



EASA Safety Information Bulletin

SIB No.: 2010-17R3
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Subject: Flight in Airspace with contamination of Volcanic Ash

Ref. Publications:

- Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds, ICAO Document 9691-AN/954 (ISBN 92-9194-888-8), second edition, 2007.
- ICAO Volcanic Ash Contingency Plan EUR and NAT Regions (EUR Doc 19)
- Guidance material preliminary issue - Draft Version 3.1 - of 'Management of flight operations with known or forecast volcanic cloud contamination' (attached to this SIB)
- [London VAAC NWP Volcanic Ash Concentration Charts.](#)

Revision 3:

This SIB has been revised for the following reasons:

- Revision of the colour scheme for the London Volcanic Ash Advisory Centre (VAAC) Volcanic Ash Concentration Charts;
- Revision of the definitions of contamination, which correspond to those that are used in the ICAO Volcanic Ash Contingency Plan EUR and NAT Regions (EUR Doc 19)
- Introduction of draft guidance material for safety risk assessment as developed by the ICAO International Volcanic Ash Task Force.

Applicability:

All aircraft operators, owners and maintenance organisations with aircraft operating into airspace that is known or suspected to be contaminated with volcanic ash.

Description:

Flight in Airspace with a contamination of Volcanic Ash may be hazardous to aviation.

Flights even in airspace with a low contamination with volcanic ash where no imminent threat to the safety of the aircraft seems to exist – might have medium and long term consequences for the airworthiness of aircraft.

This Safety Information Bulletin introduces guidelines for aircraft operators and the relevant National Aviation Authorities to minimise the safety risk of flight operations in areas known or forecast to be affected by volcanic cloud.

A further refined safety risk assessment methodology approach – developed under the umbrella of the ICAO International Volcanic Ash Task Force – is introduced as guidance, to allow operators to show and convince their National Aviation Authorities that flights can be executed safely because the risks are controlled and mitigated.

Furthermore, this unique guidance for safety risk assessment has been evaluated and tested and is promoted to be used to evolve into a system where the operators demonstrate to the satisfaction of the National aviation Authority to be able to manage and control their risks.

With regard to flights in airspace with a contamination of volcanic ash, it is essential that priority be given to maintain the continuing airworthiness of aircraft in order to support the continuation of safe operations.

Aircraft and Engine TC-Holders are being requested by EASA to develop the instructions necessary for continued safe flight, such as specific pre- and post-flight inspections, and those for continued airworthiness, taking into account the effects of operation of aircraft in airspace with low contamination volcanic ash. Those instructions are also requested for aircraft parked in areas that may be contaminated by the fall out and settling of volcanic ash. Special emphasis is requested for those systems that are most sensitive to any exposure to volcanic ash.

The sensitive systems are known to be, but may not be limited to, engine compressors and turbines, engine oil systems, aircraft pitot- and air data systems, aircraft environmental control systems, and those aircraft systems that provide cooling air for computer systems installed on the aircraft.

The VAAC in London, in accordance with international regulations, produces volcanic ash concentration charts that predict and depict areas of contamination with volcanic ash. The charts show forecast ash concentration levels in 3 altitude bands and in 3 different zones. This information is produced for the purpose of facilitating the decisions to be taken by the national authorities with regards to their respective airspace. The zones are based on volcanic ash tolerance levels defined by aircraft and engine manufacturers to ensure continued safe flight. The zones are identified as follows:

Definitions:

The following definitions of contamination, which correspond to those in the ICAO Volcanic Ash Contingency Plan EUR and NAT Regions (EUR Doc 019), are now valid:

- **Area of Low Contamination** (to be displayed in Cyan): an airspace of defined dimensions where volcanic ash may be

encountered at concentrations equal to or less than 2×10^{-3} grams/m³

- **Area of Medium Contamination** (to be displayed in Grey): an airspace of defined dimensions where volcanic ash may be encountered at concentrations greater than 2×10^{-3} grams/m³, but less than 4×10^{-3} grams/m³
- **Area of High Contamination** (to be displayed in Red): an airspace of defined dimensions where volcanic ash may be encountered at concentrations equal to or greater than 4×10^{-3} grams/m³, where no ash concentration guidance is available.

These definitions replace the previously used terms Enhanced Procedure Zone (EPZ), Time Limited Zone (TLZ) and No-Fly Zone (NFZ).

Recommendations: When operating in an airspace or area of Low Contamination, the following should apply:

Unless specific pre- and post-flight inspections and ICA have been defined by the aircraft and engine TC holders, and until those instructions have been made available to the operators and owners,

(1) (a) Accomplish daily inspections when operating in an area of low volcanic ash contamination, to detect any erosion, accumulation of volcanic ash, or aircraft- and/or engine damage or system degradation:

- wing leading edges
- navigation and landing lights, radomes
- landing gear
- horizontal stabiliser
- all extruding structure
- pitot tubes and static ports
- windows and windshields
- engine inlets and nacelles
- engine compressors and turbines
- engine oil systems
- rotor blades

Based on the results of the above inspections, more detailed inspections may be necessary.

Unless specific instructions have already been provided by aircraft and engine TC holders to be applied after encountering a volcanic ash, the above inspections should also be performed after each flight, whenever the following phenomena are observed or detected or experienced during flight

- Acrid odours similar to electrical smoke
- Rapid onset of engine problems
- St. Elmo's fire

- Bright white/orange glow appearing at the engine inlets
- Dust in the cockpit or cabin
- Sudden (unexpected) outside darkness
- Airspeed fluctuations
- Landings lights casting sharp, distinctly visible beam

(1) b) Protect and cover aircraft that are parked in areas that may be contaminated by the fall out or settling of volcanic ash in accordance with the Aircraft and Engine TC holders advice where possible. Any volcanic ash residues must be removed prior to operations and following the TC Holder's recommendations where available.

(2) Report any encounter with volcanic ash, or any other relevant findings, to the engine- and aircraft TC holders, the National State of Registry of the aircraft and to the National Authority of the State through which flight was conducted.

In addition, operators should report to EASA for EASA to produce a synthesis of findings and trends resulting from these inspections so that improvements could be brought to the procedures recommended by this SIB.

(3) In addition to the above, to enable flight in airspace or areas with Medium or High Contamination, the following recommendations are provided, subject to approval of the Competent Authority of the EU Member State or associated country. Two approaches (A or B) are recommended:

(A) Operators may be authorised to resume flight operations in areas or airspace with a Medium or High Contamination, by presenting to their National Competent Authority an acceptable safety case. The safety case should contain, but is not limited to, the following

- (i) An assessment of the risks for flight operations, per aircraft type, in the area or airspace with a Medium or High Contamination prior to the planned operations (A description of recommended safety risk assessment methodology can be found in guidance material preliminary issue - *Draft Version 3.1* - of 'Management of flight operations with known or forecast volcanic cloud contamination' as attached to this SIB)
- (ii) Data from the engine and aircraft manufacturers that support flight operations, per aircraft type, in this zone, and when applicable, the limitations that may apply.
- (iii) Additional (health monitoring) inspections are carried out that have been determined by the aircraft and engine manufacturers to ensure continued safe flight.

(B) The National Competent Authority of the Member State or associated country may decide to allow all flights within the area or airspace with a Medium Contamination, with or without limitations (e.g. geographic area, limitation in duration), following reconnaissance/clearance flights performed to support and justify that safe operations in the area or airspace with Medium Contamination can continue. This airspace, based on reconnaissance/clearance flights, should then be re-classified as an area or airspace with a Low Contamination.

The data and analysis from the reconnaissance/clearance flight(s) together with the subsequent decision to allow flights in the airspace in full or in part should be reported without delay to the Volcanic Ash Advisory Centres, Eurocontrol and EASA.

(4) In both cases (A) and (B) flights in areas or airspace with Low, Medium and High Contamination may only then be carried out at the operators discretion provided flight into visible ash is avoided.

(5) In both cases (A) and (B) above any necessary enhanced operational procedures should be developed and implemented by the operator, preferably based on the guidance material for safety risk assessment (SRA) Preliminary Issue draft version 3.1 as attached to this Safety Information Bulletin. Such enhanced operational procedures should include at least as a minimum:

- a briefing to pilots on the concept of flights in the area or airspace of Medium Contamination,
- additional fuel as a contingency to allow re-routing once airborne due to the changing environmental conditions, as applicable.
- the selection of en-route and/or destination alternates and/or ETOPS requirements considering special circumstances, and
- consideration to engine-out service ceiling and decompression before overflying areas containing volcanic ash

(6) Operations in airspace with any contamination of volcanic ash may result in degradation of aircraft and engine components or systems which is higher than normal. Piston engine aircraft and gliders may be less susceptible to volcanic ash.

(7) EASA requests the feedback from EU Member States and associated countries, the airspace management organisations and operators for improvement of this SIB and the Agency would like to be informed of any difficulties that are being experienced on implementing the safety recommendations contained in this SIB. The SIB will be revised as necessary.

Contacts:

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Reports can be submitted to EASA by E-mail: volcano@easa.europa.eu.

To obtain a copy of the ICAO Document 9691-AN/954, contact the ICAO Customer Services Unit, telephone +1 514-954-8022, facsimile +1 514-954-6769, or by e-mail request to sales@icao.int.

REVISSED

INTERNATIONAL CIVIL AVIATION ORGANIZATION

INTERNATIONAL VOLCANIC ASH TASK FORCE



GUIDANCE MATERIAL

**MANAGEMENT OF FLIGHT OPERATIONS
WITH KNOWN OR FORECAST
VOLCANIC CLOUD CONTAMINATION**

PRELIMINARY ISSUE

- Draft Version 3.1 -

19 December 2010

REVIEWED

THE DESIGNATIONS AND THE PRESENTATION OF MATERIAL IN THIS PUBLICATION DO NOT IMPLY THE EXPRESSION OF ANY OPINION WHATSOEVER ON THE PART OF ICAO CONCERNING THE LEGAL STATUS OF ANY COUNTRY, TERRITORY, CITY OR AREA OF ITS AUTHORITIES, OR CONCERNING THE DELIMITATION OF ITS FRONTIERS OR BOUNDARIES.

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SUMMARY

The ICAO Volcanic Ash Task Force (IVATF) has developed a globally applicable process to facilitate the management of flight operations into, or near, areas of known or forecast volcanic cloud through the provision of appropriate information to assist in minimising safety risk in such operations. The approach is based on formalising a risk assessment process for use by an operator wishing to conduct such an operation and an evaluation process for use by that operator's State in assessing whether or not the risk of that operation is minimised to an acceptable level by that operator's use of this process. It is intended that the State of the Operator or State of Registry, as appropriate, would make this determination on behalf of all other Provider States through whose airspace the resultant flight operations are planned to be conducted.

Important Notes

1. *This guidance material has been developed through the work of the ICAO International Volcanic Ash Task Force (IVATF) which formed in July 2010 as a response to the eruption of the Eyafjallajökull volcano in March and April 2010.*
2. *This guidance material is provided as a draft version for the preliminary implementation of the guidance material in flight operations management and the procedures of State aviation authorities. As the work of the IVATF and its sub-groups progress revisions and updates will be made. The final draft version will require ICAO approval prior to issuance as an ICAO document.*
3. *The approach of this guidance material is in line with a new approach to flight in proximity to volcanic cloud and into areas with limited ash concentrations; it is in line also with existing safety advice not to fly into areas of "visible" ash.*
4. *The work of the IVATF does not replace the existing ICAO Annex 3 provisions covering the International Airways Volcano Watch (IAVW) system of oversight and production of warnings nor does it replace the guidance material provided under that system. However, the work of the IVATF will provide new complementary guidance material and it will inform the further development and enhancement of the IAVW.*

1. DEFINITIONS

1.1 Abbreviations

ACC	Area Control Centre
AIREP	Special Air Report - a message from an in-flight aircraft to a ground station describing significant in flight conditions
AIS	Aeronautical Information Service
ALOS	Acceptable Level of Safety
AML	Aircraft Maintenance Log
ANSP	Air Navigation Service Provider
ASHTAM	A special series NOTAM notifying a change in activity of a volcano, a volcanic eruption and/or volcanic ash cloud that is of significance to aircraft operations
ASR	Air Safety Report - used by an operator to document its safety incidents
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
CDM	Collaborative Decision Making
ETOPS	Extended Range Twin-engine Operations
FIR	Flight Information Region
LIDAR	Light Detection and Ranging: an optical remote sensing technology to measure the position and density of a volcanic ash cloud
MEL	Minimum Equipment List
MET	Meteorological Service
MWO	Meteorological Watch Office
NAA	National Aviation Authority
NOTAM	Notice to Airmen - Notices concerning the establishment, condition or change to any facility, service or procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations
OEM	Original Equipment Manufacturer – in this document this usually refers to the relevant airframe and engine manufacturers
SIGMET	Significant Meteorological Information message

SMS	Safety Management System
SRA	Safety Risk Assessment
VAA	Volcanic Ash Advisory message
VAAC	Volcanic Ash Advisory Centre
VAG	Volcanic Ash Advisory message in graphical form
VAR	Volcanic Activity Report from aircraft (the real-time part of the VAR is issued in the same manner as an AIREP Special)
VO	Volcano Observatory
VOLCEX	Regular ICAO volcanic ash exercises to validate and improve regional volcanic ash contingency plans and procedures.

1.2 Volcanic Ash Contamination Levels

Where no ash contamination levels are given, as has been historically the case, airspace is assumed to be either contaminated or not contaminated, with no consideration of severity. In 2010, within the ICAO EUR/NAT region, three ash contamination levels (low, medium, high)¹ were identified.

These contamination levels will be used operationally in the European region should there be further eruptions in the region in medium term.

In the long term, it is expected that the European contamination level initiative will be further evaluated, with respect to use outside the EUR/NAT region.

Note: The members of the ICAO Volcanic Ash Task Force continue to work towards further refinement and definition of these contamination levels.

¹ The EUR/NAT volcanic ash contamination levels are:

Area of Low Contamination: Airspace of defined dimensions where volcanic ash may be encountered at concentrations equal to or less than $2 \times 10^{-3} \text{ g/m}^3$.

Area of Medium Contamination: Airspace of defined dimensions where volcanic ash may be encountered at concentrations greater than $2 \times 10^{-3} \text{ g/m}^3$, but less than $4 \times 10^{-3} \text{ g/m}^3$.

Area of High Contamination: Airspace of defined dimensions where volcanic ash may be encountered at concentrations equal to or greater than $4 \times 10^{-3} \text{ g/m}^3$, or areas of contaminated airspace where no ash concentration guidance is available.

All modelled ash concentrations are subject to a level of uncertainty. "Defined dimensions" refers to horizontal and vertical limits.

1.3 Response Phases

The response to a volcanic event that affects air traffic can be divided into three distinct phases as described briefly below. Further information may be available in regional contingency plans (e.g. EUR Doc 019 in the EUR/NAT Region).

Alerting Phase (Pre-Eruption): The initial response, “raising the alert”, commences when a volcanic eruption is expected. Alerting information is provided by VAR/AIREP, SIGMET, NOTAM or ASHTAM, as appropriate, and disseminated to affected aircraft in flight by the most expeditious means. This information is also transmitted to meteorological or volcanological agencies. If it is considered that the event could pose a hazard to aviation, a *Danger Area* around the volcanic sources will be declared by NOTAM. During this phase, clearances will not normally be issued through a *Danger Area*.

There will be limited availability of information on the extent and severity of the expected volcanic event; however, it is essential that the information that is available is promulgated as a matter of urgency. Regardless of the extent of information available, the Pre-Eruption Alerting Phase actions should be carried out in every case.

NOTE: Wherever this document discusses the possible establishment of *Danger Areas*, States are not prevented from establishing Hazard, Restricted or Prohibited Areas in their FIRs if considered necessary.

The focus of this phase is to advise operators of the potential volcanic safety risk to assist in the planning of alternative routes.

Reactive Phase (Eruption Onset): The Reactive Phase commences at the outbreak of the volcanic eruption and expulsion of volcanic ash clouds into the atmosphere. A “Start of Eruption SIGMET” will be issued and a *Danger Area* declared by NOTAM. During this phase, clearances will not normally be issued through a *Danger Area*.

This phase is characterised by a limited availability of information on the extent and severity of the volcanic event. Hence, during this phase, it is expected that operators will remain clear of areas predicted to be contaminated by volcanic ash.

The focus of this phase is to protect aircraft in flight from the hazards of the eruption.

Proactive Phase (Eruption): The Proactive Phase commences with the issuance of the first VAA and VAG after completion of reactive responses. Supplementary modeled ash concentration charts may be available. The volcanic ash forecasts up to T+18 hours are used to prepare SIGMET which are issued as soon as practicable, but not more than 12 hours

before the commencement of the period of validity, and are valid for up to 6 hours. The T+12 hours and T+18 hours (and further into the future, if available) volcanic ash forecasts are used to prepare NOTAM/ASHTAM. As appropriate, Danger Areas will be notified via NOTAM.

The VAA/VAG will consist of information on the current position of the volcanic cloud and its expected position(s) in T+6, T+12 and T+18 hours. Supplementary ash concentration modelling charts may be available from the VAAC.

During this Phase, operators should only operate in the affected area in accordance with their SRA.

VAA/VAG, SIGMET and NOTAM will continue to be issued as set out in the respective standard procedures until the airspace is clear of volcanic ash. The issue times for these products will be the standard issue times unless there is a rapid change in the situation in which case revised material would be issued as quickly as possible.

The focus of this phase is to protect aircraft in flight from the hazards of the eruption, advise operators of the potential volcanic safety risk to assist in the planning of alternative routes and to provide for overall management of airspace.

1.4 Other Definitions

Service Provider: In the context of this document, includes approved training organizations, aircraft operators and approved maintenance organizations, organizations responsible for type design and/or manufacture of aircraft, air traffic service providers and aerodromes.

State of the Operator: A Contracting State that has the regulatory authority with regard to aircraft operators having been issued an Aircraft Operator's Certificate (AOC) by that State.

State of Registry: A Contracting State that has the regulatory authority with regard to aircraft entered on its Register.

Volcanic Cloud: The sum of the material ejected from a volcano into the atmosphere and transported by winds aloft. It comprises volcanic ash, gases and chemicals² (refer section 2.1 of ICAO Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds - Doc 9691).

Volcanic Ash: is comprised predominantly of silica together with smaller amounts of the oxides of aluminium, iron, calcium and sodium. The glassy silicate material is very hard and extremely abrasive (refer section 2.1 of ICAO Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds - Doc 9691).

² Although the specific material being warned for is the ash contained in the volcanic cloud, it is understood that other elements of the cloud may also be undesirable to operate through.

2. INTRODUCTION

There are areas of volcanic activity worldwide that are potentially hazardous to aviation. Volcanic clouds can also be transported long distances by winds into non-volcanic areas. This document sets out guidelines for aircraft operators and the relevant National Aviation Authorities to minimise the safety risk of flight operations in areas known or forecast to be affected by volcanic cloud.

2.1 The hazard

Volcanic clouds may cause:

- the malfunction, or failure, of one or more engines leading not only to reduction, or complete loss, of thrust but also to failures of electrical, pneumatic and hydraulic systems;
- blockage of pitot and static sensors resulting in unreliable airspeed indications and erroneous warnings;
- windscreens to be rendered partially or completely opaque;
- smoke, dust and/or toxic chemical contamination of cabin air requiring crew use of oxygen masks, thus impacting communications; electronic systems may also be affected;
- erosion of external and internal aircraft components;
- reduced electronic cooling efficiency leading to a wide range of aircraft system failures;
- aircraft to be manoeuvred in a manner that conflicts with other aircraft;
- deposits of volcanic ash on a runway degrading braking performance, most significantly if the ash is wet; in extreme cases, this can lead to runway closure.

2.2 Managing the risk

States are required to implement a State Safety Programme, to set an Acceptable Level of Safety and to require all aviation Service Providers to implement a Safety Management System.

The principle of the operator having direct accountability for the safety of its operations is clearly defined in ICAO Annex 6. That Annex specifies an SMS as a key part of an operator's approach to exercising this accountability. ICAO Doc 9859 (Safety Management Manual) provides detailed general guidance on the establishment of an SMS and on the conduct of a Safety Risk Assessment.

One of many issues requiring such an SMS approach, if safe operations are to be assured, relates to operations into airspace with known or forecast volcanic cloud contamination or at aerodromes with runway volcanic ash contamination. The operator is accountable for assessing the risk of such operations and for determining and implementing appropriate mitigation measures. This document describes the SRA approach central to this decision-making process.

Regulatory authorities of the State of the Operator or State of Registry, as appropriate, have an obligation to ensure that the operators they supervise are competent and capable of conducting a robust SRA and that the assessment process itself is robust. It is expected that an NAA would assert satisfaction that it has discharged these responsibilities fully, by formally accepting the SRA of the aircraft operator. This present document sets out the process that NAAs should use in evaluating operator safety risk assessments.

It is further expected that the NAA should maintain adequate ongoing surveillance of the operator so that it can quickly identify those operators who fail to maintain adequate competence, capability and robust procedures to ensure continued safe operations relating to volcanic hazards; in such cases, it is expected that the NAA would take such action as may be necessary to control the risk associated with the operator's lack of competence, capability or necessary procedures. This document indicates how NAAs should maintain the necessary level of oversight.

The safety control measures set out in this document are intended to be sufficiently robust that a State whose airspace is potentially affected by volcanic clouds can, without further investigation, be confident in the ability of operators from other States to undertake operations in their airspace with minimal risk.

There are many other contributors to the overall volcanic risk mitigation system such as Meteorological Watch Offices, Air Navigation Service Providers including Aeronautical Information Services, Meteorological Service providers, Volcanic Ash Advisory Centres, Volcano Observatories and Original Equipment Manufacturers of aircraft and engines. Their cooperation in supplying operators and NAAs with the information necessary to support the pre-flight SRA process and the in-flight and post-flight decision making process is essential if safe operations are to be assured.

2.3 Coordinating the response to a volcanic event

Actions required of the above contributors to secure safe operations in, and close to, known and forecast volcanic ash cloud contaminated areas are set out in other ICAO documents such as:

- ICAO Procedures for Air Navigation Services – Air Traffic Management (PANS),
- ICAO Procedures for Air Navigation Services – Rules of The Air and Air Traffic Services (ICAO Doc 4444),
- ICAO Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds (ICAO Doc 9691),
- ICAO International Airways Volcano Watch (IAVW) Handbook (ICAO Doc 9766), and
- Regional contingency plans such as the EUR/NAT Contingency Plan (EUR Doc 019).

This document, in addressing the role of the aircraft operator and of the operator's NAA, is complementary to the documents listed above. In time, it is expected that the guidance material will be consolidated.

To ensure good coordination between all concerned, it is recommended that operators and their NAAs participate in annual volcanic risk exercises normally organised by ICAO (VOLCEX). In the EUR region, for example, information on these exercises is available on the ICAO Paris website <http://www.paris.icao.int/>.

3. AIRCRAFT OPERATOR

3.1 Responsibilities

- a) The operator is responsible for the safety of its operations.
- b) In order to decide whether or not to operate in airspace, or use aerodromes, which may be contaminated by volcanic clouds, the operator must produce an SRA.

NOTE: Guidance on the production of an SRA is provided in Appendices A (advice on conducting an SRA), B (procedures to be included in an SRA) and C (hazards to be considered). Each operator should develop its own list of procedures and hazards since these must be relevant to the specific equipment, experience and knowledge of the operator, and to the routes to be flown.

- c) The operator must have its SRA accepted by its supervising NAA before initiating operations into airspace, or at aerodromes, which may be contaminated by volcanic clouds.

NOTE: Subject to the provisions set out below regarding the updating of SRAs, it is intended that the operator should present the NAA with an SRA covering its overall operations in which volcanic clouds are a hazard rather than an SRA for each flight.

- d) An operator must have satisfied its NAA regarding the likely accuracy of the information sources it uses in its SRA, its own competence and capability to interpret such data correctly and to reliably resolve any conflicts between data sources that may arise correctly.
- e) The operator must revise its SRA when changes that are material to the integrity of the SRA occur; it must inform its NAA of such updates in a timely manner.
- f) Prior to committing to operations into, or near, volcanic ash contaminated areas, the operator must obtain from the OEMs specific information regarding the susceptibility of the aircraft they operate to volcanic cloud-related airworthiness effects, the nature of these effects and the related pre-flight, in-flight and post-flight precautions to be observed by the operator. These must be reflected in the SRA.

NOTE: If no suitable information is available from the OEMs, then it is expected that the operator will constrain its risk assessment accordingly; it should be assumed that the aircraft or engine has no tolerance to volcanic cloud exposure.

- g) The operator must ensure that those of its personnel needing to be familiar with the details of the SRA receive all relevant information (both pre-flight as well as in-flight) in order to be in a position to apply appropriate mitigation measures as specified by the SRA, especially when the situation deviates from any scenario contemplated in the SRA.
- h) The operator must ensure that any volcanic cloud related incidents are reported immediately to the nearest ATS unit using the VAR/AIREP procedures and followed up by the more detailed part of the VAR on landing together with, as applicable, an ASR and AML entry.

3.2 Procedures

- a) The operator must have documented procedures for the management of operations in and around airspace, or at aerodromes, which may be contaminated by volcanic ash.

NOTE: Procedures must include crew action in the event that they encounter a volcanic cloud (see Appendix E).

- b) These procedures must ensure that, at all times, flight operations remain within accepted safety boundaries despite any variations in information sources, equipment, operational experience or procedures. Procedures should include those for flight crew, flight planners, dispatchers, operations and maintenance personnel such that they are equipped to evaluate correctly the risk of flight into airspace contaminated by volcanic clouds and plan accordingly.

- c) Engineering personnel must be provided with procedures allowing them to correctly assess the need for, and execute, relevant maintenance interventions.
- d) Before committing to operations in and around airspace, or at aerodromes, which may be contaminated by volcanic ash, the operator must ensure that its procedures are accepted by its NAA.
- e) The operator must demonstrate, to the NAA's satisfaction, that it has sufficient qualified staff to ensure that its SRA process generates well supported operational risk management decisions, and that staff are appropriately trained and current.
- f) The operator should encourage its flight operations staff to take up opportunities to be involved in volcanic ash exercises (conducted in their region).

3.3 Sequence of Actions

3.3.1 Alerting Phase (Pre-Eruption)

- a) The operator must have a robust mechanism for ensuring that it is constantly vigilant for any alerts of volcanic activity relevant to its operations. The staff involved must understand the threat to safe operations that such alerts represent. Some operators include this expertise within their "Operations Unit".
- b) To ensure flight safety during the alerting phase, the operator should respond, in accordance with its volcanic ash procedures, to the alerts provided by the relevant competent bodies and to any Danger Areas promulgated.
- c) Due to the probable lack of reliable information during this phase, it is expected that flight crews will initiate or accept re-routes to avoid the affected area and that flights are planned to remain well clear. Fuel requirements due to possible disruption must be assessed.
- d) It is expected that following initial actions will be taken:
 - Alert senior management;
 - Determine if any aircraft in flight could be affected, alerting the crew and re-routing as required;
 - Brief flight crew and revise flight and fuel planning in accordance with the SRA;
 - Alert flight crew and operations staff to the need for increased monitoring of AIREP/VARs, SIGMETs and NOTAMs;
 - Initiate the gathering of all data relevant to determining the risk;

NOTE: If the appropriate ATFM Unit organises regular data sharing teleconferences, the operator should make arrangements to participate

- Apply mitigations identified in the SRA process.

3.3.2 Reactive Phase (Eruption Onset)

- a) During this period, there is likely to be uncertainty regarding the status of the eruption and of the associated volcanic cloud. The operator's procedures should include a requirement for crews to initiate or accept re-routes to avoid the affected airspace.
- b) The operator should ensure that flights are planned to remain clear of the affected area and that consideration is given to available alternate aerodromes and fuel requirements.
- c) The operator must ensure that its Operations Unit, or equivalent, and its crews, have access to plots of the affected area from SIGMETs and NOTAMs.
- d) The operator must monitor, and take into account, SIGMET and NOTAM updates, VAR/AIREPs and other relevant data sources (such as ATFM unit teleconferences, if available).

3.3.3 Proactive Phase (Eruption)

- a) During this phase, the operator can expect the responsible VAAC to provide VAA/VAGs defining, as accurately as possible, the vertical and horizontal extent of volcanic clouds. This may be set out in a format showing forecasted areas of contamination levels, if defined by the VAAC provider State concerned.
- b) As a minimum, the operator must monitor, and take account of, this VAAC information and of relevant SIGMETs and NOTAMs, all of which it should treat as reliable and accurate.
- c) Other sources of information are likely to be available such as VAR/AIREPs, satellite imagery and a range of other information from State and commercial organisations such as, in some regions, regular ATFM unit teleconferences.
- d) The operator should also take account of those additional sources of information it considers accurate and relevant to plan its operations in accordance with its SRA.
- e) The operator must resolve, reliably and correctly, any differences or conflicts among the information sources, notably between published information and observations (pilot reports, airborne measurements, etc.); the operator must, as soon as possible, report such discrepancies to the appropriate authorities including the responsible VAAC and MWO.

- f) Given the dynamic nature of the volcanic hazards, the operator must ensure that the situation is monitored closely and operations adjusted to suit.
- g) The operator should be aware that, depending on the State concerned:
 - i. Danger Areas may be established that differentiate between various levels of volcanic ash contamination such as the Low, Medium and High contamination thresholds currently being used in Europe;
 - ii. Danger Areas may be established covering airspace containing volcanic ash regardless of the contamination level. If no graduation of the volcanic ash contamination is given, operators should treat the whole area as if it contains High volcanic ash contamination.

Note: VAACs that are not currently doing so are being encouraged to work towards providing information on contamination levels.

- h) The operator should solicit reports from its crews operating in or close to areas affected, concerning any encounters with volcanic emissions, and ATC requirements. These reports should be passed immediately to the responsible VAAC and MWO.
- i) For the purpose of flight planning, the operator should treat the horizontal and vertical limits of the Danger Area to be over-flown as they would mountainous terrain. The operator must take account of the risk of cabin depressurisation or engine failure resulting in the inability to maintain level flight above the Danger Area, especially when conducting ETOPS operations. Additional MEL restrictions should be considered.
- j) When the airspace is no longer contaminated by volcanic ash, a NOTAMC cancelling the active NOTAM will be promulgated. A new NOTAM/ASHTAM will be promulgated to update the situation.

4. NATIONAL AVIATION AUTHORITY

4.1 Allocation of Responsibilities

- a) ICAO Annex 6, Chapter 3, requires the State of the Operator (or State of Registry, if appropriate) to establish a State Safety Programme, a fundamental component of which, is a safety oversight function. As part of this function, the State is required to evaluate those operators under its supervision. It falls, therefore, to that State to evaluate the relevant competence and capability of those who plan to operate in, or near, areas where the presence of volcanic ash clouds is known or forecast.

- b) To achieve this outcome, the NAA of the State of the Operator or Registry (referred to as “the NAA” hereafter) must ensure that the operators it supervises are competent and capable of conducting a robust safety risk assessment in respect of volcanic cloud contamination and that the process itself is robust.
- c) The NAA should assert that it has discharged these responsibilities fully, by formally accepting the SRA of the aircraft operator, thus authorising that operator to conduct operations into, or near, potentially contaminated areas. The guidance that follows indicates the process that the NAA should use in achieving this outcome.

NOTE: The significant of the NAA accepting, rather than approving, the operator’s SRA is that the operator clearly retains responsibility for managing the risks and mitigating measures.

- d) The safety risk control measures set out in this document are intended to be sufficiently robust that a Provider State whose airspace is potentially contaminated by volcanic ash can, without further investigation, be confident in the ability of operators, successfully evaluated by another State, to undertake operations with minimal safety risk in their airspace.

4.2 NAA Responsibilities

- a) In accordance with ICAO Annex 6, Chapter 3, paragraph 3.3, the State of the Operator/Registry should require any operator planning to operate in areas where the presence of volcanic ash is known or forecast to carry out an SRA prior to initiating operations.
- b) The NAA must be satisfied, prior to the planned operation, that any operator it supervises that intends to operate in airspace, or to/from aerodromes affected by volcanic ash, has completed an SRA relevant to its type of operation, and which has been found acceptable to the NAA.
- c) The NAA must evaluate the SRA to determine whether the operator has demonstrated that it has the competence and capability to understand the nature of the hazards and the associated impact on the equipment being operated.
- d) The NAA must also be satisfied that the operator has the necessary procedures and that they are robust.
- e) The NAA must, in addition, be satisfied that sufficient numbers of qualified staff are available to the operator, and that they are adequately trained and current in relation to the duties necessary to assure safe operations in or near areas of known or forecast volcanic ash contamination.

- f) The NAA must be satisfied with the information sources an operator uses in its SRA, and its competence and capability to interpret the information correctly and resolve confliction.
- g) The NAA must be satisfied that the operator has taken account of detailed information from its OEMs concerning volcanic ash-related airworthiness aspects of the aircraft they operate, and the related pre-flight, in-flight and post-flight precautions to be observed by the operator.
- h) Whilst ash contamination continues to be a relevant operational hazard, the NAA is responsible for monitoring the performance of the successfully evaluated operator against its SRA such that it can quickly identify when the operator fails to maintain adequate competence, capability or robust procedures to ensure continued safe operations relating to volcanic hazards; in such cases, it is expected that the NAA would take such action as is necessary to secure safe operations.

4.3 Objectives

- a) In order to evaluate an operator's SRA, the NAA must understand the nature of volcanic hazards and their effects on aircraft.
- b) The NAA must have an understanding of the volcanic ash forecasting methodology and its likely accuracy and of the capabilities and limitation of observational capabilities of tools such as satellite imagery
- c) The NAA must have a thorough understanding of SRA principles and methodology.
- d) The NAA should solicit such information from OEMs as is necessary to confirm the airworthiness-related decisions of the operator.
- e) The NAA must develop a methodology that allows it to evaluate the acceptability of the SRA submitted by the operator and to appraise both the risk and mitigating procedures identified therein. This must include pre-flight, in-flight and post-flight activities. An example of an evaluation tool can be found at Appendix F. This evaluation process should be repeated at suitable intervals.
- f) The NAA must have the means to impose such restrictions on its operators as are necessary to minimise the volcanic ash safety risk.
- g) An operator may fail to establish and maintain an acceptable SRA, and associated resources and procedures, or may exhibit a lack of understanding of relevant issues; in such cases, it is expected that the NAA supervising the operator will prohibit it from operating near or in airspace, and into or out of aerodromes, that are known or forecast to be contaminated by volcanic ash.

- h) The NAA should encourage those of its staff involved in evaluating operator SRAs to take up any opportunity to be involved in such VOLCEX exercises as are conducted in their region.
- i) Where an NAA considers that it lacks the capability to assess an operator's SRA, it should enlist the assistance of an NAA with this capability.

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APPENDIX A

GENERAL GUIDANCE TO COMPLETING A SAFETY RISK ASSESSMENT

A1 Introduction

Risk is an assessment of the likelihood and severity of adverse consequences resulting from a hazard. To help an operator to decide on the likelihood of a hazard causing harm, and to assist with possible mitigation of any perceived safety risk, all pertinent information available should be taken into account and relevant stakeholders consulted.

The safety risk from each hazard should be assessed using a suitable safety risk register. The safety risk should be derived by considering the severity of the safety risk outcome arising from the hazard, together with the likelihood of that outcome.

The severity of any adverse consequences resulting from a particular hazard should be assessed using a suitable severity scale.

ICAO's generic safety risk assessment process is described in the ICAO *Safety Management Manual* (Doc 9859 Section 6.3, Issue 1, 2006). Alternative approaches, aligned with an organisation's approved SMS, would be equally appropriate.

A2 The Process Steps

When made specific to the issue of intended flight into, or close to, volcanic ash contaminated airspace, then the process involves:

- Identifying the hazard (i.e. airspace or aerodromes with known or forecast contamination by volcanic ash with characteristics harmful to the airworthiness and operation of the aircraft);
- Evaluating the likelihood or probability of this happening;
- Considering the seriousness of the hazard occurring (i.e. the actual level of damage expected to be inflicted on the particular aircraft from exposure to that volcanic ash);
- Determining whether the consequent risk is acceptable and within the organisation's risk performance criteria;
- Taking action to reduce the safety risk to as low as reasonable practicable and at least to an acceptable level.

A2.1 Hazard Identification

The hazard, in the context of this document, is airspace or aerodromes with known or forecast contamination by a volcanic ash cloud with characteristics harmful to the airworthiness and operation of the aircraft.

Guidance on the list of procedures to be considered is given in Appendix B. Guidance on the risks to be considered is given in Appendix C. Neither of these lists is exhaustive; the operator must develop its own taking into account its specific equipment, experience, knowledge and type of operation.

A2.2 Risk Likelihood

For each hazard, the likelihood, or probability, of adverse consequences should be assessed, either qualitatively or quantitatively, using a suitably calibrated likelihood or probability scale. When assessing likelihood or probability, the following factors should be taken into account:

- Any uncertainties in available information;
- The duration of exposure to the hazard and associated severity;
- Any historic incident or safety event data relating to the hazard. This can be derived using data from OEMs, regulators, other operators, Air Navigation Service Providers, internal reports etc;
- The expert judgement of relevant stakeholders notably from OEMs.

The results of this phase of the assessment should be recorded in a risk register, an example of which is at Appendix D.

A2.3 Risk Severity

For each hazard, the potential adverse consequences or outcome should be assessed. Again, the results of this phase of the assessment should be recorded in a risk register, such as that reproduced at Appendix D.

A2.4 Risk Tolerability

At this stage of the process, the safety risks should be classified in a range from acceptable to unacceptable. Appropriate mitigations for each identified risk should then be considered, recorded on the risk register and implemented. Mitigations must be adopted in order to reduce all the safety risks.

By these means, the mitigation process should reduce the overall safety risk to as low as reasonably practicable and to at least an acceptable level.

Not all risks can be suitably mitigated; in such cases, the operation should not proceed.

A2.5 Mitigating Actions

Mitigating actions by themselves can introduce new risks. Where an organisation has an effective SMS, procedures should exist for continuous monitoring of hazards and risk, with qualified personnel establishing the mitigating actions or halting affected operations.

As the circumstances on which the original assessment was predicated may change, an operator without an effective SMS should repeat the safety risk assessment following any mitigation process and at regular intervals.

A3 Records

The results of the safety risk assessment should be documented and submitted to the operator's NAA. Mitigating actions should be completed and verified and supported by evidence prior to the start of operations.

Any assumptions should be clearly stated, and the safety risk assessment reviewed at regular intervals, to ensure that the assumptions and decisions remain valid.

Any safety performance monitoring requirements should also be identified and undertaken through the organisation's safety risk management processes.

APPENDIX B

PROCEDURES TO BE CONSIDERED BY AN AIRCRAFT OPERATOR WHEN CONDUCTING A SAFETY RISK ASSESSMENT

Considerations	Guidance
Preparation	
Type Certificate Holder Guidance	<p>The operator must obtain advice from the OEMs of the aircraft it operates concerning operations in potentially contaminated airspace and/or to/from aerodromes contaminated by volcanic ash. This advice must set out:</p> <ul style="list-style-type: none"> – the features of the aircraft that are susceptible to airworthiness effects related to volcanic ash clouds; – the nature and severity of these effects and how these vary with the varying characteristics of ash clouds; – the effect of volcanic ash on operations to/from contaminated aerodromes; – the related pre-flight, in-flight and post-flight precautions to be observed by the operator – The recommended continuing airworthiness inspections associated with operations in volcanic ash contaminated airspace and to/from volcanic ash contaminated aerodromes.
Guidance for Operator Personnel or their Service Providers	<p>The operator must publish procedures for flight planning, operations and maintenance ensuring that:</p> <ul style="list-style-type: none"> – flight planners, operations staff and dispatchers are equipped to evaluate correctly the risk of flight into volcanic ash-contaminated airspace, or aerodromes, and can plan accordingly; – flight crew planning and operational procedures enable them to avoid areas and aerodromes with unacceptable volcanic ash contamination levels; – flight crew can detect volcanic ash and execute the associated escape manoeuvres; – engineering personnel are able to assess the need for, and to execute, any necessary maintenance interventions.

Considerations	Guidance
Operator procedures	
Provision of Enhanced Flight Watch	<p>The operator must:</p> <ul style="list-style-type: none"> – closely and continuously monitor VAA, VAR/AIREP, SIGMET, NOTAM and ASHTAM information, and information from its crews, concerning the volcanic ash cloud hazard; – ensure that the latest information is communicated to its crews and planners in a timely fashion.
Flight Planning	<p>The operator must plan flights to remain clear of areas with an volcanic ash contamination level beyond that for which it has developed an SRA accepted by its NAA. The operator's process must be sufficiently flexible to allow re-planning at short notice should conditions change.</p>
Departure, Destination and Alternates	<p>For the airspace to be traversed, or the aerodromes in use, the operator must determine, and take account of:</p> <ul style="list-style-type: none"> – the degree of known or forecast contamination; – any additional aircraft performance requirements; – required maintenance considerations; – fuel requirements for re-routeing and extended holding.
Routeing Policy	<p>The operator must determine, and take account of,:</p> <ul style="list-style-type: none"> – the shortest period in and over the contaminated area; – the hazards associated with flying over the contaminated area; – drift down and emergency descent considerations.
Diversion Policy	<p>The operator must determine, and take account of:</p> <ul style="list-style-type: none"> – maximum allowed distance from a suitable alternate; – availability of alternates outside contaminated area; – diversion policy after an volcanic ash encounter.
Minimum Equipment List / Dispatch Deviation Guide	<p>The operator must consider additional restrictions for dispatching aircraft with unserviceabilities which might affect:</p> <ul style="list-style-type: none"> – air conditioning packs; – engine bleeds; – air data computers; – standby instruments;

	<ul style="list-style-type: none"> – navigation systems; – de-icing systems; – engine driven generators; – Auxiliary Power Unit (APU); – Airborne Collision Avoidance System (ACAS); – Terrain Awareness Warning System (TAWS); – Autoland systems; – provision of crew oxygen; and – supplemental oxygen for passengers. <p>(This list is not exhaustive)</p>
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Considerations	Guidance
Flight Crew Procedures	
Standard Operating Procedures	<p>The operator must ensure that crews review changes to normal and abnormal operating procedures regarding:</p> <ul style="list-style-type: none"> – pre-flight planning; – in-flight monitoring of volcanic cloud affected areas and avoidance procedures; – diversion policy; – communications with ATC; – in-flight monitoring of engine and systems potentially affected by volcanic ash contamination; – in-flight indications of a volcanic ash encounter; – procedures to be followed if a volcanic cloud is encountered; – unreliable erroneous airspeed; – non-normal procedures for engines and systems potentially affected by volcanic ash contamination; – engine-out and engine relight; – escape routes; and – operations to/from aerodromes contaminated with volcanic ash. <p>(This list is not exhaustive)</p> <p>Note: In promulgating changes to SOPs, it is anticipated that the normal practice of the operator will be to not only ensure appropriate briefing of these changes but also to ensure that any necessary training is completed.</p>

Technical Log	<p>The operator must ensure that crews:</p> <ul style="list-style-type: none"> – make an Technical Log entry for each operation to or from an aerodrome which may be contaminated; – make an Technical Log entry related to any actual or suspected volcanic ash encounter; – confirm, prior to flight, completion of maintenance actions related to an Technical Log entry for a volcanic ash encounter on a previous flight.
Incident Reporting	<p>The operator must specify crew requirements for:</p> <ul style="list-style-type: none"> – reporting an airborne encounter (VAR); – post-flight reporting (VAR); – filing a mandatory occurrence report where required by the State.

Considerations	Guidance
Maintenance Procedures	
Maintenance Procedures	<p>An operator operating in, or near, areas of volcanic ash contamination, should:</p> <ul style="list-style-type: none"> – enhance vigilance during inspections and regular maintenance and make appropriate adjustments to maintenance practices; – have produced a continuing airworthiness procedure to follow when a volcanic ash encounter has been reported or suspected; – ensure that a thorough investigation is carried out of any signs of unusual or accelerated abrasions or corrosion or of volcanic ash accumulation; – co-operate in reporting to OEMs and the relevant authorities their observations and experiences from operations in areas of volcanic ash contamination; – comply with any additional maintenance recommended by the OEM.

Note: The above list is not exhaustive; the operator must develop its own list taking into account its specific equipment, experience, knowledge and type of operation.

APPENDIX C

HAZARDS TO BE CONSIDERED BY AN AIRCRAFT OPERATOR WHEN CONDUCTING A SAFETY RISK ASSESSMENT

Activity or Issue	Hazard	Potential Outcome
Flight Planning		
Lack of awareness, or incorrect interpretation, of regulations or restrictions mandated by the Authorities of the State in which the airspace or aerodromes are known or forecast to be contaminated by volcanic clouds	Safety restrictions imposed, or safety requirements defined, by the Authorities not correctly incorporated into the flight planning process	Inadvertent volcanic ash encounter
Lack of awareness, or incorrect interpretation, of volcanic ash concentration information provided to Operator's flight planners	Volcanic ash concentration data not correctly incorporated into the flight planning process	Inadvertent volcanic ash encounter
Lack of awareness, or incorrect interpretation, of volcanic ash concentration information provided to crews at pre-flight briefing	Crews unaware of correct extent and position of volcanic clouds	Inadvertent volcanic ash encounter
Incorrect, or misunderstood, information regarding status of aircraft away from base	Aircraft no longer in compliance with airworthiness requirements	Operation by aircraft not legally authorized to operate
Incorrect, or misunderstood, information regarding status of crew away from base	Crew out of compliance or recency	Operation with crew not legally authorized to operate
Ground equipment in temporary storage state	Equipment not operating as designed or intended following temporary storage	Dependent on equipment concerned
etc		

Activity or Issue	Hazard	Potential Outcome
In-flight (volcanic cloud avoidance)		
Communication of volcanic cloud movement to crews in-flight	Crews unaware of the position or extent of the volcanic ash-contaminated area	Inadvertent volcanic cloud encounter
Change in location of volcanic ash-affected area that incorporates an area in which an aircraft is flying	Crews unaware of the position or extent of the volcanic ash-contaminated area	Inadvertent volcanic cloud encounter
Provision of graphical data to crews	Crews unaware of the position or extent of the volcanic ash-contaminated area	Inadvertent volcanic cloud encounter
etc		
In-flight (inadvertent volcanic cloud encounter)		
Pitot and probe blockage	<ul style="list-style-type: none"> – Unreliable, or erroneous, airspeed – Aircraft control problems – Thrust control reduced 	Loss of control
Window abrasion	<ul style="list-style-type: none"> – Restricted external vision – Loss of visual reference 	Loss of control / runway excursion
Turbine and compressor damage	<ul style="list-style-type: none"> – Anomalous engine behaviour – Loss of thrust: single engine – Loss of thrust: all engines 	<ul style="list-style-type: none"> – Increased crew workload – Diversion – Forced landing
Fuel Contamination	Loss of thrust: all engines	Forced landing
Air-conditioning Pack volcanic cloud ingestion	<ul style="list-style-type: none"> – Loss of cabin pressurisation – Noxious fumes in cabin 	Emergency descent / Diversion / Loss of control
Equipment Cooling Failure due volcanic cloud ingestion	Anomalous behaviour of aircraft systems	<ul style="list-style-type: none"> – Increased crew workload – Diversion – Forced landing – Loss of control
Volcanic cloud static charge	Prolonged loss of communications	<ul style="list-style-type: none"> – Increased crew workload – Increased ATC workload
Escape Manoeuvre	Conflict with another aircraft	Mid air collision
etc		

Post-flight		
Failure to report an volcanic cloud encounter	Unreported damage	Aircraft departs in an un-airworthy state
	Operator and ATC not aware of the position of a volcanic cloud	Other aircraft encounter volcanic clouds
etc		

Note: The above list is not exhaustive; the operator must develop its own list taking into account its specific equipment, experience, knowledge and type of operation.

Appendix D

Example of a Risk Register

Hazard		Incident Sequence Description	Existing Controls	Outcome (Pre-Mitigation)			Additional Mitigation Required	Outcome (Post-Mitigation)			Actions and Owners	Monitoring and Review Requirements
No.	Description			Severity	Likelihood	Risk		Severity	Likelihood	Risk		
1	Turbine & Compressor damage	Loss of thrust – all engines	Avoidance, crew procedures	High	Remote	Unacceptable	Flight planning, crew procedures & training to avoid volcanic clouds	High	Extremely Remote	Review	Flight Operations	Further information from OEMs, improved volcanic ash modelling
2	Flight planned in NOTAMed volcanic ash affected airspace	Inadvertent entry into volcanic ash affected airspace	Avoidance	Medium	Possible	Unacceptable	Ops monitoring of NOTAMs improved. Procedures to alert crews. Crew in flight monitoring	Medium	Extremely Remote	Acceptable	Operations, Flight Operations	

APPENDIX E

PILOT RESPONSE WHEN ENCOUNTERING A VOLCANIC CLOUD

E1 Recognising a volcanic ash encounter

Note that airborne weather radar does not detect volcanic ash, and low concentrations may not be detected by the crew. The following are a list of symptoms which may be expected if volcanic ash is encountered:

- a) Odour: When encountering a volcanic ash cloud, flight crews usually notice a smoky or acrid odour that can smell like electrical smoke, burned dust, or sulphur;
- b) Static discharges: An electrostatic phenomenon similar to St. Elmo's fire or glow can occur. In these instances, blue-coloured sparks can appear to flow up the outside of the windshield or a white glow can appear at the leading edges of the wings or at the front of the engine inlets;
- c) Changing engine conditions: Surging, torching from the tailpipe and flameouts can occur; engine temperatures can change unexpectedly and a white glow can appear at the engine inlet;
- d) Engine restarts: Engines may accelerate to idle very slowly, especially at high altitudes (could result in inability to maintain altitude or Mach number);
- e) Haze: Most flight crews, as well as cabin crew or passengers, see a haze develop within the aircraft; dust can settle on surfaces;
- f) Airspeed: If volcanic ash fouls the pitot tubes, the indicated airspeed can decrease or fluctuate erratically, with associated effects on aircraft systems;
- g) Pressurization: Cabin pressure can change, including possible loss of cabin pressurization;
- h) Landing lights: Can cast sharp distinct shadows;
- i) Cockpit windows: Possible loss of visibility due to windows becoming cracked or discoloured due to the sandblast effect of the volcanic ash.

E2 Escape from a volcanic cloud encounter

Should a volcanic cloud be encountered, operators should follow the recommendations of their OEMs, which are overriding. The following generalised response will normally apply:

- a) Make a 180° turn. Generally this will provide the shortest route out of the cloud, due to the possibility of it extending over a vast area;

- b) Decrease thrust if conditions permit. High thrust and hence turbine temperatures increases the risk of volcanic particles melting and causing build-ups in the turbine area;
- c) Don crew oxygen masks (100%);
- d) Report to ATC. Any observation of volcanic activity or volcanic cloud encounter should be reported immediately to ATC using the VAR/AIREP procedures and subsequently by filing the more detailed part of the VAR;
- e) Increase bleed demand, e.g. select wing and engine anti-ice ON. This increases the surge margins and reduces the likelihood of a flameout;
- f) Start the APU. This provides an additional generator in case of a flameout;
- g) Monitor engine parameters and airspeed indications. The latter may be rendered unreliable by ash. Be prepared to use the unreliable airspeed indication drills;
- h) File an ASR and make a Technical Log entry.

Note: The effects of volcanic ash on the engine may alter the engine in-flight restart envelope. Engine stall and surge margin can be reduced. Crews should be aware that loss of all engine power in such circumstance can result in significant altitude loss with restart altitude potentially far below the upper corner of the windmill relight envelope.

Note: The content of this Appendix is the subject of work underway in IVATF AIR 05 team. The outcome from that work will be reflected here noting that there is an overlap with the information set out in ICAO Doc 9766 (IAVW Manual) 4.7 "Action To Be Taken By Pilots In The Event Of Entry Into A S02 Cloud"

APPENDIX F

GUIDANCE TO NAAs ON EVALUATING AN OPERATOR'S CAPABILITY TO CONDUCT FLIGHTS SAFELY IN RELATION TO VOLCANIC CLOUD

F1 State roles

- a) This document has been written recognising that primary responsibility for the supervision of operators operating in proximity to, or into, areas known or forecast to be contaminated by volcanic ash clouds, rests with the NAA of the State of Registry or State of the Operator as appropriate.
- b) The guidance set out below is intended to assist such NAAs in their task of authorising operators of their State to undertake operations into airspace that is potentially contaminated by volcanic ash.
- c) For States whose airspace is potentially contaminated by volcanic ash, it is intended that the control measures specified in this document should be sufficient to satisfy their need to be confident in the ability of operators from other States to undertake operations safely into airspace that is known or forecast to be contaminated by volcanic ash; no further action on the part of States whose airspace is potentially contaminated by volcanic ash is intended.

F2 NAA of the State of Registry / State of the Operator

- a) The responsibility of the NAA of the State of Registry/Operator is to be assured that the operator has put in place all necessary measures to assure a safe outcome from flights into, or in proximity to, areas with known or forecast contamination by volcanic material.
- b) The primary mechanisms for the NAA to gain the necessary confidence in the operator's ability to minimise safety risk in operations are an ongoing evaluation of the operator's Safety Risk Assessment (SRA) and of the operator's continuing competence and capability.
- c) The objective of the SRA is to demonstrate that the operator has the capability and competence to:-
 - understand the hazards associated with volcanic ash clouds and their affect on the equipment being operated;
 - be clear on where these hazards may exceed acceptable safety risk limits;
 - identify and implement mitigations including suspension of operations where mitigation cannot reduce the risk to within safety risk limits;

- produce and execute effectively robust procedures for planning and operating flights through, or near, potentially contaminated airspace safely and implement any associated training.
- d) It is assumed that acceptable safety risk limits are exceeded when there is no longer a high level of confidence that the aircraft can continue to be operated with minimal safety risk and landing at its intended destination.
- e) In order to be assured that the operator understands the hazards, the NAA should assess the range of sources that the operator is intent on using to drive its risk assessment such as VAAC forecasts, NOTAMs, satellite data, LIDAR data etc. Is there a high degree of confidence that this data will be up to date, correct and properly interpreted?
- f) In order to be confident that the operator knows what its safety risk limits are, the NAA should assess what OEM guidance the operator has used to indicate the volcanic ash tolerance of its equipment? The type of operation being flown and the previous experience of the operator should also be taken into account.
- g) To assess whether the operator has robust documented procedures to ensure that the operation stays within limits, the NAA should check that:
- an acceptable risk assessment been completed and recorded in a formal Hazard Log (example at appendix D);
 - that all recorded mitigations have been correctly put in place;
 - the operator's management team can demonstrate adequate knowledge of the hazards involved;
 - the operational procedures specified by the operator are robust;
 - that the operator's staff are trained in the relevant procedures.
- h) An analysis of the output from the operator's Safety Risk Assessment allows the NAA to review its Hazard Analysis competency and Safety Culture in a coherent way, and provide an indication of the degree of confidence. A Safety and Risk Assessment Matrix is given at Appendix G to guide NAAs through the process of evaluating operator Safety Risk Assessments. It is acknowledged that the nature of this assessment is such that it does not lend itself to a substantive quantitative approach though such an approach would be welcome in due course.
- i) In using the Safety and Risk Assessment Matrix, it is expected that any "NO" rating in the Authorisation section would result in prohibition of planned operations or suspension of ongoing operations. It is expected also that any unacceptable elements in the evaluation process would result in operational restrictions up to and including prohibition or suspension of operations. Similarly, should the operator fail to achieve any elements of best practice, then the NAA should anticipate an increased likelihood of the operator failing

to sustain acceptable standards; in such cases, the NAA would be expected to enhance its surveillance of the operator accordingly.

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APPENDIX G SAFETY AND RISK ASSESSMENT MATRIX

THE OPERATION

Operator	
AOC No	
Aircraft Type(s)	
Engines	
No of aircraft	
Zones of Operation	

AUTHORISATION

Has the operator satisfactorily demonstrated:	Adequate understanding of the nature and location of the hazards?	YES/NO
	Clarity as to its safety risk limits?	YES/NO
	Robust documented procedures to ensure that the operation stays within limits?	YES/NO
	Adequate competence and capability to reliably execute its documented procedures on an on-going basis?	YES/NO
Has this demonstration been documented?	By the Operator?	YES/NO
	By the NAA?	YES/NO
Authorisation	Has the SRA been accepted thus signifying that the NAA is satisfied that the operator can operate, in accordance with its procedures, into areas of known or forecast contamination by volcanic material?	YES/NO

EVALUATION

Factor	Evaluated As			Notes
	<u>Unacceptable</u>	<u>Acceptable</u>	<u>Best Practice</u>	
Safety Policy	No policy in place, or poorly developed/ inappropriate	An appropriate safety policy is in place	Management commitment to the safety policy is evident in all that the operator does	
	No evidence of commitment to/ action in line with the policy	The policy is linked to other company practices/activities	Safety is integral to business improvement in all relevant aspects of the operator's activity	
	Policy has not been approved at senior management level nor communicated effectively to staff	Policy has been approved and promulgated by senior management and is understood by all staff	Evidence that the policy has been approved and promulgated by senior management, is understood by all staff and staff understand and act on the policy in day to day business	

Understanding Risks	Operating procedures and practices do not reflect adequately the risks and hazards from this kind of activity	Operating procedures and practices reflect adequately the known risks/hazards of this type of activity	Evidence that the procedures and practices reflect well the known risks/hazards of this type of activity and the operator is proactive in receiving and sharing information regarding relevant risks/hazards with aviation community	
	No particular effort made to identify or assess hazards/risks specific to this particular operation	An adequate Hazard identification and prioritisation carried out for this specific operation	Clear evidence of a regular review and update of hazard/risk assessment in light of own and others' experience	
	No documented picture of risks/ hazards faced ("Safety Risk Profile")	Documented Safety Risk Profile is in place	Staff understand the Safety Risk Profile and demonstrate commitment to their part in risk control	
	Own experience not factored into any documented picture of risks/ hazards the operator faces	Own incident & occurrence experience is factored into picture of risks/hazards faced	Leaders in understanding of relevant risks, based on own knowledge and evidence from elsewhere	