capability for wind shear and turbulence detection.

Action(s)	Affected area	Start date	End date	Expected outcome
9.1 Draft guidance material to explain that on-board weather detecting equipment to be used should preferably be of the latest generation, in particular for weather radars. 9.2 Consider amendments to Regulation (EU) No 965/2012 (Air-Ops) in particular the relevant provisions related to the airborne weather detecting equipment in OPS Part-CAT, Part-NCC and Part-SPO, to encourage the installation of the latest generation of on-board weather radar.	9.1 Regulation (EU) No 965/2012 (Air-Ops): 9.2 CAT.IDE.A.160 NCC.IDE.A.145 SPO.IDE.A.132	9.1 Q1 2018 9.2 Q3 2018	9.1 Q3 2018 9.2 Q2 2019	Operators to install latest on-board weather radars/weather detection equipment, in particular with regard to capability to detect wind shear and turbulence. This guidance material will support the safety promotion activities related to the use of the latest generation of on-board weather radars.

Attachment B: Glossary

Abbreviation/Term	Meaning
ACARS	Aircraft Communications Addressing and Reporting System
AIM	Aeronautical Information Management
AMC	Acceptable Means of Compliance
AMET	Advanced MET Information (ICAO ASBUs)
ANSP	Air Navigation Service Provider
ASBU	Aviation System Block Upgrades
ATC	Air Traffic Control
ATIS	Air Traffic Information Service
ATM	Air Traffic Management
ATS	Air Traffic Service
AWO	All Weather Operations
CAT	Commercial Air Transport To avoid confusion with 'Clear Air Turbulence', 'Commercial Air Transport' will always be used in full in this document
CAT	Clear Air Turbulence
CB	Cumulonimbus
CEF	Connecting Europe Facility
CIT	Convective Induced Turbulence
D-ATIS	Digital Automated Terminal Information Services
DM	Deployment Manager (SESAR)
Doc	Document (ICAO)
D-VOLMET	Data link-VOLMET
EC	European Commission
EFB	Electronic Flight Bag
EU	European Union
EUR	The ICAO European region
FAA	Federal Aviation Administration
FL	Flight Level
FLTOPS	Flight Operations (ICAO Panel)
FMS	Flight Management System
FOC	Flight Operations Centre
GANP	Global Air Navigation Plan
GM	Guidance Material
HAIC	High altitude ice crystals
HF	High Frequency
IATA	International Air Transport Association

Abbreviation/Term	Meaning
ICAO	International Civil Aviation Organization
ICI	Ice Crystal Icing
IFW	In-Flight Weather
IORS	The Internal Occurrence Reporting System (IORS) is a EASA system for collecting, centralising and processing all safety related occurrences reported to the Agency
IP	Internet Protocol
Kts	Knots (nautical miles per hour)
LOC-I	Loss of control in-flight
MET	Meteorology/Meteorological
METAR	Aerodrome Routine Meteorological Reports
METSP	Meteorological Service Provider
NAA	National Aviation Authorities
NAT	The ICAO North Atlantic region
NCC	Non-commercial operations with complex motor-powered aircraft
NCO	Non-commercial operations with other Non-complex aircraft
NM	Nautical mile
NM	Network Manager
NPA	Notice of Proposed Amendment
Ops	Operations
PANS	Procedures for Air Navigation Services
PWS	Predictive wind shear (referring to a system)
RMT	Rulemaking Task
RWS	Reactive wind shear (referring to a system)
SATCOM	Satellite Communications
SESAR	Single European Sky ATM Research
SG	Study Group
SIGMET	Information concerning en-route weather phenomena, which may affect the safety of aircraft operations
SIGWX	Significant Weather
SPA	Special Approvals
SPECI	Aerodrome special meteorological report
SWIM	System Wide Information Management
TAF	Terminal Aerodrome Forecast
VAA	Volcanic Ash Advisory
VAAC	Volcanic Ash Advisory Centre
VHF	Very High Frequency
VOLMET	VOLMET broadcast. Provision, as appropriate, of current METAR, SPECI, TAF and SIGMET by means of continuous and repetitive voice broadcasts

Abbreviation/Term	Meaning
VSD	Vertical Situation Display
WAFC	World Area Forecast Centre
WAFS	World Area Forecast System
WG	Working Group
WIP	Weather Information to Pilots
WXR	On-board weather radar

Attachment C: Information for use by operator or flight crew, extracted from Part-MET (MET.OR.240)

MET.OR.240 Information for use by operator or flight crew

(a) An aerodrome meteorological office shall provide operators and flight crew members with:
(1) forecasts, originating from the WAFS, of the elements listed in points (1) and (2) of point MET.OR.275(a);
(2) METAR or SPECI, including TREND forecasts, TAF or amended TAF for the aerodromes of departure and intended landing, and for take-off, *en-route* and destination alternate aerodromes;
(3) aerodrome forecasts for take-off;
(4) SIGMET and special air-reports relevant to the whole route;
(5) volcanic ash and tropical cyclone advisory information relevant to the whole route;
(6) area forecasts for low-level flights in chart form prepared in support of the issuance of an AIRMET message, and an AIRMET message for low-level flights relevant to the whole route;
(7) aerodrome warnings for the local aerodrome;
(8) meteorological satellite images;
(9) ground-based weather radar information.

(b) Whenever the meteorological information to be included in the flight documentation differs materially from that made available for flight planning, the aerodrome meteorological office shall:
(1) advise immediately the operator or flight crew concerned;
(2) if practicable, provide the revised meteorological information in agreement with the operator.

MET.OR.275 World area forecast centre responsibilities

(a) The WAFC shall provide, in a digital form:
(1) gridded global forecasts of:
(i) upper wind;
(ii) upper-air temperature and humidity;
(iii) geopotential altitude of flight levels;
(iv) flight level and temperature of tropopause;
(v) direction, speed and flight level of maximum wind;
(vi) cumulonimbus clouds;
(vii) icing;
(viii) turbulence;

(2) global forecasts of significant weather (SIGWX) phenomena, including volcanic activity and release of radioactive materials.