IVATF/2-REPORT

SECOND MEETING

OF THE INTERNATIONAL VOLCANIC ASH TASK FORCE (IVATF/2)

(Montréal, Canada, 11 to 15 July 2011)

INTERNATIONAL CIVIL AVIATION ORGANIZATION

TABLE OF CONTENTS

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Agenda Item 1: Opening of the meeting and organizational matters

1.1 Place and duration

1.1.1 The second meeting of the International Volcanic Ash Task Force (IVATF/2) was held at ICAO Headquarters, Montréal, Canada, 11 to 15 July 2011.

1.1.2 The meeting was opened on 11 July 2011 at 1400 hours by Mr. M. Costa, Chief, Accident Investigation Section, on behalf of Ms. N. Graham, Director, Air Navigation Bureau, ICAO Headquarters. Mr. Costa welcomed the participants and highlighted that the meeting was an ideal opportunity to determine what progress had been made over the last 12 months on the tasks assigned to the IVATF Sub-Groups, and identify what further effort would be required in order for the IVATF to deliver on its mandate over the next 12 months. Mr. Costa emphasized that the continued contribution of the experts played a pivotal role in how the international civil aviation community could better respond to the hazards posed by volcanic ash.

1.2 **Attendance**

1.2.1 The meeting was attended by experts from 14 States and 10 international organizations. The list of participants is given in **Appendix 1A**.

1.3 **Programme coordinator, project managers and officers of the Secretariat**

1.3.1 The Programme Coordinator of the IVATF, Mr. P. Lechner, presided over the meeting throughout its duration.

1.3.2 The Project Managers of the four IVATF Sub-Groups were as follows: Mr. L. Lachance on behalf of the Air Traffic Management Sub-Group (ATM SG); Mr. R. van der Boom on behalf of the Airworthiness Sub-Group (AIR SG); Ms. M. Guffanti on behalf of the Science Sub-Group (SCI SG); and Mr. A. Tupper on behalf of the International Airways Volcano Watch Coordination Group (IAVW CG).

1.3.3 Mr. G. Brock, Chief, Meteorology (MET) Section was the Secretary of the meeting, assisted by Mr. R. Romero, Technical Officer, MET Section; Mr. F. Robert, Technical Officer, Air Traffic Management (ATM) Section; Mr. M. Marin, Technical Officer, Flight Operations (OPS) Section; Mr. M. Hohm, Technical Officer, Future Aviation Systems and Technology (FAST) Section; Mr. A. Coutu, Technical Officer, OPS Section; and Mr. K. Theil, Consultant/MET.

Agenda Item 1: Opening of the meeting and organizational matters
1.1: Adoption of the working arrangements

1.4 **Adoption of the working arrangements**

1.4.1 The meeting adopted appropriate working arrangements.

Agenda Item 1: Opening of the meeting and organizational matters
1.2: Adoption of the working arrangements

1.5 **Adoption of the agenda**

1.5.1 The following agenda was adopted:

Agenda Item 1: Opening of the meeting and organizational matters

1.1: Adoption of the working arrangements
1.2: Adoption of the agenda
1.3: Follow-up of IVATF/1 action(s)

Agenda Item 2: Report of the Science Sub-Group (SCI SG)

2.1: Volcanic ash cloud detection/avoidance systems and associated guidance
2.2: Situational awareness improvements of impending volcanic eruptions
2.3: Supporting requirements for airworthiness determination
2.4: Technologies and systems to support improved eruption source parameterization for dispersion modelling
2.5: Model improvements and validation
2.6: Health effects on aircraft occupants of exposure to volcanic sulphur dioxide
2.7: Other issues

Agenda Item 3: Report of the Airworthiness Sub-Group (AIR SG)

3.1: Volcanic ash cloud airworthiness effects and associated criteria, procedures and guidance
3.2: Pre-flight/dispatch and in-flight crew procedures and guidance
3.3: Maintenance and inspection procedures and guidance
3.4: Aerodrome procedures impacting on airworthiness
3.5: Airworthiness certification implications
3.6: Original equipment manufacturer crisis response plan
3.7: Other issues

Agenda Item 4: Report of the Air Traffic Management Sub-Group (ATM SG)

4.1: Air traffic management contingency planning, procedures and guidance
4.2: Flight planning information dissemination
4.3: Operational information exchange
4.4: Other issues

Agenda Item 5: Report of the International Airways Volcano Watch Coordination Group (IAVW CG)

5.1: Volcanic ash-related provisions and guidance
5.2: Collaborative decision making
5.3: Transport and dispersion modelling
5.4: Volcanic ash data files
5.5: Volcano observatory arrangements
5.6: Other issues

Agenda Item 6: Future work programme

Agenda Item 7: Any other business

Agenda Item 1: Opening of the meeting and organizational matters
1.3: Follow-up of IVATF/1 action(s)

1.6 **Follow-up of IVATF/1 action(s)**

1.6.1 The IVATF recalled that at its first meeting (IVATF/1 held 27 to 30 July 2010) had formulated Action agreed 1/1 concerning the deliverables of the IVATF for 2010 to 2011. In addition, the IVATF recalled that four Sub-Groups of the IVATF had been established – namely an Air Traffic Management Sub-Group (ATM SG), an Airworthiness Sub-Group (AIR SG), a Science Sub-Group (SCI SG) and an International Airways Volcano Watch Coordination Group (IAVW CG) – to progress the work of the task force during the intersession period. Each Sub-Group had had a number of tasks assigned at IVATF/1 (Appendix B of the IVATF/1 report refers).

1.6.2 Concerning part a) of Action agreed 1/1, relating to the endorsement of the deliverables and corresponding milestones, the IVATF was informed that two additional tasks (with deliverables and milestones) had been added to the 25 tasks established at IVATF/1. The IVATF was pleased to note that progress reports on all of the 27 tasks had been prepared by the respective IVATF Sub-Groups for consideration under Agenda Items 2 to 5 inclusive.

1.6.3 The IVATF noted that, taking into consideration the progress reports, the meeting would be expected to identify those tasks that could be considered complete (i.e. having been delivered within the allotted time) and those tasks that were considered incomplete and thus required further attention, perhaps with a refocusing of the activity and/or a revised milestone. The IVATF noted that all outstanding tasks, plus any new tasks identified, would form part of the future work programme developed under Agenda Item 6. Recalling that tasks allocated to the IAVW CG would be transferred to the International Airways Volcano Watch Operations Group (IAVWOPSG) for follow-up action, the meeting noted that it would *only* be possible to determine those proposals suitable for IAVWOPSG/6 consideration (15 to 23 September 2011, Dakar, Senegal) once the IVATF/2 meeting had concluded. Therefore, the IVATF concurred that the Secretariat would work with the IAVW CG after IVATF/2 in order to prepare an IAVWOPSG/6 working paper accordingly.

1.6.4 Concerning part b) of Action agreed 1/1, relating to the endorsement of a template for use by the IVATF Sub-Group Project Managers to report progress at quarterly teleconferences, the IVATF was pleased to note that the template had been used for teleconferences held on 27 October 2010, 26 January 2011 and 20 April 2011, with the quarterly progress reports available on the IVATF website[1].

1.6.5 Concerning part c) of Action agreed 1/1, relating to the recommendations identified by the European and North Atlantic Volcanic Ash Task Force (EUR/NAT VATF) that were to be addressed by the IVATF Sub-Groups concerned, the IVATF was pleased to note that all recommendations had been encapsulated within the tasks and deliverables of the respective IVATF Sub-Groups, and that consequently the progress reports at Agenda Items 2 to 5 inclusive would provide a necessary status update. The IVATF was informed that, recognizing the importance to the EUR/NAT Region that the recommendations were being addressed by the IVATF Sub-Groups, the Secretariat would ensure that States in the EUR/NAT Region would be apprised accordingly of the progress being made by the IVATF, through the EUR/NAT Regional Office.

1.6.6 In view of the foregoing, noting in particular:

[1] http://www2.icao.int/en/anb/met/ivatf/Progress%20Reports/Forms/AllItems.aspx

a) the online availability of quarterly progress reports of the IVATF Sub-Groups;

b) that the IAVW Coordination Group would prepare, following the IVATF/2 meeting, a working paper for the IAVWOPSG/6 meeting on the appropriate IAVW recommendations stemming from the IVATF; and

c) that the recommendations arising from the EUR/NAT VATF had been or were being addressed as part of the IVATF Sub-Group deliverables;

the IVATF agreed that the status of follow-up of IVATF Action agreed 1/1 could be considered complete.

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Agenda Item 2: Report of the Science Sub-Group (SCI SG)
2.1: Volcanic ash cloud detection/avoidance systems and associated guidance

2.1 Volcanic ash cloud detection/avoidance systems and associated guidance

2.1.1 As follow-up to IVATF task TF-SCI01, the Science Sub-Group (SCI SG) of the IVATF presented a progress report on ways and means to improve volcanic ash cloud detection/avoidance systems that could be used to support pre-flight and en-route decision making by operators and regulators. The SCI SG progress report comprised three parts – ground-based remote-sensing observations and systems, satellite-based remote-sensing observations and systems, and recommendations for conducting airborne sampling of volcanic ash clouds (including experience gained from the measurements obtained during the eruption of the Eyjafjallajökull volcano in Iceland in April and May 2010).

2.1.2 The IVATF was apprised of the capabilities and limitations of a number of ground-based remote-sensing systems, including lidar (light detection and ranging), ceilometers, sunphotometers and weather radar. In addition, the utility of techniques such as multi-axis differential absorption spectroscopy (MAX-DOAS), infrared and ultra-violet imaging cameras, aerosol sondes and lightning detectors were described. In some instances, the integrated use of these systems, such as combining lidar and sunphotometers, had been demonstrated to be a very powerful tool for the microphysical characterization of volcanic clouds, and thus providing important inputs to performing satellite validation, dispersion model evaluation and data assimilation in the forecast models. The IVATF noted that a further important aspect was the potential integration of ground-based observations with other platforms, such as aircraft and satellite, which would require further study.

2.1.3 The IVATF noted that, in the context of ground-based remote-sensing observations and systems, numerous ground-based instruments could monitor volcanic ash, individually and in combination, but that there were limitations related to the range of parameters measured, cost, maintenance, technical ease of use, portability, sampling capability (time and space) and level of maturity of science and algorithms. There also was great variation in available coverage throughout the volcanically active regions of the world. Some of these techniques had already shown a high potential to be used operationally, but additional effort would be necessary. The IVATF consequently formulated the following recommendation:

> **Recommendation 2/1 —** That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to task the WMO-IUGG Volcanic Ash Scientific Advisory Group (VASAG) to perform a full assessment of the different ground-based techniques using available data sets from different volcanic eruptions and identify the means to efficiently encourage the use of existing capabilities by Volcano Observatories and Volcanic Ash Advisory Centres.

2.1.4 In the context of satellite-based remote-sensing observations and systems, the IVATF noted that quantitative volcanic ash and sulphur-dioxide (SO_2) gas retrievals from satellite data had matured substantially over the past two decades, and that products were already available for use by the Volcanic Ash Advisory Centres (VAAC) to help track and forecast ash-cloud hazards. However, to make better use of such quantitative products, it was reported that the VAACs would need scientifically-based training materials and protocols that included basic information on the physical basis, accuracy and limitations of the retrieval algorithms. Without such proper training, there would be a risk that information about ash properties derived from satellite data may be misinterpreted. The IVATF noted that in support of user training, the United States National Oceanic and Atmospheric Administration

(NOAA) had provided training material and had conducted live training sessions with VAAC Anchorage regarding the use of satellite-derived ash-cloud heights and mass loadings.

2.1.5 Concerning satellite remote-sensing of volcanic SO_2 clouds, the IVATF noted that whilst significant advances had been made since the early 1980s in both instrument development and algorithm improvement – to the extent that infrared methods had reached a high-level of maturity – a certain amount of caution was needed when considering the use of SO_2 as a surrogate for ash. For instance, several recent eruptions had demonstrated that some eruptions were ash-rich with little or no SO_2 signature, that SO_2 and ash were not always found to be coincident, and that some clouds may be predominantly SO_2 with little or no ash.

2.1.6 The IVATF noted that the recent development of quantitative satellite-derived volcanic ash and gas products, and the widespread availability of these, represented an opportunity to make better use of satellite measurements to constrain modelled ash concentrations. Sophisticated approaches for using satellite data with dispersion models using data assimilation and inversion were now being developed by the scientific community, but were not yet ready for operational use. However, constraining model forecasts using satellite-derived ash mass loading was considered more feasible to implement in an operational environment.

2.1.7 In view of the foregoing, the IVATF formulated the following recommendation:

> **Recommendation 2/2 —** That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to task the WMO-IUGG Volcanic Ash Scientific Advisory Group (VASAG) to collaborate with national satellite agencies and research groups, to develop guidance and training material regarding the operational use of quantitative satellite-derived volcanic ash and gas products.

2.1.8 The IVATF noted that a number of European research aircraft had taken airborne observations in the ash plume of the Eyjafjallajökull eruption in Iceland in April and May 2010. The most comprehensive data sets had been obtained from the German Aerospace Centre (DLR) Falcon-20E aircraft and the United Kingdom Facility for Airborne Atmospheric Measurements (FAAM) BAe 146 aircraft. Both aircraft had been equipped with a lidar and in-situ instruments for coarse and fine particles, and gas-phase plume tracers (including SO_2 and ozone). A detailed comparison of the Falcon and BAe146 measurements had been performed for flights undertaken on 17 May 2010, where both aircraft had sampled the same ash cloud in close proximity. A very good consistency of the data had been found. The Falcon and BAe146 measurements were, in many cases, consistent with the ash mass concentration predictions of the dispersion model used by VAAC London. However, there were some instances where significant over-prediction and under-prediction of the ash mass concentrations, especially for aged plumes, had been identified.

2.1.9 The IVATF considered initial recommendations regarding the types of instruments that could/should be used for undertaking research aircraft measurements of volcanic ash plumes. The types of instrumentation recommended comprised remote-sensing instruments, in-situ particle instruments and trace gas in-situ instruments, together with more standard meteorological probes used for the measurement of temperature, pressure, humidity, wind, etc.

2.1.10 Recognizing that during the eruption of Eyjafjallajökull lidar and in-situ measurements from research aircraft had been used by some State authorities to aid their decision making processes concerning airspace closures, and that such measurements also provided important data to validate satellite observations and dispersion models, the IVATF noted that valuable scientific experience had been gained that could be useful for other airborne sampling efforts. The IVATF formulated the following recommendation accordingly:

Recommendation 2/3 — That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to task the WMO-IUGG Volcanic Ash Scientific Advisory Group (VASAG) to finalize the recommendations as presented at **Appendix 2A** to this report concerning airborne measurements of volcanic ash, in view of inclusion in the ICAO *Handbook of the International Airways Volcano Watch* (Doc 9766).

2.1.11 Taking into account the three-part progress report of task TF-SCI01, and recognizing the ongoing need to develop guidance material, the IVATF agreed that task TF-SCI01 would remain open. The IVATF updated task TF-SCI01 accordingly in three parts as TF-SCI01.1, TF-SCI01.2 and TF-SCI01.3.

Agenda Item 2: Report of the Science Sub-Group (SCI SG)
2.2: Situational awareness improvements of impending volcanic eruptions

2.2 Situational awareness improvements of impending volcanic eruptions

2.2.1 As follow-up to IVATF task TF-SCI02, the SCI SG presented a progress report on improvements to the situational awareness of impending volcanic eruptions, which was recognized to be of value for aviation-risk management. Situational awareness was evaluated in terms of volcano monitoring, alerting methods and dispersion scenarios.

2.2.2 Concerning volcano monitoring, the IVATF was informed that operations were conducted by around 60 institutions worldwide, and that approximately 270 of the 470 explosive volcanoes that have erupted in the past 2 000 years have some form of continuous ground-based monitoring in place – the majority having only seismic monitoring, and in many cases just a single sensor. Well monitored volcanoes tended to be in wealthy countries, exhibit some level of unrest or recent eruptive activity, and/or pose a clear hazard to densely populated areas. Since 2004, some improvements in volcano-monitoring coverage had been made, but there were still approximately 200 recently active volcanoes with explosive potential that remain unmonitored. The IVATF noted that the most fundamental way to improve situational awareness of impending eruptions was to increase the number of volcanoes having ground-based monitoring networks, providing data to the volcano observatories (which in turn feed required information to the concerned VAAC(s)).

2.2.3 As a starting point towards the goal of increasing the number of monitored volcanoes to provide aviation situational awareness, the IVATF noted that it would be useful to have a better understanding of which specific volcanoes worldwide posed the greatest threat to aviation *and* had insufficient monitoring coverage. Such a methodology had already been developed by the United States Geological Survey (USGS) to systematically assess volcanic threat and identify monitoring gaps at each of the 169 active and potentially active United States volcanoes. The methodology included a measure of aviation threat based on both hazard factors related to potential for explosive eruptions and exposure factors related to impacts on air routes and airports. The IVATF was informed that the USGS methodology could be adapted to other volcanic regions of the world, so that the global scope of monitoring gaps could be defined and prioritized with respect to aviation.

2.2.4 Recalling the aviation colour code – the universal volcanic alert-level system for aviation as part of the International Airways Volcano Watch – and the volcano observatory notice for aviation (VONA), the IVATF noted that only a few volcano observatories worldwide routinely used the aviation colour-code or the VONA, and that wider implementation would require a sustained program of education and outreach to volcano observatories and corresponding meteorological watch offices and civil aviation authorities. The IVATF noted that the VONA required clear, concise information about major changes in volcanic unrest and eruptive activity, but that there may be additional information needs. In particular, volcano observatories may have more detailed information or important insights about eruption source parameters – such as plume height, eruption style and duration – that are key inputs to ash-dispersion models used by the VAAC. In those cases, volcano observatories could supplement VONA with other information.

2.2.5 The IVATF recognized that the increased involvement of the World Organization of Volcano Observatories (WOVO) was a means to help achieve the goal of improving situational awareness of impending eruptions through, in particular, more monitored volcanoes and more use of the aviation colour code. To this end however, the IVATF noted that WOVO was administered by a small group of scientists without a major funding base to support new projects.

2.2.6 In view of the foregoing, the IVATF formulated the following recommendations:

Recommendation 2/4 — That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to coordinate with the World Organization of Volcano Observatories (WOVO) on:

a) the issue of increasing the use by volcano observatories of the aviation colour code and Volcano Observatory Notice for Aviation (VONA); and

b) the production of a list of volcanoes that threaten aviation and are unmonitored or inadequately monitored for the risks they pose.

2.2.7 Taking into account the progress report of task TF-SCI02, and recognizing the ongoing need for guidance material to be developed, the IVATF agreed that task TF-SCI02 would remain open. The IVATF updated task TF-SCI02 accordingly in two parts as TF-SCI02.1 and TF-SCI02.2.

Agenda Item 2: Report of the Science Sub-Group (SCI SG)
2.3: Supporting requirements for airworthiness determination

2.3 Supporting requirements for airworthiness determination

2.3.1 As follow-up to IVATF task TF-SCI03, the SCI SG presented a two-part progress report on improving the understanding of 'visible ash' and preliminary recommendations for volcanic ash material for use in jet engine testing.

2.3.2 As to improving the understanding of visible ash, the IVATF was apprised of the historical usage of the term, presented with preliminary *quantitative* constraints on thresholds for observing and detecting visible ash, and noted some scientific issues that needed further attention to better understand the operational application of a visible-ash threshold for ash avoidance.

2.3.3 The IVATF noted that *qualitatively* visible ash was ash as seen by a human observer or discernible from satellite data; however, ongoing scientific analysis had proven to show that there existed considerable range – two to three orders of magnitude – in concentration values that comprise visible ash, even under good viewing conditions.

2.3.4 Concerning specifically the *quantification* of the term visible ash, the IVATF was apprised of aspects with respect to human observation and satellite detection. The IVATF noted that there was not a single quantitative threshold value for visible ash that was common across different observation conditions (e.g. time of day and background sky) and technologies. Moreover, satellite-based infrared techniques for detecting ash could have, under certain conditions, detection thresholds less than 2 mg/m^3, which was the current value used by the EUR/NAT Region to define the boundary between low and medium ash concentrations forecasts as part of the regional volcanic ash contingency plan (EUR Doc 019 / NAT Doc 006, Part II, December 2010 edition).

2.3.5 The IVATF concurred that additional scientific work was needed to better understand the operational significance of visible ash, and agreed that the first part of task TF-SCI03 would remain open (renamed as TF-SCI03.1).

2.3.6 In view of the foregoing, the IVATF formulated the following recommendations:

Recommendation 2/5 — That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to task the WMO-IUGG Volcanic Ash Scientific Advisory Group (VASAG) to:

a) assemble a database of measurements and observations of thicknesses of ash clouds from various eruptions that are obtained from all possible sources (lidar, radar, pilot reports, airborne sampling, etc.) for the purpose of better understanding the three-dimensional geometry of clouds, improving estimates of ash concentrations derived from two-dimensional (mass loading) satellite data, and improving dispersion-model output;

b) assess detection thresholds of various space-based sensors, including comparison of results from different retrieval algorithms applied to the same data for a variety of background conditions (e.g. different atmospheric water-vapour loadings). Surface measurements, airborne measurements, and space-borne lidar measurements, when available, should be used to help characterize the sensitivity of the satellite retrieval algorithms;

c) further conduct research on automatic algorithms to calculate cloud properties such as mass loading and height, as tools for VAACs in an operational environment;

d) validate VAAC-defined ash clouds against satellite and other data to help establish guidelines or standards for defining "visible ash". Validation would involve retrospective comparisons (case studies) of the edges of observed ash clouds as defined in previous VAAC advisories with the quantitative properties of the specific corresponding satellite data used to determine those edges; and

e) analyze a variety of past encounters of aircraft with ash clouds by combining dispersion model output with eruption-source information, satellite data, and other observations in order to associate ash observations and model results with affects on aircraft.

Recommendation 2/6 — That the International Airways Volcano Watch Operations Group (IAVWOPSG) be urged to more clearly specify common best practices procedures for preparing advisory products, with the goal to harmonize standard operating procedures among the VAACs to mitigate inconsistency for operators and regulators.

2.3.7 Concerning preliminary recommendations for the types of volcanic ash material to be used for jet engine tests, forming the second part of the SCI SG progress report on task TF-SCI03, the IVATF noted that such airworthiness tests were aimed at understanding the effects of lower ash concentrations that occur in the distal parts of volcanic ash clouds, often hundreds of kilometres or more from their source. The IVATF was informed that the SCI SG had not been made aware of any formal programme of engine testing undertaken since IVATF/1; but that, nevertheless, some ideas and initial recommendations about what type of volcanic material would be most suitable for any new tests was presented. The IVATF appreciated that the determination of engine testing was beyond the scope of task TF-SCI03.

2.3.8 The IVATF noted that the preliminary recommendations proposed by the SCI SG included that such airworthiness testing should use actual (authentic) volcanic ash – since synthetic mixtures would introduce yet more uncertainty into an already complex testing scheme – and that ash for engine tests should be a mixture of fine-grained particles from about 10-100 microns – equivalent to the size range expected in dispersed volcanic clouds beyond the vicinity of the volcanic source. In addition, the recommendations proposed that such tests should use volcanic ash in the compositional range of 56-64% silicon dioxide (SiO_2) – a common range for volcanic-rock compositions worldwide that encompasses many andesites and some (lower silica) dacites – and that testing should be started with dry samples (i.e. with no added volatile components such as water vapour or SO_2) in order to limit the number of complicated variables, until the test design could be re-evaluated.

2.3.9 Furthermore, the IVATF noted that the inclusion of volcano scientists familiar with explosive volcanism, and its eruptive products, in any industry development of test standards was recommended, and that original equipment manufacturers (OEM) had the appropriate expertise to define the types of engines or engine components to be used in testing.

2.3.10 Taking into account the second-part of the progress report of task TF-SCI03, the IVATF agreed that task TF-SCI03 (renamed TF-SCI03.2) could be considered complete. The IVATF formulated the following recommendations relating to the introduction of the preliminary information into ICAO guidance:

Recommendation 2/7 — That, International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to consider the inclusion of preliminary guidance information on volcanic materials for engine testing, as presented at **Appendix 2B** to this report in the ICAO *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds* (Doc 9691).

Agenda Item 2: Report of the Science Sub-Group (SCI SG)
2.4: Technologies and systems to support improved eruption source parameterization for dispersion modelling

2.4 Technologies and systems to support improved eruption source parameterization for dispersion modelling

2.4.1 As follow-up to IVATF task TF-SCI04, the SCI SG presented a progress report on the improved characterization and use of eruption source parameters (ESP) in dispersion models. The progress report highlighted that the accuracy of ash-cloud models was limited by the accuracy of ESPs such as plume height, mass eruption rate, eruption start/stop time, and the fraction of fine ash in the erupted mass.

2.4.2 The IVATF noted that estimates of plume height and eruption start/stop time could be improved through more monitoring instruments, development of new eruption detection techniques, and standardization of reporting procedures, and that estimates of the mass eruption, mass fraction of fine ash that feeds the cloud, and vertical mass distribution in the plume could be improved through modelling and better characterization of future eruptions. In addition, it was reported that the accuracy of model forecasts could be improved by comparing predictions with downwind satellite or other data, adjusting and re-running models during an event.

2.4.3 The IVATF was informed that from 2006 to 2009, as part of the work programme of the IAVWOPSG, a multidisciplinary group had developed a preliminary spreadsheet (database) of likely ESPs for future eruptions of volcanoes worldwide. The database was available as guidance material on the IAVWOPSG website[1], with the purpose of providing ESPs for situations when observations were not available – as was the case at the numerous unmonitored or poorly monitored volcanoes worldwide – and for running dispersion scenarios before possible eruptions. Experience with the database since 2009 had shown a need for several improvements, including customization of the "default" ESP for well-characterized volcanoes rather than using generic values; addition of new fields for the uncertainty in ESP for each volcano; addition of links to web pages of pertinent volcano observatories, the Smithsonian Global Volcanism Database, etc. that give the eruptive history of each volcano; and the addition of a discussion page where different groups could offer alternative ESPs. The SCI SG reflected that an improved ESP database should be a "living" document that could be changed by knowledgeable scientists to incorporate local expertise on specific volcanoes.

2.4.4 Recognizing that the knowledge and treatment of ESP was a key issue of improving ash dispersion model forecasts, and that better methods for estimating ESP remains an ongoing scientific goal, the IVATF formulated the following recommendations:

> **Recommendation 2/8 —** That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to task the WMO-IUGG Volcanic Ash Scientific Advisory Group (VASAG) to continue their efforts to improve eruption detection and measurement capability, improve knowledge and use of ESP, characterize uncertainty, improve the global ESP database, and develop probability density functions for ESP at individual volcanoes, with special attention to the most active ones.

> **Recommendation 2/9 —** That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to coordinate with the World Meteorological

[1] USGS *Preliminary Spreadsheet of Eruption Source Parameters for Volcanoes of the World* accessible via URL: http://www2.icao.int/en/anb/met/iavwopsg/Documents/Forms/AllItems.aspx

Organization (WMO) to develop procedures on how to share information (such as radar reports, satellite imagery and ground-based measurements) from its Member States with volcano observatories, in an effort to improve collaborative decision making.

2.4.5 Despite an ongoing need to develop guidance material on technologies and systems to characterize ESP, the IVATF agreed that task TF-SCI04 (renamed TF-SCI04.1) could be considered complete in view of the above recommendations passing to the IAVWOPSG. The SCI SG developed a new task (TF-SCI04.2) concerning the need for improved meteorological data gathering during a volcanic event.

Agenda Item 2: Report of the Science Sub-Group (SCI SG)
2.5: Model improvements and validation

2.5 Model improvements and validation

2.5.1 As follow-up to IVATF task TF-SCI05, the SCI SG presented a two-part progress report concerning the uncertainty in ash dispersion model forecasts (and the implications for operational products) and the ensemble strategies to assess confidence in ash-cloud forecasts.

2.5.2 In the context of the uncertainty in forecasts of ash cloud concentration at any given point in space and time, the IVATF noted that *the forecast uncertainty was at least one order of magnitude above or below the forecast value*. The SCI SG highlighted that this finding should be incorporated into recommendations for operational advisory and warning products, and that the worldwide scientific effort to improve model accuracy and reduce input uncertainties should continue.

2.5.3 The IVATF noted that the uncertainties in model forecasts could be attributed to three key components: a) uncertainty in eruption source parameters; b) uncertainty in meteorological parameters; and c) limitations in the accuracy with which current models simulate removal of ash from the atmosphere. The progress report provided a fuller explanation of these issues, together with approaches that could decrease uncertainty in model forecasts such as rapidly assimilating ground-based, airborne, or space-based observations of cloud properties into model runs.

2.5.4 Recognizing that the uncertainty in ash-cloud concentration at any given point in space and time was *at least one order of magnitude above or below* the forecast value, the IVATF was informed that this would have *significant implications* for operational products, particularly those which use specific ash-concentration values to indicate areas of ash contamination – such as the volcanic ash contingency plan of the EUR and NAT Regions, outlined above. For example, a concentration value of 2 mg/m^3, determined primarily on the basis of dispersion modelling, should be recognized as representing a range from about 0.2 to 20 mg/m^3 because of the uncertainties in the forecast. Consequently, a concentration value 4 mg/m^3 – as currently used in the EUR/NAT Region to delineate between medium and high areas of ash contamination – would fall within the uncertainty range of the next lower boundary. Thus, the IVATF was informed that there was *no meaningful distinction* between modelled ash concentrations thresholds of 2 and 4 mg/m^3 (as used in the current volcanic ash contingency plan of the EUR and NAT Region) given current levels of uncertainty.

2.5.5 In developing operational forecast products that use modelled ash concentration values, the IVATF noted that the following points should be kept in mind: a) uncertainty in model forecasts of ash concentration depends on both uncertainties in input parameters and accuracy of models and is currently one order of magnitude at best; and b) use of ash concentration thresholds that are separated by less than an order of magnitude are not scientifically appropriate with current capabilities. The issues arising from the eruption of Eyjafjallajökull in 2010 had given new impetus to scientific efforts to improve ash-dispersion forecasts, which were underway by a variety of groups worldwide.

2.5.6 In view of the foregoing, the IVATF formulated the following recommendations:

Recommendation 2/10 — That, International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to consider the findings concerning uncertainty in ash dispersion model forecasts, as presented at **Appendix 2C** to this report, in the development of operational advisory and warning products related to volcanic ash.

Recommendation 2/11 — That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to task the WMO-IUGG Volcanic Ash Scientific Advisory Group (VASAG) to continue to work towards the improvements in dispersion modelling as identified at the October 2010 workshop on ash dispersal forecasting and aviation.

2.5.7 In the context of ensemble strategies to assess the confidence of ash-cloud forecasts, the IVATF noted that such strategies held promise as a means to quantify the uncertainties of deterministic forecasts of ash concentrations and/or to assess model forecasts in probabilistic terms. Recognizing that traditional ash forecast products were deterministic in nature (i.e. one dispersion model with one set of inputs, at any given time, for eruption source parameters and forecast meteorology), the IVATF was informed that by broadening the traditional approach towards ensemble strategies to create probabilistic model forecast, the VAACs may be better positioned to incorporate a measure of forecast uncertainty into their advisories.

2.5.8 The IVATF was informed that no rigorous ensemble methodology for ash dispersion modelling had yet been developed, but that the scientific community was poised to begin such an effort – for example, the ENSEMBLE Project[2] of the European Commission's Joint Research Centre was a web-based platform for the inter-comparison and evaluation of atmospheric chemistry transport and dispersion models, of which the meteorological offices collocated with VAACs London, Toulouse and Montreal were participant agencies. The IVATF recognized that such collaborative efforts by the scientific community could offer a springboard to a more VAAC-focussed ensemble effort and that an evaluation of prototype products should help guide the further development of which product(s), if any, were preferred.

2.5.9 In view of the foregoing, the IVATF formulated the following recommendation:

Recommendation 2/12 — That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to task the WMO-IUGG Volcanic Ash Scientific Advisory Group (VASAG) to explore the development of near-real-time ensemble capabilities and prototype probabilistic products.

2.5.10 Taking into account the two-part progress report of task TF-SCI05, the IVATF agreed that task TF-SCI05 could be considered complete in view of the above recommendations passing to the IAVWOPSG.

[2] http://ensemble2.jrc.ec.europa.eu/

Agenda Item 2: Report of the Science Sub-Group (SCI SG)
2.6: Health effects on aircraft occupants of exposure to volcanic sulphur dioxide

2.6 Health effects on aircraft occupants of exposure to volcanic sulphur dioxide

2.6.1 The IVATF noted that subsequent to IVATF/1, the SCI SG had considered an additional task concerning the health effects on aircraft occupants of exposure to volcanic sulphur dioxide (SO_2) – task TF-SCI06 refers. The deliverable of task TF-SCI06 pertained to the development of guidance material of the expected cabin exposures from a range of eruption types, together with available toxicological data.

2.6.2 As follow-up to IVATF task TF-SCI06, the SCI SG presented a progress report on the hazard of SO_2 on aircraft occupants. The progress report highlighted that during volcanic eruptions, a number of toxic gases may be emitted in addition to ash – including but not limited to SO_2, hydrogen fluoride and hydrogen sulphide. Such gases have different atmospheric dispersion properties, and so gas clouds may be found coincident to or separate from ash clouds. Of these gases, the IVATF was informed that SO_2 was of particular importance since it may be emitted in large quantities and potentially has significant health effects, producing minor symptoms for minor exposure levels and proportionately more serious symptoms as exposure increases. The most prominent effects of SO_2 exposure being asthmatic symptoms, particularly in those susceptible to the condition.

2.6.3 The IVATF noted that SO_2 plumes may exist separate from ash and that there was a potential remote risk that hazardous concentrations of SO_2 may exist outside ASHTAM promulgated areas, but that flight through such area was unlikely to cause jet engine power loss and failure. The documented experience to date of in-flight encounters with sulphurous gases suggested that SO_2 had never been a significant immediate hazard to an aircraft or its occupants. The IVATF also pointed out that there is potential conflict between standard operating procedures (SOPs) for dealing with electrical fire (which can produce an acrid sulphurous smell) and SOPs for volcanic sulphur in the cockpit.

2.6.4 Recognizing existing guidance contained in the Handbook on the International Airways Watch (Doc 9766) with respect to the smell of sulphurous gases such as SO_2 at cruise levels, the IVATF concurred that more research should be conducted to better understand the potential significant risk of SO_2 to aircraft occupants and any associated expeditious mitigation of the risk.

2.6.5 In view of an ongoing need to develop guidance material of the expected cabin exposures from a range of eruption types, together with available toxicological data, and taking into account an update to task TF-AIR05 that would be undertaken by the AIR SG in coordination with the SCI SG, the IVATF agreed that task TF-SCI06 could be considered complete.

Agenda Item 2: Report of the Science Sub-Group (SCI SG)
2.7: Other issues

2.7 Other issues

2.7.1 No items leading to recommendations or actions agreed were addressed under this agenda item.

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Agenda Item 3: Report of the Airworthiness Sub-Group (AIR SG)
3.1: Volcanic ash cloud airworthiness effects and associated criteria, procedures and guidance

3.1 Volcanic ash cloud airworthiness effects and associated criteria, procedures and guidance

3.1.1 As follow-up to tasks TF-AIR01 and TF-AIR 02 the Airworthiness Sub-Group (AIR SG) AIR01/02 task team presented its progress report. The AIR01/02 task team had worked with the Science Sub-Group (SCI SG) to identify areas where additional scientific information was needed to better understand and correlate aeroplane and engine susceptibility to volcanic ash in more definitive terms. The SCI SG had described the types of conditions under which a volcanic ash cloud would be "visible" to the human observer and observable via satellite observations. The IVATF noted that the conditions under which volcanic ash was "visible" or "observable" provided a useful correlation between the successful service experience and the original equipment manufacturers (OEM) recommendations to avoid flight operations in visible or discernable volcanic ash.

3.1.2 The AIR01/02 task team had reviewed current ICAO guidance contained in the *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds* (Doc 9691) in order to provide additional information regarding the areas of susceptibility of the aeroplane and engines to volcanic ash. A proposal for amending paragraphs 4.2.5 and 4.3.2 to 4.3.4 of Doc 9691 had been included in the progress report of IVATF tasks TF-AIR01 and TF-AIR 02 as contained at **Appendix 3A** to the report and within Recommendation 2/15 below. Consequently, the IVATF agreed that task TF-AIR02 could be considered complete.

3.1.3 Based on the proposed amendment to Doc 9691, the IVATF concurred with the view of the AIR SG that the procedures for issuing ash concentration forecasts to supplement the VAA/VAG information during the eruption "Proactive Phase" as contained in the ICAO *Volcanic Ash Contingency Plan — EUR and NAT Regions* (EUR Doc 019/NAT Doc 006, Part II, December 2010 edition) should be modified. The IVATF consequently agreed to update task TF-AIR01 as follows:

> **Task TF-AIR01 -** To develop, in close coordination with the SCI SG and International Airways Volcano Watch Coordination Group (IAVW CG), a volcanic ash operationally applicable characteristic(s) that can be used as a threshold value for the concept of "visible ash".

3.1.4 In addition, the AIR/01/02 task team had suggested that the SCI SG and IAVW CG should provide recommendations on the best methods to forecast ash concentrations that most accurately represented the "visible ash" cloud. The IVATF was informed that the establishment of an ash concentration threshold for visible ash could be used by airlines in their risk assessments to plan flight operations. Furthermore, the AIR/01/02 task team informed the IVATF that, based on the current capability of numerical models and of the availability of volcanic eruption source information, having additional lines of concentration beyond the visible ash cloud would not provide any substantially significant information to aid in establishing safe operations in and around volcanic ash clouds. The IVATF consequently formulated the following recommendation:

> **Recommendation 2/13 —** That, once task TF-AIR01 is complete, the IVATF invites the appropriate ICAO group to amend the ICAO *Volcanic Ash Contingency Plan for the EUR and NAT Regions* (EUR Doc 019/NAT Doc 006, Part II, December 2010 edition) accordingly based on the findings of task TF-AIR01.

3.1.5 As follow-up to task TF-AIR08, the IVATF was informed of the progress made by the AIR SG AIR08 task team on TF-AIR08 Task A. The IVATF noted that the AIR08 task team had been unable to complete the task due to the current uncertainty in volcanic ash forecasting, a lack of uniformity in volcanic ash advisory output, and a lack of a quantifiable model of volcanic ash tolerance for a given aircraft/engine model. As a result, it had not been possible to adequately address the scenarios called for by TF-AIR08 Task A. Additionally, the relationship between visible ash and ash concentration level was yet to be defined (as alluded to above). The IVATF was informed that a number of the scenarios described in TF-AIR08 Task A had found validity in risk assessments and in verifying the accuracy of the ash concentration model outputs as provided by the meteorological (MET) offices collocated with VAACs London and Toulouse. The IVATF noted that such model output was unique with respect to the other seven VAACs and that this had caused operator/regulator misunderstanding and confusion. Accordingly, the AIR SG suggested this task not be pursued which the IVATF supported.

Agenda Item 3: Report of the Airworthiness Sub-Group (AIR SG)
3.2: Pre-flight/dispatch and in-flight crew procedures and guidance

3.2 **Pre-flight/dispatch and in-flight crew procedures and guidance**

3.2.1 As follow-up to tasks TF-AIR03 and TF-AIR04, the IVATF was informed of the activity of the AIR SG AIR04 task team. The AIR04 task team had developed draft guidance related to a new approach to assure safety under conditions of volcanic ash contaminated airspace and presented a proposed methodology whereby States may require aircraft operators and regulatory authorities to apply the management of flight operations into, or avoid areas of known or forecast volcanic cloud. Taking into consideration views expressed by experts, an AIR04 ad-hoc drafting group developed a revised version of the progress report on task TF-AIR04 which is included at **Appendix 3B** to this report

3.2.2 In addition, the AIR SG presented findings covering issues identified by the AIR04 task team but for which potential solutions were considered to lie beyond the remit of the team. The complete list of findings, as updated by the AIR04 ad-hoc drafting group, is presented at **Appendix 3C** to this report.

3.2.3 In view of the foregoing, the IVATF formulated the following recommendation:

> **Recommendation 2/14 —** That, the IVATF invites the appropriate ICAO group to finalize the proposed guidance on *The Management of Flight Operations with Known or Forecast Volcanic Cloud Contamination* as contained at **Appendix 3B** to this report for inclusion in an appropriate ICAO publication.

and agreed to updated task TF-AIR04 as follows:

> **Task TF-AIR04** — That the AIR04 task team findings (IVATF/2 Report, Appendix 3C) be given careful consideration and such further action, as required, so as to provide resolutions to the issues raised.

3.2.4 The IVATF noted a proposal that operations in or near volcanic ash should be treated *no differently* to any other MET hazard, expressing that the operational decision making process of an airline, whether through Safety Management System processes or as defined by Standard Operating Procedures as approved by the respective regulator, was an essential part of safe operations. Furthermore, to complete a proper safety risk assessment and in order to make safe decisions, accurate and timely information (including MET) must be available to operators.

3.2.5 The proposal indicated that safety data showed that, in spite of recent volcanic events, there had not been any fatal commercial aircraft accident related to operations in or near volcanic ash. In contrast, many fatalities had been attributed to accidents involving other MET hazards, such as thunderstorms, wind shear, turbulence, and icing.

3.2.6 Concern was expressed regarding this proposal, where it was highlighted that currently aircraft have no minimum robustness for volcanic ash from an aircraft certification perspective (i.e. no specifications or requirements as are available for lightning strikes, icing, hail, etc); therefore, operations in volcanic ash could *not* be treated in the same way as other MET hazards.

3.2.7 Despite the concern expressed, the IVATF concurred that irrespective of the viability and use of thresholds to define ash-cloud boundaries, all segments of the industry were in agreement that flight into *visible ash* was unacceptable.

3.2.8 As follow-up to task TF-AIR05, the IVATF was presented with the progress by the AIR05 task team. The AIR05 task team had reviewed current ICAO guidance material concerning flight crew procedures in the event of a volcanic ash encounter, as well as suggested changes or updates based on recent developments. These suggestions included detailing flight crew responsibility on reporting observation of volcanic activity in the following ICAO Docs 9766, 9691, *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444) and EUR Doc 019/NAT Doc 006, Part II. A proposal for amending these documents is included at **Appendix 3A** to this report. The AIR05 progress report also highlighted that some flight crew instructions within ICAO Doc 9691 were in need of updating and that type specific instructions should not be included in ICAO guidance. The IVATF was invited to consider a proposal to request all Type Certificate Holders (TCH) to produce guidance for continuing airworthiness concerning encounters with volcanic ash. The IVATF noted that Doc 9766, Chapter 4.7, *Action to be Taken by Pilots in the Event of Entry into an SO_2 Cloud* may be better placed elsewhere within the Handbook on the IAVW. A proposal to review this issue and recommend future work was considered. Accordingly, the IVATF formulated the following recommendation:

> **Recommendation 2/15 —** That, the IVATF invites the appropriate ICAO group(s) to finalize the amendment proposals to ICAO Docs 9691, 4444 and EUR Doc 019/NAT Doc 006, Part II presented at **Appendix 3A** to this report for processing.

and agreed to updated task TF-AIR05 as follows:

> **Task TF-AIR05 —** Determine, in coordination with the SCI SG, how best to relocate and revise guidance for flight into SO_2 clouds within Chapter 4.7 of Doc 9766.

Agenda Item 3: Report of the Airworthiness Sub-Group (AIR SG)
3.3: Maintenance and inspection procedures and guidance

3.3 **Maintenance and inspection procedures and guidance**

3.3.1 As follow-up to task TF-AIR06, the IVATF was informed of the activities of the AIR SG AIR06 task team. A proposal to add guidance to ICAO Doc 9691 to reflect the engine and aircraft TCH maintenance and inspection instructions with respect to operation in airspace with a low contamination of volcanic ash was presented and is included at **Appendix 3D** to this report. Accordingly, the IVATF formulated the following recommendation:

> **Recommendation 2/16 —** That, the IVATF invites the appropriate ICAO group to finalize and incorporate the proposed additional guidance material on General Advice for Aircraft Maintenance Inspection when Operating in Airspace with a Low Contamination of Volcanic Ash (**Appendix 3D**) into Doc 9691.

and agreed to update task TF-AIR06, in the context of international general aviation considerations, as follows:

> **Task TF-AIR06 —-** Develop maintenance and operations considerations for international general aviation.

Agenda Item 3: Report of the Airworthiness Sub-Group (AIR SG)
3.4: Aerodrome procedures impacting on airworthiness

3.4 Aerodrome procedures impacting on airworthiness

3.4.1 The IVATF was informed of an additional activity of the AIR SG AIR06 task team with regards to reviewing aerodrome procedures that may have an impact on airworthiness. The IVATF was informed that the AIR06 task team had been unable to gather sufficient data on written or documented procedures used by airport operators and air navigation service providers (ANSP) that may have an impact on airworthiness.

3.4.2 The IVATF was informed of ongoing work within the International Airways Volcano Watch Operations Group (IAVWOPSG) concerning guidance on the reporting of volcanic ash deposition at aerodromes (IAVWOPSG Conclusion 5/15 refers). The AIR06 task team was of the opinion that airport operators and ANSPs should document their procedures with regard to the operations at aerodromes when volcanic ash has settled on the ground or on aircraft. Accordingly, the IVATF formulated the following recommendations:

> **Recommendation 2/17 —**That, airport operations be considered for inclusion in the guidance material for *The Management of Flight Operations with Known or Forecast Volcanic Cloud Contamination* as part of the flight operations safety risk assessment.

> **Recommendation 2/18 —** That, the IVATF invites the appropriate ICAO group to improve aerodrome and air traffic management procedures by extension of written procedures.

Agenda Item 3: Report of the Airworthiness Sub-Group (AIR SG)
3.5: Airworthiness certification implications

3.5 Airworthiness certification implications

3.5.1 The IVATF was presented a progress report by the AIR SG AIR07 task team concerning airworthiness design specifications. The IVATF was reminded that a design *certification* is to compare a type design tolerance and capabilities to *quantified* reference characteristics. The IVATF was informed that reference characteristics of volcanic clouds should include chemistry, degree (density or concentration) and overall size of expected encounters, and that in the absence of defined reference characteristics into which operators want to operate rather than avoid, it could not be proven to be safe by design certification process. Since there was no means to warn the flight crew when detecting such characteristics in the flight path or on runways, a type design limitation or condition of design certification could not be respected or enforced when penetrating volcanic ash contaminated airspace. The AIR07 task team was of the opinion that a design *certification* requirement to compare design tolerance to quantified characteristics was impractical at this time. However, the meeting noted that EASA will shortly issue an advance notice of proposed amendment (A-NPA) to gather feedback for the purpose of considering design certification requirements for volcanic ash tolerance in airframes and engines.

3.5.2 The IVATF was informed that flight crews do not have the means available to comply with flight manual limitations or design certification conditions that would result from design certification efforts, since there were no technologies available to measure, record, monitor or warn flight crew of the degree of volcanic ash/dust contamination in the flight path. However, the IVATF was informed that research was commencing which related to on-board technologies that may measure volcanic cloud characteristics. Accordingly, the IVATF agreed to update task TF-AIR07 as follows:

> **Task TF-AIR07 —** To monitor, report and recommend emerging technologies that measure volcanic cloud characteristics of concern to aircraft airworthiness.

Agenda Item 3: Report of the Airworthiness Sub-Group (AIR SG)
3.6: Original equipment manufacturer crisis response plan

3.6 **Original equipment manufacturer crisis response plan**.

3.6.1 The IVATF was informed of the progress on task TF-AIR08 Task B by the AIR08 task team. The IVATF noted that the AIR SG had revised the task to reflect the following:

> *Original equipment manufacturers (OEMs) to coordinate contingency information that might be used in times of a volcanic related crisis. This information is to support a more rapid response to questions from operators. The information should be presented in a consistent format and manner to assist in a more rapid response to questions from the ANSP or regulators.*

3.6.2 The IVATF noted that, overall, activities with respect to TF-AIR08 Task B had required information and coordination with the experts of the other AIR SG task teams and the SCI SG in order to produce the material as presented at **Appendix 3E** to this report. The IVATF agreed that the material presented had led to the conclusion of TF-AIR08 Task B. Accordingly, the IVATF formulated the following recommendation:

> **Recommendation 2/19 —** That, the IVATF invites the appropriate ICAO group to incorporate the volcanic ash communication process for original equipment manufacturer (OEM) expert advice (as contained at **Appendix 3E** to this report) into an appropriate ICAO publication(s).

3.6.3 In view of the foregoing with respect to TF-AIR08 task B, and also taking into consideration the discussion concerning TF-AIR08 Task A in Agenda Item 3.1, the IVATF agreed that task TF-AIR08 overall could be considered complete.

Agenda Item 3: Report of the Airworthiness Sub-Group (AIR SG)
3.7: Other issues

3.7 **Other issues**

3.7.1 No items leading to recommendations or actions agreed were addressed under this agenda item.

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Agenda Item 4: Report of the Air Traffic Management Sub-Group (ATM SG)
4.1: Air traffic management contingency planning, procedures and guidance

4.1 Air traffic management contingency planning, procedures and guidance

4.1.1 As follow-up to IVATF task TF-ATM01, the Air Traffic Management Sub-Group (ATM SG) of the IVATF presented a draft template for a regional ATM contingency plan for volcanic ash, taking into consideration existing contingency plans in various States and ICAO Regions.

4.1.2 The IVATF was informed that after a review of a number of documents, only the ICAO EUR and NAT Regions contingency plan (EUR Doc 019/NAT Doc 006, Part II) could be used as a basis for further development.

4.1.3 The IVATF noted that the ATM SG had decided to retain the three levels of ash contamination as an example within the draft template, as currently used in the EUR/NAT contingency plan (December 2010 edition). The levels were "Areas of low contamination", "Areas of medium contamination" and "Areas of high contamination". The IVATF noted that no figures had been included in the draft template for each specific concentration level, since this would be based on the outcome of activities of the other Sub-Groups of the IVATF.

4.1.4 In addition, the IVATF was informed that the issuance of NOTAM, ASHTAM and SIGMET messages was on the work programme of other Sub-Group activities, and that the inclusion of information related to the promulgation of such messages within the ATM contingency plan template would be based on the outcome of those activities accordingly.

4.1.5 The IVATF noted that collaborative decision making (CDM) aspects had been considered by the ATM SG, where it had been noted that the decision to fly in areas of volcanic ash contamination should rest with the aircraft operators, be conducted in accordance with safety risk assessment principles and the requirements accepted by the State of the Operator.

4.1.6 In view of the foregoing, the IVATF formulated to the following recommendation:

> **Recommendation 2/20 —** That, the draft template ATM contingency plan for volcanic ash, as presented at **Appendix 4A** to this report be accepted by IVATF as a first draft, with the understanding that further work would be required on matters such as concentration levels, the concept of Danger Areas and response phases.

4.1.7 The IVATF considered a proposal to harmonize the wording and processes used to describe the ATM "response phases" of a volcanic ash event. The IVATF was informed that the proposal had been coordinated with the ATM SG, the AIR SG and the IAVW Coordination Group (IAWV CG) of IVATF.

4.1.8 In addition, the IVATF considered a proposal to harmonize the rules for establishing Danger Areas for volcanic ash contamination. The IVATF recalled that a Danger Area was defined by ICAO as: *an airspace of defined dimensions within which activities dangerous to the flight of aircraft may exist at specified times*. (Annex 15 refers). The IVATF noted that although no specific Standard existed that directs States to establish a Danger Area for any particular hazard, volcanic ash contamination would constitute a condition considered "dangerous to the flight of aircraft".

4.1.9 Supported by safety management principles, ICAO was invited to consider the need to review the traditional concept of dealing with Danger Areas, and to establish global guidance on the establishment of areas of airspace affected by volcanic ash contamination.

4.1.10 The IVATF was informed that the current Volcanic Ash Contingency Plan of the EUR and NAT Region described that the establishment of Danger Areas for volcanic ash contamination was the prerogative of individual States, and therefore that it was left to the discretion of States to decide at which level of ash concentration a danger area was to be established. The IVATF proposed that a review the concept of Danger Areas, in the context of the application of safety management principles, should be undertaken.

4.1.11 In view of the forgoing, the IVATF agreed that task TF-ATM01 should remain open, and updated the task accordingly.

Agenda Item 4: Report of the Air Traffic Management Sub-Group (ATM SG)
4.2: Flight planning information dissemination

4.2 **Flight planning information dissemination**

4.2.1 As follow-up to IVATF task TF-ATM02, the ATM SG presented a progress report concerning flight planning information dissemination and consequential recommendations for improvements of ICAO provisions (including guidance).

4.2.2 In particular, the IVATF noted that task TF-ATM02 had been to investigate the current use of NOTAM for volcanic ash and ASHTAM, volcanic ash advisories and SIGMET for volcanic ash, as well as reviewing and assessing the benefits of new products.

4.2.3 The deliverable of task TF-ATM02 had been to establish procedures to enhance pre-flight and in-flight information dissemination technologies to ensure notification of all flights affected, taking into account the need for simplification, and that differences between the needs and capability of States would have a bearing on the choice.

4.2.4 The IVATF noted that NOTAM, ASHTAM, volcanic ash advisories (VAA) and SIGMET for volcanic ash were closely related, and that the existence of additional products and graphical variants of VAA and SIGMET for volcanic ash were either already available or under development. In addition, the progress report indicated that a digital NOTAM format was being discussed within the AIS/AIM community, and that many advanced information products were dependent on the availability of technological solutions both on the ground and in the aircraft.

4.2.5 The task TF-ATM02 progress report revealed that the "status" of such volcanic ash-related messages, described as either warnings or information, needed to be clarified, since various interpretations of ICAO provisions appeared to exist within service provider and user communities. In addition to the various interpretations, the IVATF was informed that a number of national deviations from ICAO provisions had been identified, and that many deficiencies in national or regional implementation had been reported.

4.2.6 Concerning the need to review and assess the benefits of new volcanic ash-related products, the IVATF noted that this activity had not been undertaken by the ATM02 task team since only one new product had been available, namely the modelled ash concentration charts produced by the meteorological offices collocated with VAACs London and Toulouse. Since discussion on the underlying concept had not concluded, a more detailed review had not been undertaken by the ATM02 task team.

4.2.7 The IVATF noted that the complete achievement of task TF-ATM02 could only be realized once issues related to tasks TF-AIR01, VAA02, VAA05 and VAA06 were resolved. The IVATF agreed that task TF-ATM02 should remain open, and updated the task accordingly.

4.2.8 In view of the foregoing, the IVATF formulated the following recommendations:

> **Recommendation 2/21 —** That appropriate ICAO groups, such as the AIS-AIM SG, OPLINKP or OPSP, working on advanced technologies for dissemination of information, be provided with operational requirements from an IVATF perspective to help them develop appropriate systems; and that ICAO develops a migration plan to these advance technologies.

Recommendation 2/22 — The IAVWOPSG and other ICAO groups (where necessary) be invited to review the detailed results of the investigation into flight planning information dissemination, as presented at **Appendix 4B** to this report.

Recommendation 2/23 — That detailed operational requirements for information on volcanic contaminants, such as altitude bands, be provided by IATA and IFALPA in coordination with the IAVW CG.

Agenda Item 4: Report of the Air Traffic Management Sub-Group (ATM SG)
4.3: Operational information exchange

4.3 Operational information exchange

4.3.1 As follow-up to IVATF task TF-ATM03, the AIR SG presented a progress report concerning operational information exchange, including recommendations for improvement of relevant ICAO provisions.

4.3.2 The IVATF recalled that task TF-ATM03 had been to develop procedures for the issuance, reception and dissemination of pilot reports regarding volcanic activity, in terms of special air reports as well as post-flight reporting. The IVATF noted that this would ultimately result in an amendment of ICAO provisions to enhance the transmission/reception of information regarding volcanic activity.

4.3.3 The IVATF noted that the requirements for Aircraft Observations and Reports were contained in Chapter 5 of ICAO Annex 3 – *Meteorological Service for International Air Navigation*, where paragraph 5.5 specified the need for pilots to provide special observations related to volcanic ash cloud or pre-eruption volcanic activity or eruption. This requirement was repeated in ICAO Doc 4444 – *Procedures for Air Navigation Services – Air Traffic Management*, where a "special air-report of volcanic activity" form was contained at Appendix 1 of PANS-ATM (including detailed instructions for reporting). Despite these requirements, the IVATF was apprised that a lack of special air-reports on volcanic activity had been noted by the International Airways Volcano Watch Operations Group (IAVWOPSG) at various meetings and reported to IVATF/1.

4.3.4 The IVATF noted that volcanic activity reports (VAR) served three different purposes:

a) immediate notification to other aircraft concerning the volcanic ash hazard;

b) input to the information chain for the volcanic ash hazard; and

c) post-flight review of occurrences (including airworthiness related issues).

4.3.5 The progress report to task TF-ATM03 included a series of recommendations, including the need to amend ICAO provisions, to ensure that guidance for the dissemination of VARs beyond meteorological watch offices (MWO) was included in regional contingency plans and that a global repository for filed VARs should be established so that post-event analysis could be conducted and conclusions drawn. The IVATF agreed to update task TF-ATM03 accordingly, and noted that it was linked with (new) task TF-VAA12 of the IAVW CG.

4.3.6 In view of the foregoing, the IVATF formulated the following recommendations:

Recommendation 2/24 — Clarification is required from the IAVW CG with regards to what volcanic activities need to be reported by pilots (for example pre-eruption volcanic activities).

Recommendation 2/25 — The ATM SG in coordination with the IAVW CG to examine ways to improve the quantity and quality of information on volcanic activities, including AIREP.

Recommendation 2/26 — IAVW CG, in coordination with the ATM SG and AIR SG, work on:

a) the development of a universal VAR form and accompanying briefing material;

b) a method to ensure that post-flight maintenance findings are appended to the VARs; and

c) developing means to ensure that VAR forms are available in electronic form; i.e. as part of templates within the datalink (ACARS, FANS) system or in electronic flight bags (EFB).

Agenda Item 4: Report of the Air Traffic Management Sub-Group (ATM SG)
4.4: Other issues

4.4 Other issues

4.4.1 The ATM SG developed three new tasks during the meeting (namely TF-ATM04, TF-ATM05 and TF-ATM06) as presented at **Appendix 6B** to this report.

4.4.2 No items leading to recommendations or actions agreed were addressed under this agenda item.

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Agenda Item 5: Report of the International Airways Volcano Watch Coordination Group (IAVW CG)
5.1: Volcanic ash-related provisions and guidance

5.1 Volcanic ash-related provisions and guidance

5.1.1 As follow-up to IVATF task TF-VAA01, the International Airways Volcano Watch Coordination Group (IAVW CG) of the IVATF presented a progress report on the identification of volcanic ash related provisions and guidance that needed to be updated. The IVATF noted that the IAVW CG had decided to only consider global provisions and guidance that needed to be updated, thereby electing to *exclude* consideration of regional and/or local provisions and guidance.

5.1.2 Accordingly, the IVATF noted that the IAVW CG had determined that the following ICAO Annexes and manuals, containing volcanic ash-related provisions and guidance respectively, warranted update, but that presently it was premature to anticipate the specific changes required:

i) Annex 3 – *Meteorological Service for International Air Navigation*; Annex 11 – *Air Traffic Services*; and Annex 15 – *Aeronautical Information Services*; and

ii) *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444); *Aeronautical Information Services Manual* (Doc 8126); *Manual of Aeronautical Meteorological Practice* (Doc 8896); *Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services* (Doc 9377); *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds* (Doc 9691); *Handbook on the International Airways Volcano Watch* (Doc 9766); *Global ATM Operational Concept* (Doc 9854); and *Manual on Air Traffic Management System Requirements* (Doc 9882).

5.1.3 Taking into account the progress report presented, and in particular the prematurity of anticipating specific changes, the IVATF agreed that task TF-VAA01 could be considered complete.

5.1.4 As follow-up to IVATF task TF-VAA02, the IAVW CG presented a progress report on an assessment of the need for the Volcanic Ash Advisory Centres (VAAC) to enhance the provision of volcanic ash advisories (VAA), as currently provided in accordance with Annex 3. The progress report highlighted a number of points including, the pertinence of making available volcanic ash advisories in graphic format (VAG) on the public Internet websites of the VAACs, appropriate means to communicate uncertainty in the forecasts, unification of the presentation of VAG amongst the VAACs, alternative formats beyond textual and graphical products, the frequency of issue and time-steps provided in the forecasts, standardized vertical layers/segmentation, and the possibility of producing ash concentration forecasts in graphical format as an ICAO requirement.

5.1.5 The IVATF noted that the assessment had indicated that users had expressed a clear desire to receive information concerning the uncertainty in the volcanic ash forecasts provided by the VAACs, but that there were practical constraints on how best to provide such information. Concerning this and the other points included in the progress report on task TF-VAA02, the IVATF supported a proposal that the IAVW CG (including representatives of the VAACs, WMO and users) should further consider how volcanic ash advisories, including those in graphical format, should be enhanced The IVATF recognized that there was a need to determine a optimal level of service (i.e. minimum number of products), in order to prevent downstream difficulties for end users (i.e. information overload). The IVATF updated task TF-VAA02 accordingly.

5.1.6 As follow-up to IVATF task TF-VAA06, the IAVW CG presented a progress report investigating the provision of SIGMET for large complex volcanic ash events, with a view, in particular, to improving their graphical depiction and the potential conveyance of additional information such as forecast uncertainty. The IVATF noted that a complex volcanic ash cloud was one where the ash cloud moved in different directions at different levels in the atmosphere. Noting the Annex 3 Recommended Practice concerning SIGMET in graphical form (Annex 3, Appendix 6, paragraph 1.1.7 refers), the IAVW CG had identified five options for the improved graphical representation of complex volcanic ash clouds.

5.1.7 Each of the five options presented had respective benefits and limitations – for example, some proposals would require little or no modification to existing Annex 3 provisions, yet would enable the description of complex volcanic ash situations, whilst others would result in a graphic that could address such complex events but would result in the text based equivalent SIGMET being too detailed or too long for efficient use. The IVATF formulated the following recommendation~~s~~ accordingly:

> **Recommendation 2/27 —** That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to evaluate the five options for the depiction of complex volcanic ash clouds in graphical SIGMET, as presented at **Appendix 5A** to this report, in view of determining which, if any, may be suitable for global applicability

5.1.8 The IVATF concurred that further study would be required prior to determining the feasibility of adding measures of uncertainty and/or levels of ash concentration. The IVATF updated task TF-VAA06 accordingly.

5.1.9 The IVATF was informed that task TF-VAA10 had been added to the work programme of the IAVW CG during the intersession period relating to the development of a Concept of Operations (ConOps) for volcanic ash information services in support of international air navigation.

5.1.10 As follow-up to IVATF task TF-VAA10, the IAVW CG presented a progress report on the development of a ConOps for volcanic ash, noting that draft material presented was a very first attempt at providing a framework on which to develop and define services to support, amongst others, collaborative decision making amongst the VAACs, services needed from volcano observatories, services and skills required at MWOs, and information required by users in support of decision making to avoid airspace contaminated by volcanic ash. In addition to defining functional and performance requirements for volcanic ash, the IVATF noted that the draft ConOps proposed the defining of a roadmap, including timelines, for the improvement of services, thus helping to define gaps in service provision that would need to be addressed.

5.1.11 The IVATF welcomed the initiation of a ConOps for volcanic ash, and proposed that its further development should remain within the remit of the IAVW CG, and should be considered a high priority. The IVATF recognized that, since the ConOps was a “living document”, there would be utility in increasing the visibility of the ConOps to other ICAO groups such as the Air Traffic Management Requirements and Performance Panel (ATMRPP), in order for the IAVW CG to mature the ConOps by July 2012.

5.1.12 Recognizing that a number of volcanic ash exercises (i.e. simulations), initiated by the EUR/NAT Office, had been held over recent years to test the effectiveness of the regional volcanic ash contingency plan, and had been held in previous years in some other Regions, the IVATF was invited to consider the need for specific guidance to support the conducting of such exercises in any of the ICAO Regions.

5.1.13 The Secretariat outlined that as part of the planning, execution and debriefing of volcanic ash exercises in the EUR/NAT Region, the EUR/NAT Volcanic Ash Exercises Steering Group (VOLCEX/SG) prepared, as routine, an exercise directive, initial exercise reports and a final exercise report, and that such documentation conformed to a set of volcanic ash exercise operating instructions developed by the EUR/NAT VOLCEX/SG. The Secretariat also outlined that the findings and recommendations stemming from the regional exercises routinely fed to improvements to the regional volcanic ash contingency plan.

5.1.14 The IVATF agreed that consideration should be given to the preparation of guidance to support volcanic ash exercises testing the effectiveness of the volcanic ash contingency plans in *any* ICAO Region, and decided that the IAVW CG undertake this as part of their future work programme. The IVATF updated task TF-VAA10 accordingly.

Agenda Item 5: Report of the International Airways Volcano Watch Coordination Group (IAVW CG)
5.2: Collaborative decision making

5.2 Collaborative decision making

5.2.1 As follow-up to IVATF task TF-VAA03, the IAVW CG presented a progress report on the need to promote collaborative decision making (CDM) amongst the VAACs, air traffic management and operators, with a view to promoting improved forecast capability and accuracy and improved situational awareness. The IVATF noted how volcanic ash CDM processes and tools were already utilized to good effect in several parts of the world, including in Alaska as part of a United States NOAA/NWS and FAA collaborative venture, and in Europe as part of EUROCONTROL's European Crisis Visualization Interactive Tool for Air Traffic Flow and Capacity Management (EVITA). The IVATF welcomed an initiative by EUROCONTROL and the United States Federal Aviation Administration to lead the effort on the development of CDM.

5.2.2 The IVATF was afforded an insight into these national/regional CDM processes and tools, as well as an illustration of CDM in action with some of the associated challenges. In addition, the IVATF was invited to consider the need to include CDM in the proposed ConOps.

5.2.3 In view of the foregoing, the IVATF welcomed the concept of using CDM in support of improving the situational awareness of volcanic ash, with the purpose of improving decision making and improved forecasting of ash contaminated airspace. The IVATF decided that the further development of CDM concepts for volcanic ash should remain within the remit of the IAVW CG. The IVATF updated task TF-VAA03 accordingly.

5.2.4 The IVATF recognized that there would be utility in improving the visibility of the CDM for volcanic ash to other ICAO groups such as the Air Traffic Management Requirements and Performance Panel (ATMRPP), in order for the IAVW CG to mature proposals by July 2012.

Agenda Item 5: Report of the International Airways Volcano Watch Coordination Group (IAVW CG)
5.3: Transport and dispersion modelling

5.3 Transport and dispersion modelling

5.3.1 Recalling IVATF task TF-VAA04 concerned an assessment of transport and dispersion models used for predicting the composition and movement of volcanic ash clouds, the IAVW CG progress report on task TF-VAA04 outlined that, by agreement, the Science Sub-Group (SCI SG) had led the investigation of the issues identified in close coordination with the WMO/IUGG Volcanic Ash Scientific Advisory Group (VASAG).

5.3.2 The IVATF noted that the SCI SG had, under Agenda Item 2.5 (Model improvements and validation), presented a comprehensive progress report on the issues identified, and that consequently task TF-VAA04 could be considered complete in view of further work expected within the IAVWOPSG and the related WMO/IUGG VASAG in the context of developing the use of transport and dispersion models in support of the IAVW.

Agenda Item 5: Report of the International Airways Volcano Watch Coordination Group (IAVW CG)
5.4: Volcanic ash data files

5.4 Volcanic ash data files

5.4.1 As follow-up to IVATF task TF-VAA05, the IAVW CG presented a progress report investigating the benefits of the VAACs generating comma separated variable (CSV) data files, or similar, to represent the volcanic ash cloud contamination areas. Such files, essentially containing latitude-longitude coordinate set data, could be used to represent the boundary of an ash cloud, thus enabling users to generate bespoke charts. The IVATF noted that there appeared to be a clear user need for such data files, and that direct ingestion of the data files into flight planning systems and plotting on a flight watch route screen were just two examples of supporting users' operational decision making and situational awareness.

5.4.2 The progress report outlined that there was no concern amongst the VAACs of making such data files available on the public Internet websites of the VAACs, but that consideration would have to be given to the possibility that some VAACs may not have resources available to produce such additional products as routine. Recognizing moves towards open industry standards such as Extensible Markup Language (XML) and Geography Markup Language (GML) to support, not least, aeronautical information exchange and meteorological information exchange, the IAVW CG progress report highlighted that XML/GML may be the preferred data file format compared with CSV, but that CSV should be considered as a supplemental format provided that the file format was standardized. In addition, the progress report outlined that the maximum number of geographical coordinate points used to define ash contaminated areas should be standardized, or alternatively, a maximum data file size should be specified.

5.4.3 In view of the foregoing, the IVATF decided that the IAVW CG should continue to monitor the development of data formats within ICAO and WMO frameworks, with a view to preparing mature proposals by July 2012. The IVATF updated task TF-VAA05 accordingly.

Agenda Item 5: Report of the International Airways Volcano Watch Coordination Group (IAVW CG)
5.5: Volcano observatory arrangements

5.5 Volcano observatory arrangements

5.5.1 As follow-up to IVATF tasks TF-VAA07, TF-VAA08 and TF-VAA09, the IAVW CG presented a progress report addressing appropriate steps to promote arrangements by concerned States to support volcano observatories, arrangements necessary to develop closer cooperation between volcanological, meteorological and aviation agencies, and consideration of the need for the establishment of an office of volcanologists (or an "office of aviation volcanology") under an international umbrella.

5.5.2 In the context of these tasks, the IAVW CG had identified a common thread concerning the necessity for appropriate monitoring by responsible State volcano observatories, and that failures in such available intelligence had long been considered one of the most critical risks of the IAVW, particularly in the developing world. To this end, the progress report outlined the issues and proposed a number of remedial approaches.

5.5.3 Recognizing that provisions concerning State volcano observatories already existed in Annex 3, supported by guidance within the Handbook on the IAVW (Doc 9766) and recently developed guidance for volcano observatories on the IAVW, the IVATF noted that fundamental to the provisions and guidance was the principle that a well-functioning system would capture cooperative requirements for aviation safety in a structured manner. However, the IVATF was informed that up to now, the current arrangements as dictated by Annex 3 and Doc 9766 had not been implemented except in isolated cases, and that the implementation of revised provisions and guidance could be reasonably forecast to be inadequate without targeted intervention.

5.5.4 The IVATF noted that a special problem is posed by lack of any monitoring on many long-quiet but potentially active volcanoes. An appropriate strategy would be to establish permanent but relatively simple monitoring at presently unmonitored volcanoes, and to quickly enhance that monitoring when a volcano re-awakens.

5.5.5 It was considered premature to define a certification process for volcano observatories. Nevertheless, the IVATF recognized that improved communication between volcano observatories and aviation stakeholders was considered essential for supporting the IAVW. In this regard, an essential measure for the IAVW could be the regular assessment of the readiness of States to respond to volcanic eruptions. In addition, it was proposed that some legislative or other formal agreement would be required to reinforce the role of some State volcano observatories, supported by improved guidance for States. The IVATF noted that as volcanic monitoring techniques constantly improved, any IAVW guidance related to these matters should in general be principle-based rather than prescriptive with regards to technology and that in addition to technological strategies, appropriate institutional strategies were very important.

5.5.6 The IVATF was informed of an ongoing concerted effort by the WMO/IUGG Volcanic Ash Scientific Advisory Group (VASAG) to explore the observed and potential future role of third parties (particularly research scientists) during volcanic crises in providing additional information and interpretation. In this regard, the IVATF noted that a key guidance document produced by the International Association of Chemistry and Volcanology of the Earth's Interior (IAVCEI), which articulated protocols to be followed during a volcanic crisis, could in general be adapted for use in an IAVW context.

5.5.7 In view of the foregoing, the IAVW CG had prepared proposed revisions to Doc 9766, and that such proposals should form the basis for developing any required complementary amendments to the recently developed guidance for State volcano observatories on the IAVW, and any other related guidance.

5.5.8 Addressing State volcano observatory provisions, the IAVW CG progress report suggested that the existing wording of Annex 3, paragraph 3.6 could be construed as leaving the option open for concerned States to *not* monitor active volcanoes within their area of responsibility. The IVATF concurred with a view expressed in the IAVW CG progress report that it was *necessary and reasonable* for Annex 3 to require that active volcanoes be monitored for the purposes of the IAVW, whether or not the concerned State chose to monitor for other purposes. The IVATF noted that for concerned States that currently chose not to monitor some volcanoes, this would be a significant change in practice.

5.5.9 Concerning a proposal at the last meeting to consider the need for the establishment of an office of volcanologists (or an office of aviation volcanology) under an international umbrella (task TF-VAA09 refers), the IAVW CG had considered that the proposal had merit, but that there would be various practical issues that would have to be addressed, including funding. For example, if a new United Nations (UN) treaty organization was proposed, would it be focused primarily on volcanology rather than aviation? Hence, while aviation could give support and encouragement to such a development, it would be inappropriate and difficult from an aviation perspective to be the main driver of such a creation. The IVATF concurred that other options should be investigated, noting that an appropriate first step in establishing an office of volcanologists, or other alternatives, would be to request WMO to consider whether they were able to provide support to promote improvements in volcano observatory products for aviation, improvements in communications between volcano observatories and the aviation community, and function as a bridge to ICAO. The IVATF noted that should such a request to WMO not be fully successful or should the revised guidance for the role of volcano observatories not be fully implemented through ICAO's direct liaison with States, a more far-reaching proposal may become necessary.

5.5.10 In view of the foregoing, the IVATF agreed to update task TF-VAA07, and considered tasks TF-VAA08 and TF-VAA09 to be complete in light of the formulation of the following recommendations:

Recommendation 2/28 — That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to consider revising the *Handbook on the International Airways Volcano Watch* (Doc 9766), taking into account the material presented at **Appendix 5B** to this report (and a further update to be developed by the IAVW CG concerning channels of communication), and to consider the implications on other ICAO guidance.

Recommendation 2/29 — That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to consider whether Annex 3, paragraph 3.6, should be amended to read: "*Contracting States with active or potentially active volcanoes shall arrange that selected State volcano observatories, as designated by regional air navigation agreement, shall monitor these volcanoes and when observing significant pre-eruption volcanic activity […]*"

Note.– The IAVWOPSG may wish to consider the ramifications of this amendment, if any, in the context of the ICAO Universal Safety Oversight Audit Programme (USOAP), and consider what supplementary guidance may be required to assist States in implementing these arrangements.

Recommendation 2/30 — That, the International Airways Volcano Watch Operations Group (IAVWOPSG) be invited to consider the possibility of undertaking a Special Implementation Project to ensure the effective implementation of IAVW procedures in ICAO States.

Agenda Item 5: Report of the International Airways Volcano Watch Coordination Group (IAVW CG)
5.6: Other issues

5.6 **Other issues**

5.6.1 The IAVW CG developed two new tasks during the meeting (namely TF-VAA11 and TF-VAA12) as presented at **Appendix 6B** to this report.

5.6.2 No items leading to recommendations or actions agreed were addressed under this agenda item.

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Agenda Item 6: Future work programme

6.1 **Terms of reference**

6.1.1 The IVATF noted that the modus operandi and terms of reference of the IVATF had remained unchanged since the establishment of the IVATF in May 2010. The IVATF was invited to review an update to the terms of reference, and concurred that the changes proposed, plus others developed during the meeting, merited immediate introduction. In particular, the IVATF supported that, for efficiency, the IVATF would be expected to complete all of its work by July 2012, and that any tasks and associated deliverables outstanding by that date would be transferred to the IAVWOPSG or other appropriate ICAO groups. The IVATF concurred that the composition of such groups should be reviewed in light of any tasks that would be transferred.

6.1.2 The modus operandi and terms of reference, as updated by the IVATF, is presented at **Appendix 6A** to this report.

6.2 **Work programme**

6.2.1 Taking into account the progress that had been made since the last meeting with respect to the twenty-seven tasks of the IVATF (as addressed under Agenda Items 2 to 5 inclusive), the IVATF concurred that an updated detailed work programme, containing expected deliverables and milestones, was an essential part of ensuring efficient and effective work of the sub-groups over the coming twelve months.

6.2.2 Accordingly, each of the four IVATF Sub-Groups formulated an updated work programme, taking into account those tasks stemming from IVATF/1 that could be considered complete, those tasks that were still outstanding, and any new tasks that had arisen from IVATF/2.

6.2.3 To maintain an overall awareness of the progress being made on the tasks, the IVATF agreed to maintain a programme of quarterly teleconferences of the IVATF Sub-Groups.

6.2.4 The future work programme of the four IVATF Sub-Groups for the period 2011 to 2012 is presented at **Appendix 6B** to this report.

6.2.5 In view of the foregoing, the IVATF formulated the following Action agreed:

Action agreed 2/1 — IVATF terms of reference and deliverables for 2011 to 2012

That, the IVATF endorses:

a) the updated terms of reference as presented at **Appendix 6A** to this report; and

b) the deliverables and the corresponding milestones for 2011 to 2012 as contained at **Appendix 6B** to this report.

Note. — The IVATF will be kept informed of progress through quarterly reports prepared by the IVATF Sub-Group project managers.

6.3 Critical issues

6.3.1 In addition to the development of a future work programme, the IVATF was invited to identify up to three critical issues per sub-group considered to be currently hampering the progress of the IVATF. The issues identified were prioritized in order of perceived importance, and were generally of a non-technical and/or non-operational nature.

6.3.2 The list of critical issues identified by the IVATF is presented at **Appendix 6C** to this report. The Secretariat outlined that the issues identified by the IVATF would be addressed, as appropriate, to a Volcanic Ash Challenge Team, of which ICAO was in the closing stages of establishing.

6.3.3 In view of the foregoing, the IVATF formulated the following Action agreed:

Action agreed 2/2 — Addressing critical issues identified by the IVATF

That, ICAO take necessary action to address the critical issues considered to be hampering progress, as identified and prioritized by the IVATF and presented at **Appendix 6C** to this report, in view of ensuring that the IVATF is able to fulfil its stated mandate by July 2012.

6.4 Next meeting

6.4.1 Recognizing that the work of the IVATF was expected to be concluded, to the extent possible, by July 2012, the IVATF agreed to convene two meetings over the coming twelve months. Accordingly, the IVATF agreed that IVATF/3 and IVATF/4 should be tentatively scheduled for February and June 2012 respectively, at ICAO Headquarters, Montréal, and that the Secretariat would confirm arrangements with members via memorandum no later than 30 September 2011.

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Agenda Item 7: Any other business

7.1 **Any other business**

7.1.1 The IVATF was informed of an IATA position statement. The IVATF agreed that specific IATA points concerning agenda items 2, 3 and 4, be reflected at **Appendix 7A** of this report.

7.1.2 No other items were addressed under this agenda item.

7.1.3 The meeting closed at 1300 hours on 15 July 2011.

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APPENDIX 1A

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Key: (M) = Member; (Alt) = Alternate; (Adv) = Advisor

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APPENDIX 2A

RECOMMENDATIONS FOR CONDUCTING AIRBORNE SAMPLING OF VOLCANIC ASH CLOUDS

(Extracted from IVATF/2 WP/19)

1.1 The following recommendations for airborne sampling of ash plumes result from the experience with the Eyjafjallajökull eruption in 2010. It is important to perform airborne measurements in the eruption plume as soon as possible after the eruption to get early information on the source term and ash properties. Therefore, research aircraft with suitable instrumentation should be available on a short notice (within 1-2 days). The aircraft should be capable of making measurements in the entire range of flight levels used by commercial air traffic, i.e. at altitudes up to 40,000 ft. It is recommended that experienced pilots and scientists conduct the missions. The planning of the flights should be based on all information available including data from satellites, ground-based observing systems, and predictions from dispersion models.

1.2 The recommended instrumentation of the aircraft includes a combination of remote-sensing (Lidar, IR camera, DOAS) and in-situ measurement systems for particles and gas-phase plume tracer. The Lidar provides information on the horizontal and vertical extent of the ash plume with qualitative information on the ash concentration and serves as pathfinder for the in-situ measurements. For the in-situ sampling the ash plume is best intercepted with a stacked level profile though the entire vertical extent of the plume. Thereby data are obtained that are best suited for comparison with satellite observations and dispersion models. Table 1 hereunder provides a list of recommended instrument types and measurements.

1.3 The mass concentration of ash cannot be measured directly but is determined from the particle number size distribution measured with the wing-mounted optical laser aerosol spectrometer for given refractive index and density of the particles. Therefore, it is important to cover the entire size range of ash particles in the plume. The resultant uncertainty in ash mass concentration is about a factor of 2 (Schumann et al., 2011).

Instrumentation	Measured quantity
Remote sensing instruments	
Nadir-viewing Lidar	aerosol backscatter ratio, depolarization
IR remote sensor (AVOID)	IR radiance at different wave-length
DOAS	SO_2 slant column density
In situ particle instruments	
Condensation particle counter (with heated and unheated channels)	integral number of ultrafine particles (0.005 < D_p < 2.5 µm) and non-volatile fraction
Optical particle counter (Grimm OPC 1.129)	fine particles (0.25 µm < D_p < 2.5 µm)
PCASP-100X /UHSAS-A Wing-mounted aerosol spectrometer	fine particles, dry state (0.15 µm < D_p < 3.0 µm)
FSSP-300 / CAS Wing-mounted aerosol spectrometer	size distribution coarse mode, ambient state (1 µm < D_p < 30/50 µm)
2D-C probe (wing-mounted)	shape and size distribution of very large particles, water droplets and ice-crystals (25 µm < D_p < 800 µm)
Nephelometer	particle scattering at three wavelength
Impactor sampler (in cabin)	chemical composition of fine particles (< 2.5 µm)
Particle Collector (wing-mounted)	chemical composition of coarse particles
Trace gas in-situ instruments	
Chemical ionization mass spectrometer	SO_2 , HCl mixing ratio
UV absorption detector	O_3 mixing ratio
Vacuum UV fluorescence detector	CO mixing ratio
Cavity ring down spectrometer	CO_2, CH_4 mixing ratio
Meteorological data	
Standard probes	position, temperature, pressure, humidity, wind

Table 1: Aircraft instrumentation for volcanic ash cloud sampling

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APPENDIX 2B

PRELIMINARY RECOMMENDATIONS FOR VOLCANIC ASH MATERIAL FOR USE IN JET ENGINE TESTING

(Extracted from Appendix to IVATF/2 WP/09)

1. INTRODUCTION

1.1. Information about reported encounters of aircraft with volcanic ash clouds (1953-2009), including the type and severity of damage to engines and airframes, is given in Guffanti et al. (2010) [1]. Recently declassified technical reports on volcanic-ash engine tests funded by the Defense Nuclear Agency (now the Defense Threat Reduction Agency) and conducted at the facilities of the Calspan Corporation during the 1980's and early 1990's are available at http://www.dtra.mil/Info/FOIA/FrequentlyRequestedRecords.aspx. Those tests involved high ash concentrations (tens to hundreds of milligrams per cubic meter), whereas current interest is directed at understanding the effects of lower concentrations that occur in distal parts of ash clouds several hundred kilometres or more from the volcanic sources.

1.2. This short report from the Science Sub-Group of the International Volcanic Ash Task Force (IVATF) offers some ideas and initial recommendations about what kind of volcanic material would be most suitable for any new tests that may be undertaken to determine the effects of volcanic ash on jet engines.

2. DISCUSSION

2.1. Volcanic ash is a mixture of small fragments of rock, mineral, and glassy material produced by explosive eruptions of volcanoes. During ash-producing eruptions, hot gas-charged magma abruptly depressurizes as it nears the Earth's surface and violently explodes out of a surface vent. The ejected magma is frothy with expanding gas and quickly cools in the air, fragmenting into pieces of pumice, glassy shards (not unlike pulverized window glass), and sharp-edged bits of minerals and rocks. The proportion of glass to minerals and rock material will vary from volcano to volcano. The mass of fragments (called tephra) — along with sulfur dioxide (SO_2) and other gases released from the decompressing magma—is entrained upward in a convecting, columnar mass. The larger pieces of tephra fall out of the column within minutes to hours and are deposited around the volcano, while the smallest particles (called ash) can remain suspended as volcanic clouds in the atmosphere for up to days.

2.2 Additionally, ash clouds can be produced from pyroclastic flows (hot, fast-moving, ground-hugging currents of gas and magmatic particles) when a mass of smaller particles rises convectively above the ground flow. On occasions, such ash clouds have reached altitudes of several kilometres.

[1] Guffanti, Marianne, Casadevall, T.J., and Budding, K, 2010, Encounters of aircraft with volcanic ash clouds—A compilation of known incidents, 1953-2009: U.S. Geological Survey Digital Series 545. Online at http://pubs.usgs.gov/ds/545/

2.3 The size of individual ash particles in volcanic clouds can range from less than one micron (a micron is a micrometer, 10^{-6} m) up to several hundred microns. In clouds >1,000 km from their source, particles typically are microns to tens of microns in diameter.

2.4 Magmatic gases such as SO_2, CO_2, H_2S, HCl, and HF are erupted along with solid particles and react with water vapour in the erupting column and atmosphere. Of particular importance in a volcanic cloud is SO_2, some of which remains in that form in the atmosphere while some converts to sulphuric acid (H_2SO_4) which can be adsorbed onto volcanic ash particles.

2.5 The first-order compositional scheme for volcanic material, including ash, is based on silica content (reported as SiO_2). The scheme has three basic categories: mafic, intermediate, and silicic. Mafic materials are relatively low in silica (<52% SiO_2 as in basalt magma). Silicic material is relatively high in silica (>64% SiO_2 as in dacites and rhyolites). Intermediate compositions are 52 to 63 SiO_2 as in andesites. The following relationships are important when considering tests:

- Mafic material has a higher melting temperature than more silicic material (e.g., ~1200^{o}C for mafic minerals compared to ~800^{o}C for silicic minerals)

- Glass will melt at lower temperatures than minerals of the same composition (e.g., ~1100^{o}C for mafic glass and ~650^{o}C for silicic glass)

- Other parameters being equal, finer-grained ash will melt more easily than coarse grained ash because the entire finer particle can be heated more quickly.

2.6 Some initial volcanological recommendations about basic testing parameters are the following:

- Testing should use actual (authentic) volcanic ash. Synthetic mixtures created to simulate volcanic ash should *not* be used because doing so introduces yet more uncertainty into an already complex testing scheme.

- Ash for engine tests should be a mixture of fine-grained particles from about 10-100 microns, the size range expected in dispersed volcanic clouds beyond the vicinity of the volcanic source. It is not critical to have the ash be naturally pulverized; artificially pulverizing and sieving large-size tephra would produce virtually the same material. Ideally, the ash should be “fresh” – i.e., not consisting of hydrated glass (i.e., glass into which water has diffused) as one might find in geologically older, weathered ash.

- Tests should use volcanic ash in the compositional range of 56-64% SiO_2, a common range for volcanic-rock compositions worldwide that encompasses many andesites and some (lower silica) dacites. Candidate volcanoes for such material include those whose eruptions are known to have caused damage to aircraft in-flight:
    - Mount St. Helens, Washington, 1980
    - Galunggung, Indonesia, 1982
    - Redoubt, Alaska, 1989-1990
    - Pinatubo, Philippines, 1991
    - Rabaul, Papua New Guinea, 2004
    - Soufriere Hills, Montserrat, 1995-present

- Testing should be started with dry samples—i.e., with no added volatiles components, such as water vapour or SO_2—in order to limit the number of complicated variables until test design can be re-evaluated.

2.7 Ash in sufficient bulk for testing likely will involve collection of several thousands of kilograms (several tonnes) of material. Depending on shipping concerns, the distance of a collection site to a testing site may be an issue.

2.8 Inclusion of volcano scientists familiar with explosive volcanism and its eruptive products in any industry development of test standards is recommended, to refine the recommendations presented here and answer questions as they arise. It also recommended that data from the previous Calspan tests be carefully reviewed to determine if there are any important results regarding the type of volcanic materials that might be applicable to any future tests.

2.9 Original Equipment Manufacturers have the appropriate expertise to define the types of engines, or engine components to be used in testing.

3. CONCLUSIONS

3.1 The information in this paper provides a starting point for what volcanic material to use, should a program to test jet engines with volcanic ash be formulated.

3.2 Further recommendations about the engineering objectives and design of actual tests are best formulated by an industry standards group of experts.

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APPENDIX 2C

EXPLANATION OF SOURCES AND SIGNIFICANCE OF UNCERTAINTY IN MODEL FORECASTS OF ASH DISPERSION

(Extracted from Appendix to IVATF/2 WP/11)

1. INTRODUCTION

1.1 In support of the IVATF, a workshop on ash dispersal forecasting and aviation was held in Geneva, Switzerland, on 18-20 October 2010 under the auspices of the WMO, the International Association of Volcanology and Chemistry of the Earth's Interior, and the University of Geneva. The workshop was a forum for scientists to document the capabilities and sensitivities of different dispersion models and to identify possible improvements related to input parameters, data assimilation, probabilistic forecasts, and ensembles. Technical results from the workshop are documented and available at http://www.unige.ch/hazards/Workshop.html.

1.2 This appendix further examines scientific aspects of modelling pertinent to the operational use of dispersion forecasts—namely, the sources and significance of the uncertainties inherent in such forecasts. For simplicity the term "ash" is used throughout this document to indicate all volcanic fragments injected into the atmosphere, although technically "ash" refers only to fragments smaller than 2 mm, and "tephra" refers to fragments of all sizes.

1.3 Uncertainties in model forecasts depend on both input uncertainty and model accuracy. Input uncertainty is a measure of the degree to which input conditions are known (related to both the detection techniques used and to the variability of the natural system). In ash dispersion models, input uncertainty includes uncertainty in parameters at the eruptive source (e.g., plume height, start and stop time, mass eruption rate, particle size distribution) and in the meteorology (e.g., wind velocity and direction, temperature, humidity). Most dispersion models use meteorological parameters calculated in external numerical weather prediction (NWP) models.

1.4 Dispersion model accuracy is a measure of the degree to which a model can replicate the location, movement, and properties of the volcanic cloud quantitatively at all scales of space and time, assuming the input conditions to be known exactly. It is related to: the integrity of the governing equations; the accuracy with which constitutive relations calculate properties such as air density or settling velocity; the degree to which all processes of importance are included (advection, dispersion, meander, particle aggregation, wet removal, etc.); the accuracy of numerical solution techniques; and model setup parameters such as the grid spacing (for Eulerian models) or number of particles released (for Lagrangian models).

2. DISCUSSION

2.1 Sources of forecast uncertainty can be described in terms of three key components: (1) uncertainty in eruption source parameters, (2) uncertainty in meteorological parameters, and (2) limitations in the accuracy with which current models simulate ash removal, especially through processes such as particle aggregation.

2.2 Input Uncertainty—Eruption Source Parameters (ESP)

These comprise all volcanological parameters that characterize the input of volcanic ash to the atmosphere. Some parameters, such as plume height and eruption start/stop time, can be obtained by direct observation. Others must be derived from known relationships with observable properties (e.g., mass eruption rate and erupted mass) or from direct observations of past eruptions (e.g., particle properties, such as size, density and shape). Eruption source parameters vary among volcanoes and among eruptions at a particular volcano. They primarily consist of:

- *Start and end time of eruption*. These parameters are fundamental and can be difficult to obtain accurately if the volcano is not adequately monitored.

- *Height of the eruptive plume*. Plume height can range from less than a kilometer to nearly 50 km, and can vary over time as an eruption progresses. Plume height can be estimated using satellites, ground-based instruments (such as radar, lidar, and cameras), and visual observations from the ground or aircraft. All of these types of estimates have uncertainties and present a challenge when meteorological clouds are present. For past eruptions where multiple observations were available, estimates from different observers or instruments have differed by up to several kilometers. Accurately representing changes in eruption height with time is a challenge for modelers if frequent observations are not available.

- *Mass eruption rate (MER)*: This is the rate at which ash is emitted into the atmosphere (mass per time). Ash concentration in volcanic clouds is directly related to MER, which ranges over more than five orders of magnitude for historical eruptions worldwide. The MER currently cannot be determined directly during an eruption; it is generally estimated by empirical correlation with eruptive column height. There is a general 4^{th} power relation between plume height and mass eruption rate of sustained vertically-rising plumes supported by theory. However, when observed plume heights and MER are plotted together, there is a considerable scatter in the empirical relationship between them, which reflects both real variance and measurement errors. As an example, a column height of 10 km correlates best with an MER of about 1.8 million kg/s; but within one standard-deviation error, MER could range an order of magnitude from approximately 0.7 million kg/s to approximately 8 million kg/s — more than an order of magnitude. Empirical correlations also don’t consider effects of wind or of atmospheric humidity in tropical environments, which can strongly affect column height for small eruptions.

- *Mass distribution of material in the plume by elevation*: Volcanic plumes are driven upward by buoyancy of hot gas and air, and mass is distributed vertically according to settling velocity of particles in relation to the vertical velocity of the plume. Operational models use dedicated plume parameterization to distribute the mass vertically or use simple assumptions, such as uniform distributions. The actual mass distribution in volcanic plumes and the factors that affect it are not well understood, although modelling studies show that it can significantly affect dispersion forecasts.

- *Particle-size distribution and the mass of ash that enters the distal cloud.* Most operational ash-cloud models use a parameter that represents the total mass of fine ash that is erupted *and not deposited* close to the vent. Fragments larger than about a hundred microns fall to the ground within hours, accumulating within a few hundred kilometers of the vent to form a deposit that is recognizable on the ground. Fragments smaller than several tens of microns can stay aloft for days and compose a distal ash cloud. The amount of fine ash directly influences ash-cloud concentration in distal areas. Studies of proximal and medial deposits (<100 km) have found that the mass fraction of fine ash ranges from a few percent to several tens of percent, but is commonly tens of percent for medium or large eruptions. By contrast, instrumental measurements of a few ash clouds measured >1000 km from the source suggest that cloud mass is typically a few percent of total erupted mass. This difference, between the fraction of fine ash in deposits and clouds, is largely explained by the fact that fine ash clumps together, or aggregates, to form clusters that fall from the cloud more rapidly than predicted by the settling rate of individual particles. Currently, no operational models include this aggregation process. As a consequence, the input term for most VAAC models implicitly considers only the mass fraction of fine ash in the distal eruption cloud (the mass of fine ash removed by aggregation is not included). It is important to bear in mind that in such a case the mass considered is not the mass derived from empirical relationship of mass eruption rate at source. Some models also divide this mass into several size bins, each with its own density. The mass fraction of fine ash that escapes aggregation, the size distribution within this mass, and factors that affect these parameters, are not well established.

2.2 Input Uncertainty—Meteorology / Numerical Weather Prediction (NWP)

Numerical weather prediction models calculate the three-dimensional wind field, temperature, pressure, and moisture content that are used in ash-dispersion models. A few research NWP models calculate meteorology and ash-cloud dispersion simultaneously, but all dispersion models currently used by VAACs take the meteorological output of NWP models and use it as input in a separate step. Atmospheric NWP models can run at global, regional and local scales, and their accuracy is affected by the underlying science and the quality and quantity of supporting observational data:

- The predictive skill of modern NWP models is generally high, due partly to quality control and model improvement cycles at National Meteorological Centers, and use of remote-sensing data to constrain meteorology over remote oceans and in the upper atmosphere. Nevertheless, uncertainties vary with time and location. Uncertainties in numerically predicted wind fields have led to discrepancies of up to several hours in the time of arrival of distal ash clouds. During a handful of recent eruptions, dispersion model forecasts were discounted because the direction of predicted ash migration disagreed with satellite observations. Examples include eruptions in 2008 at Chaitén volcano in Chile and 2003 at Anatahan volcano in the U.S. Commonwealth of the Northern Mariana Islands.

- During the passage of a front or upper trough, the wind field varies rapidly in space and time; thus small timing or positional errors in the NWP model can significantly impact the dispersion prediction.

- The ability of an ash dispersion model to resolve ash layer depth and transport is a function of the vertical and horizontal resolution of the NWP. Typically features smaller than 2-3 times the NWP resolution cannot be well resolved.

2.3 Model Accuracy

As described above, model accuracy depends on various aspects of dispersion modelling. Here we investigate only the aspect of ash-removal processes as it is probably a major source of inaccuracy in all current dispersion models.

- Ash is removed from the atmosphere by various processes including gravitational settling, precipitation and particle aggregation. Precipitation processes include scavenging of ash by falling raindrops and raindrop formation. These are calculated in some models but they depend on NWP-derived estimates of cloud water and precipitation rates, which are not highly accurate. Particle aggregation is affected by electrostatic charge, and by the presence of liquid water or ice in the atmosphere. As mentioned aggregation is not yet considered in operational models and only a few research models attempt to calculate the rate of aggregation. This means that assumptions must be made about the input parameters. Consequently, current models are not able to forecast the full lifecycle of ash clouds because they don't accurately consider important ash-removal processes.

2.4 Summary of Sources of Uncertainty

Uncertainty or inaccuracy in any of the above sources *individually* can translate into large errors in forecast output under certain circumstances. In fact, most of both eruptive and meteorological input parameters strongly depend on each other. For example, a plume height that is modeled to extend to a kilometer below the base of the jet stream will produce an ash dispersal pattern that differs dramatically from one that extends a kilometer above. A brief eruption that is modeled to occur an hour before the passage of a rapidly moving storm front will distribute ash in a substantially different pattern than one that occurs an hour thereafter. In the unlikely event that plume height is known exactly and the mass eruption rate is calculated from plume height using well-known empirical relations, the uncertainty in mass eruption rate is plus or minus an order of magnitude. Holding all other variables constant, concentration is linearly related to mass eruption rate. Therefore, one order of magnitude variation in the mass eruption rate translates directly to one order of magnitude uncertainty in ash-cloud concentrations. Given that other uncertainties also exist, **uncertainty in ash-cloud concentration at any given point in space and time is at least one order of magnitude above or below the forecast value.**

2.5 Implications for Operational Products

This conclusion has significant implications for operational products, such as the EUR/NAT approach which uses specific ash-concentration values to outline areas of low, medium, and high ash contamination (see UK CAA guidance document[1]). In the EUR/NAT approach, a concentration value of 2 mg/m^3 defines the boundary (contour line) between zones of medium and low ash contamination. If that boundary is determined primarily on the basis of dispersion modelling, it could be recognized as representing a range from about 0.2 to 20 mg/m^3 because of forecast uncertainties. This means that the value of 4 mg/m^3 used to define the boundary between medium and high contamination falls within the uncertainty range of the next lower boundary. Thus, there is no meaningful distinction between modelled ash concentrations of 2 and 4 mg/m^3 given current levels of uncertainty.

2.6 Approaches for Decreasing Uncertainty in Model Forecasts

[1] http://www.caa.co.uk/docs/1425/20110210GuidanceRegardingFlightOperationsInTheVicinityOfVolcanicAsh.pdf/

Forecast uncertainty can be decreased on two fronts by reducing input uncertainty and increasing model accuracy.

- *Input uncertainty* can be reduced by improving the detection techniques used, incorporating observational data, the increasing speed at which observational data can be incorporated into models. Different forecasting phases require different strategies to reduce input uncertainty. Forecasts that are run early in an eruption, when few or perhaps no observations are available, may be based on dedicated ESP probability density functions (PDFs) compiled for each given volcano or, in cases where dedicated PDFs are not available, on standard ESP that account for related uncertainties. The first simulation run just after the onset of an eruption may also rely on ESP that can be detected in near-real-time (i.e. plume height). This can benefit from data assimilation of ESP of increasing accuracy as soon as these are made available. Observations may be assimilated into models from both direct measurements (e.g., source term/characteristics) and indirectly through combination with other models (e.g. using models to invert for vertical mass distribution in the eruptive plume from satellite images and/or radar information). Numerous techniques are possible, varying in hierarchy from user manually changing inputs, inverse modelling techniques or full variational data assimilation (as done by NWP models). Within dispersion modelling some of the techniques are currently immature, and therefore the key issues here are to explore and evaluate potential techniques and to determine the computational/timing implications for operational delivery.

- *Model accuracy* can increase by better representation of ash-removal mechanisms such as aggregation and wet deposition, and by other improvements to model physics and numerics. Numerical improvements may include, for example, the description of the lateral spread of umbrella clouds or automatic mesh refinement in Eulerian models that can resolve features to higher accuracy while decreasing simulation time.

3 CONCLUSIONS

3.1 Uncertainty in model forecasts of ash concentration depends on both uncertainties in input parameters and accuracy of models and is currently at least one order of magnitude above or below actual ash concentrations. The use of ash concentration thresholds that are separated by less than an order of magnitude is not scientifically appropriate with current capabilities. Uncertainty is an intrinsic aspect of volcanic eruptions and of detection techniques currently available to determine crucial eruptive parameters. As evidenced by the 2010 Geneva Workshop, an effort is underway in the scientific community to decrease this uncertainty and its effect on model forecasts.

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APPENDIX 3A

PROPOSED AMENDMENTS TO ICAO DOCUMENTS

3A.1 ICAO DOC 9691

Editorial note: Text to be added ~~Text to be deleted~~

3.2 AIRBORNE OBSERVATION

3.2.1 ~~Since the heightened concern prompted by the Galunggung eruption in 1982, it is a fact that many volcanic eruptions in remote areas have first been reported by pilots. Direct visual observation from the air being little different from observation from the ground except for the enhanced viewpoint from the cockpit, most of the foregoing points made in respect of the latter generally apply also to the former. One point which bears closer examination, however, is the reporting by pilots of “pre-eruption volcanic activity”.~~ Although improvements are constantly made, only a minority of all active volcanoes in the world is subject to scientific monitoring. Due to their commanding view from the cockpit and regular travel over remote areas, pilots are often the first to observe a volcanic eruption or volcanic ash cloud. In view of the danger volcanic ash presents to aircraft, it is therefore of utmost importance that, workload permitting, States require aircraft pilots to report observed volcanic activity in a timely manner in accordance with ICAO Annex 3, Chapter 5.5 g) and h) and to record a special air-report in accordance with Annex 3, Chapter 5.9. However, ~~S~~striking a balance between the continual reporting of a volcano which produces smoke/steam virtually every day on the one hand and ignoring all but a full-fledged eruption on the other hand, is rather difficult. The explanation for “pre-eruption volcanic activity”, in this context, is given in Annex 3 — Meteorological Service for International Air Navigation as: “unusual and/or increasing volcanic activity which could presage a volcanic eruption”. It is accepted that pilots should only report what they see and the interpretation of this meaning by pilots will be largely subjective, nevertheless special air-reports of volcanic activity should still be made by pilots in these circumstances, and the relevant area control centre will decide if it is necessary to issue a NOTAM. Pilots should make and transmit a special aircraft observation in accordance with 5.5 g) and h) of Annex 3, in the event that pre-eruption volcanic activity or a volcanic eruption is observed or a cloud of volcanic ash is encountered or observed which may affect the safety of other aircraft operations, and to record a special air-report in accordance with Annex 3, Chapter 5.9. ~~Although most airborne weather radars also operate in the X band, except for the unlikely case of an aircraft actually encountering the ascending ash column immediately after the eruption, within a few hours the larger ash particles are most likely to have settled out and the aircraft radar will not be able to detect the ash cloud. As will be seen later, even though the ash cloud is not detectable by airborne radar, it still presents a serious hazard for the aircraft.~~ In order to make pilots aware of the importance of reporting volcanic activity and to familiarize them with the means to do so, it is recommended States require the airlines to cover this in operations manuals and to train aircrew in observation and reporting of volcanic activity and make guidance material available to them through, for example, recurrent training manuals. Symptoms of inadvertent flight into volcanic ash can be found in the next paragraph. For procedures on dealing with volcanic ash encounters aircrew may be referred to OEM instructions and procedures. General information on this subject can be found in Chapter 4.4. of this manual.

3.2.2 If an aircraft actually encounters a volcanic ash cloud, depending on the density of the cloud and the time of exposure, the pilot will generally observe one or more of the following unusual effects which indicate unmistakably that the aircraft has entered a volcanic ash cloud, as follows:

a) at night, static electric discharges (St. Elmo's fire) visible around the cockpit windshield;
b) bright, whitish glow from inside the jet engines;
c) outside darkness during daylight hours;
d) ~~b)~~ very fine volcanic ash particles and dust appearing in the cabin, leaving a coating on cabin surfaces;
e) ~~c)~~ acrid odour noticeable, similar to electrical discharge;
f) smell of sulphur; odour similar to a struck match;
g) reduced forward visibility due to abrasion of cockpit windows;
h) ~~d)~~ at night, landing lights cast sharp, distinct shadows on the volcanic ash cloud as opposed to the normally fuzzy, indistinct shadows cast on water/ice clouds;
i) engine malfunctions, such as stalls, increasing Exhaust Gas Temperature (EGT), torching, flameout, and thrust loss;
j) other system anomalies such as unreliable airspeed indication and degraded radio communication may also be noticeable;
k) nuisance cargo fire warnings due to the volcanic ash in the air.

Additional engine and/or system anomalies may be noticeable. These are dealt with in Chapter 4, as is the action to be taken by the pilot in these circumstances. It is worth emphasizing again that volcanic ash cloud does not produce "returns" or "echoes" on the airborne weather radar.

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3.4 FORECASTING THE MOVEMENT OF VOLCANIC ASH CLOUDS

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~~3.4.8 Unfortunately, at present there are no agreed values of ash concentration which constitute a hazard to jet aircraft engines. This matter is discussed in detail in Chapter 4, but it is worth noting here that the exposure time of engines to ash and the thrust settings at the time of the encounter both have a direct bearing on the threshold value of ash concentration that constitutes a hazard. In view of this, the recommended procedure in the case of a volcanic ash encounter is exactly the same as for low-level wind shear: regardless of the ash concentration — AVOID AVOID AVOID.~~

4.2 EFFECT ON JET ENGINES

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4.2.5 The following are observations and trends noted from the United States Government funded, Calspan testing of military engines in the 1980 and 1990's:

1) The damage observed in the engines following exposure to a simulated volcanic ash environment varies dependent on the following considerations, power setting at time of exposure (turbine inlet temperature), and amount of time is exposed to volcanic ash, type of ash and concentration level. At lower power setting or lower turbine inlet

temperatures, the predominate flow path damage condition is air foil erosion. At higher power settings or higher turbine inlet temperatures, the predominate damage condition shifts from airfoil erosion to debris and glassification build up in the combustor and turbine sections.

2) The damage observed in the engines following exposure to a simulated volcanic ash varies dependent on the following considerations, ash chemistry (melting point), ash particle size distribution, and ash concentration.
3) The Hot Section Tests demonstrated; 1) the amount of buildup on a turbine nozzle guide vane is highly dependent on the chemistry of the dust ingested, 2) cooled nozzle guide vanes accumulate less debris than uncooled nozzles guide vanes, and 3) a reduction in nozzle guide vane cooling accelerates the rate of debris accumulation. This testing included approximately six dust blends and ingested concentrations were varied between 200 and 1,000 mg/m^3.
4) F107 small engine test series (1st engine): 1) all ingestion testing completed at steady state maximum power, i.e. engine transient performance was not evaluated, 2) a 14 hour test with “earth mix” ingested at moderate levels of 5 to 100 mg/m^3, with ingestions of 100 mg/m^3 for ~3% of test time, 3) during last quarter of testing moderate instabilities were observed, no conclusion as to the origin of instability was established, 4) Compressor erosion was observed post-test, 5) little, if any, glassification debris on combustor or turbine nozzles was noted. Maximum TIT was 1880^{o}F. Ingested material size ranged from 40 to 250 microns, relatively large particles. Post-test findings observed significant (unserviceable) compressor erosion as well as opened compressor and turbine clearances (blade to casing).
5) F100 mid-size engine test series (2nd engine): 1) all ingestion testing completed at steady state military power with TIT of ~2500^{o}F, i.e. engine transient performance was no evaluated, 2) total test duration 20 minutes with relatively high ingestion level of ~500 mg/m^3, 3) The engine “purge” cycle, which is a reduction in power to idle then slow acceleration to maximum (dry) power, did expel a portion of the glassification debris on the nozzle guide vanes to recover some performance. Subsequent ingestion showed build up at a more rapid rate than was originally observed. Significant compressor blade erosion and open tip clearance irreversibly degraded engine operability and performance. The overall engine condition was beyond economic repair following this testing. A general conclusion from the two F100 engine test series, was that exposure to moderate level of volcanic ash ingestion would first be observable in the engine by erosion of the compressor air foils and exposure to higher levels of volcanic ash would first be observable by glassification build up on the turbine nozzle guide vanes.
6) YF101 mid-size engine test series observations: 1) all ingestion testing completed at steady state military power, i.e. engine transient performance was no evaluated, 2) engine performance deterioration was observable within the first 2.5 minutes of dust ingestion at a rate of 80 mg/m^3, 3) Following first test series (10 minutes of operation) compressor erosion and nozzle guide vane debris accumulation was observed, and 4) mid-way through the testing the engine was damaged to a point of not being airworthy from a operability stand point. Maximum TIT calculated to be ~2560^{o}F. This testing included approximately four dust blends and ingestion

concentrations were varies between 80 and 455 mg/m^3. At the end of the test the engine condition was beyond economic repair commercially.

It is recognized that traces levels of volcanic ash can remain in the atmosphere for days, week, and even months following a volcanic eruption. These trace levels, which are undetectable to the human senses and not likely visible, have not been a hazard to safe flight. It is recognized though that even these trace levels of volcanic ash, like sand or dust do cause irreversible economic damage to these otherwise serviceable engines leading to premature removal or reduced on-wing life. Additional insight into turbofan engine susceptibility is gained from worldwide commercial operations in Desert Sand & Dust. Manufactures have worked to reduce engine susceptibility to desert sand & dust damage leading to premature removal or reduce on-wing life. Specifically, compressor airfoil erosion damage and turbine damage from sand & dust debris adhering to turbine nozzles and the loss of cooling to hot section parts. Environmental air quality data has been used to assess particulate in the air to compare mass loading between regions to understand the air environmental impact on engine durability. This environmental quality data has been used to provide partial substantiation of an engine's ability to safely operate in an environment contaminated by low levels of volcanic ash. Based on environmental air quality measurements for particulate matter and concentration levels provide some insight into the level of volcanic ash tolerable to an engine from a safety hazard stand point. It is recognized that the composition of typical sand & dust does differ from volcanic ash in particular the level of calcium carbonate which is as a major constitute leading to turbine damage. Exposure to desert sand and dust environment is at relatively low altitude, where the volcanic ash environment is both at the surface and up to and including cruise altitudes the exposure time can be significantly longer for the volcanic ash hazard. Additionally, it should be noted that for an equivalent airflow the ingestion level increases with increased altitude as a result of reduced air density at altitude. One such robustness test conducted by an engine manufacturer exposed a ground test engine to a mixture of desert sand specifically formulated to assess hot section robustness to desert sand ingestions. In this test the engine was exposure to sand concentration of approximately 750mg/m^3, injected into the engine low pressure compressor, for ten minutes to assess damage of a proposed design improvement. The engine successfully ran and produced thrust the whole ten minutes, however at the end of the test the engines operability was reduced to the point of negative operability margin. It was not determined how long the engine would have continued to run with positive transient operability margin.

The test results summarized above are likely applicable to engines of similar construction and thermodynamic cycle parameters. However, modern engines have evolved both in material application and thermodynamic cycle to improve cost of ownership and to reduce emissions in the environment. In the area of materials changes many more recently certified engines have incorporated material changes to the air foils to reduce erosion and have new material and coating to tolerate higher temperature operation. In the area of cycle changes, today's high performance engines run higher combustion and turbine inlet temperatures to improve emissions and customer economics (fuel burn). Of these areas of change, the following general conclusions can be made: 1) materials changes to improve desert sand erosion should reduce the airfoils susceptibility to volcanic ash, 2) the coatings and material changes in the combustion and turbine section of the engine have an unknown impact on glassification of volcanic ash accumulation, and 3) the increases in combustor and turbine section temperatures will increase the engines susceptibility to volcanic ash. Quantifying these susceptibilities such that a single volcanic ash concentration could be used universally for every volcanic eruption is not practical. However, it should be assumed that a modern jet engines will be at least as or more susceptible to volcanic ash as the engines tested above.

4.3 EFFECT ON AIRFRAME AND EQUIPMENT

…

4.3.2 ~~One of the most important probes protruding from the airframe is the pitot-static system which, in addition to abrasion, suffers blockage by volcanic ash. This can render the airspeed instrument unreliable and may result in a complete loss of airspeed information in the cockpit. Blockage of fuel and cooling system holes is possible but has not been reported following actual volcanic ash encounters. Certainly, fuel, oil and cooling systems can be heavily contaminated by volcanic ash, necessitating a complete cleaning and fluid and filter replacement. Following a volcanic ash encounter, virtually the whole fuselage can be contaminated, necessitating a thorough cleaning of the cockpit instrument panel, circuit breaker panels, passenger and baggage compartments, etc. The electrical and avionics units can be so heavily contaminated that complete replacement is necessary, mainly due to the strong possibility that all the units could have suffered from overheating. This could assume increasing importance in the case of fly-by-wire aircraft in respect of the filtering of the air used in the electronic units cooling systems. The ash also contaminates the cargo-hold fire-warning system and can generate nuisance fire warnings which are due to the volcanic ash in the air and not smoke from a fire.~~ The Original Equipment Manufacturers (OEMs) do not recommend flight operations in visible ~~or discernable~~ volcanic ash clouds. Precaution must also be used when operating aircraft on the ground in areas contaminated with volcanic ash fallout. The following information provides general guidance and considerations for operations in the event of a volcanic ash event. Operators should consult their appropriate OEMs for the latest information regarding volcanic ash guidance.

Figure 4-3 illustrates areas in general where an airplane can be susceptible to volcanic ash. If the airplane inadvertently or otherwise has a volcanic ash encounter, the operator should conduct a Volcanic Ash Conditional Inspection in accordance with the OEM’s Airplane Maintenance Manual (AMM) before the next flight.

If an operator is operating in low level ash concentration (not visible), the areas of the airplane as illustrated in Figure 4-3 should receive closer attention during hangar visits and potentially adjust their maintenance practices based upon their maintenance observations to prevent unscheduled maintenance. Observations should check for signs of unusual or accelerated abrasions and / or ash accumulation.

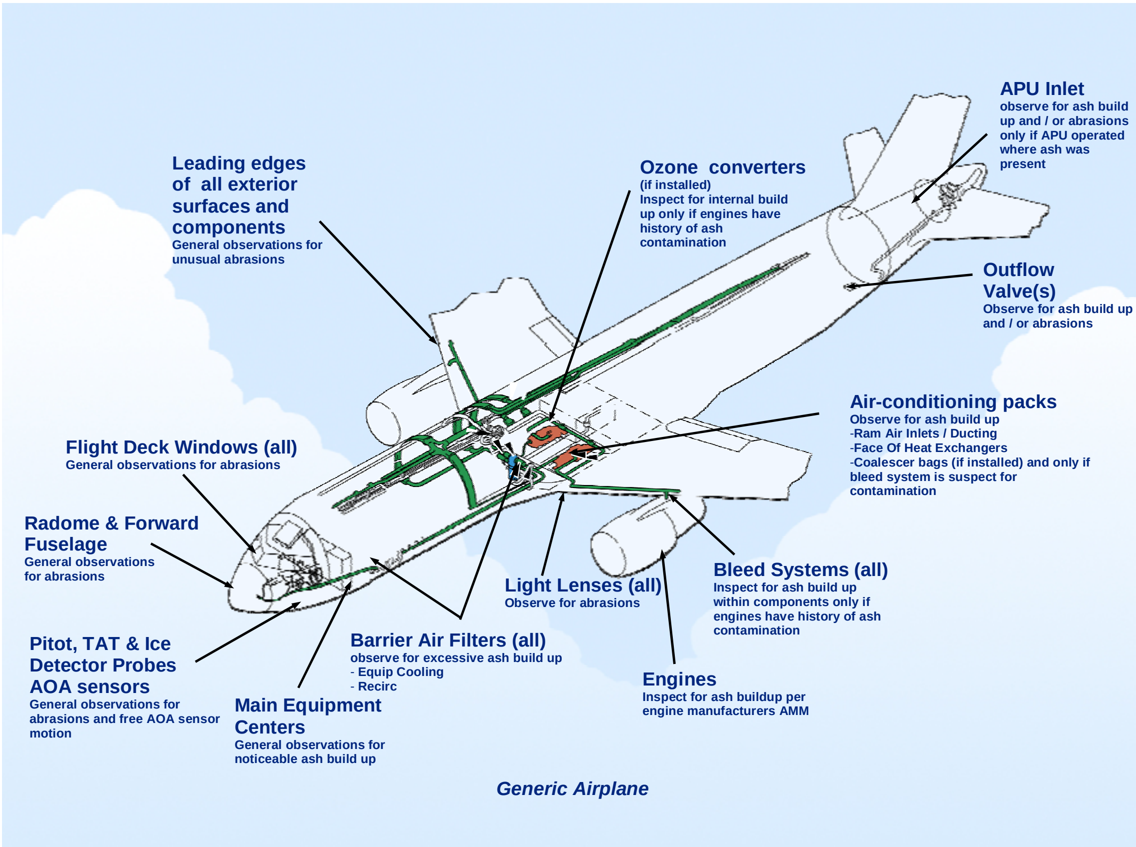

Figure 4-3. Airframe & Systems areas of observations for operations in vicinity of volcanic ash

The airframe, engines, and systems can normally handle operations in low volcanic ash concentrations (not visible), without requiring unique or special subsequent inspections outside the normal operating and maintenance experience of individual airlines. Airframe, engines, and systems degradation can occur at different rates, however, within many operating environments. Since this normal degradation occurs and varies between operating environments, airlines typically adjust their maintenance practices to ensure that airplane degradation (e.g., plugged heat exchangers, filters, abrasions, etc.) does not cause unscheduled airplane downtime. This same maintenance philosophy applies to operations in low levels of ash concentrations where a flight crew has not reported a volcanic ash encounter.

4.3.3 Ground Operations at Airports Impacted by Volcanic Ash

The following provides general recommendations for airplane ground operation at airports that are impacted by volcanic ash. Airlines should contact their OEMs for more specific advice for their airplanes and operations.

- **Protect the airplane from ash.** For ground operations originating at airports impacted by volcanic ash, OEMs advise operators to take special precautions to protect airplanes from the adverse effects of volcanic ash.

- **Remove ash from the airplane prior to flight.** Prior to flight, the operator must ensure that critical components such as inlets, probes, and static ports are free of volcanic ash. Volcanic ash will be similar in appearance to talcum powder. If ash is detected on or in the vicinity of a parked airplane, OEMs suggests that operators clean the areas of the airplane where ash is present, including the fuselage crown, horizontal surfaces, inlets, and exposed chrome common to the landing gear, to remove all traces of ash. OEMs strongly advise against water or detergent washing of the engine gaspath, as this can cause accumulation of foreign material in the engine cooling flow passages. Operators should follow the engine manufacturer's recommendations for engine gaspath cleaning. Operators should pay special attention to the removal of volcanic ash from engine and APU inlets; areas around probes, ports, vents and drain holes; as well as ram air ducts and all windows. Operators should be aware that airplane washing processes, without proper sealing of ports and tubes, can introduce ash debris or water into pitot static systems. If there are no signs of volcanic ash, normal operations may be conducted.

- **Remove all covers and blanking material prior to flight.** Flight crews should ensure that all materials used to mask or blank inlets, probes, and ports are removed.

- **Determine safe ground routing.** After an airplane is free from any volcanic ash contamination, the operator should coordinate with the local airport authority to determine which ramps, taxiways, and runways are clear of ash contamination. This information must be passed to flight crews prior to beginning ground operations.

- **Maintenance and ground personnel training.** Operators should ensure that their maintenance and ground personnel are properly trained to inspect for signs of volcanic ash contamination and to know the proper techniques for removal of volcanic ash from airplanes.

- **Operator's recurrent flightcrew training.** As part of an operator's recurrent flightcrew training, they should consider reviewing the airspeed unreliable, volcanic ash, single engine failure, dual/multiple engine failure, and engine in-flight start non-normal checklists.

Preventing flight into potential ash environments requires planning in the following areas:

- Dispatch should provide flight crews with information about volcanic events, such as potentially eruptive volcanoes and known ash sightings that could affect a particular route.
- Alternative routes should be identified or re-planned in order to avoid airspace containing a visible volcanic ash cloud.
- In the vicinity of a volcanic ash cloud, and where required, escape routes should be identified in the event of an unplanned descent due to an engine failure or cabin depressurization.
- Flight should be planned to remain upwind of volcanic ash or dust clouds, where possible.
- Flight crews should remember that airborne weather radar is ineffective in distinguishing ash from small dust particles.

4.3.4 Standard that has resulted in safe operations during volcanic eruptions

Since the introduction of the VAACs and the communication channels between them, the WMO, and the aviation community, the number of significant in-flight volcanic ash encounters has diminished dramatically, even though the number of volcanic ash events has continued through the years. One key element that has enhanced operational safety -- compared to the 1982 Galunggung volcano and 1989 Mt. Redoubt B747 events -- has been the diligence and expertise of the VAACs and WMOs reporting on "observed" or "visible" volcanic ash clouds. These "observations" by the VAACs and WMOs have been primarily based on satellite imagery, either visual or infrared. This "observed" information has been used in correlation with dispersion models and meteorological expertise to forecast where a volcanic ash cloud will likely be several hours in the future. This use of a composite of all available information by meteorologists to forecast the location of a volcanic ash cloud has served aviation well. These observed reports and forecasts that are correlated to direct observations, along with operators avoiding flight planning or flights into "visible" or "observed" volcanic ash cloud, has resulted in safe and efficient operations in recent years. [It is important to note that there can be significant uncertainty in the forecast dispersion model predictions due to the inaccuracy of the source parameters (i.e., amount of debris ejected from the volcano, how high the debris was ejected, time since eruption, etc.) and the variation between forecast dispersion models used by different VAACs.]

The most significant hazard to an airplane from a volcanic ash encounter is the impact on the engines and the potential consequent loss of all thrust. There are other significant hazards to the airplane such as erroneous airspeed, but none of these hazards are catastrophic by themselves. Each of these other hazards can be mitigated through flight crew procedures or training that allows for continued safe flight and landing. As discussed in paragraph 4.2.5, above, today's jet engines have demonstrated capability in low levels of volcanic ash, provided that operation in visible ash is avoided. Information relating visible ash to volcanic ash parameters such as cloud thickness, particle size, and ash concentration, has been consolidated in IVATF/2 working paper WP/08. The information provided in IVATF/2 working paper WP/08, the engine demonstrated capability described in paragraph 4.2.5, and the stipulation of avoiding operations in visible ash, can be used as factors in a flight operation risk assessment to ensure safe, efficient operations. However, it should also be noted that even operations in low levels of ash concentration (non-visible) can result in increased maintenance costs due to accelerated airplane and engine degradation.

4.4 RECOMMENDED GENERAL PROCEDURES TO MITIGATE THE EFFECT OF VOLCANIC ASH

4.4.1 ~~The foregoing analysis of the effect of volcanic ash on aircraft forms the basis for the procedures recommended for use by pilots whose aircraft inadvertently encounter a volcanic ash cloud.~~ The foregoing analysis of the effect of volcanic ash on aircraft should form the basis for the procedures of aircraft manufacturers in their aircraft operating manuals for each particular aircraft type once a volcanic ash cloud is encountered. Therefore aircrew should most importantly be required to always follow aircraft manufacturers' procedures and recommendations. As general guidance for States to require flight crew, the following general procedures are recommended:

~~a) In such circumstance, the following general procedures have been recommended:~~

i) taking into account airspace, terrain and traffic, if possible, *immediately reduce thrust to idle.* This will lower the exhaust-gas temperature (EGT), which in turn will reduce the fused ash build-up on the turbine blades and hot-section components. Volcanic ash can also cause rapid erosion and damage to the internal components of the engines;

ii) *turn autothrottles off (if engaged)*. The autothrottles should be turned off to prevent the system from increasing thrust above idle. Due to the reduced surge margins, limit the number of thrust adjustments and make changes with slow and smooth thrust-lever movements;

iii) *exit volcanic ash cloud as quickly as possible*. Volcanic ash may extend for several hundred miles. The shortest distance/time out of the ash may require an immediate, descending 180-degree turn, terrain permitting. Setting climb thrust and attempting to climb above the volcanic ash cloud is not recommended due to accelerated engine damage/flame-out at high thrust settings;

iv) *turn engine and wing anti-ice and all air conditioning packs on*. ~~Turn on the engine and wing anti-ice systems and place all air conditioning packs to "on", in order to~~ This further improves the engine stall margin by increasing the bleed-air flow. It may be possible to stabilize one or more engines at the idle thrust setting where the EGT will remain within limits. An attempt should be made to keep at least one engine operating at idle and within limits to provide electrical power and bleed air for cabin pressurization until clear of the volcanic ash;

v) *start the auxiliary power unit (APU), if available*. The APU can be used to power the electrical system in the event of a multiple-engine power loss. The APU may also provide a pneumatic air source for improved engine starting, depending on the aircraft model; and

vi) *put flight crew oxygen masks on at 100 per cent, if required*. If a significant amount of volcanic ash fills the cockpit or if there is a strong smell of sulphur, put on oxygen mask and select 100 per cent. Even though sulphur is slightly toxic, manual deployment of passenger oxygen masks is not recommended if cabin pressure is normal because the passenger oxygen supply will be diluted with volcanic ash-filled cabin air. If the cabin altitude exceeds 4 250 m (14 000 ft), the passenger oxygen masks will deploy automatically in most commercial airplanes.

~~b) In the event of engine flame-out:~~

~~*i) turn ignition on*. Place ignition switches to "on" as appropriate for the engine model (position normally used for in-flight engine start). Cycling of fuel levers (switches) is not required. For aircraft equipped with autostart systems, the autostart selector should be in the "on" position. The autostart system was designed and certified with a "hands-off" philosophy for emergency air starts in recognition of crew workload during this type of event;~~

~~*ii) monitor EGT*. If necessary, shut down and then restart engines to keep from exceeding EGT limits;~~

~~*iii) close the outflow valves*, if not already closed;~~

~~*iv) do not pull the fire switches*;~~

~~*v) leave fuel boost pump switches "on" and open crossfeed valves;*~~

~~*vi) do not use fuel heat — this would be undesirable if on suction fuel feed*;~~

vii) *restart engine according to aircraft operation manual procedures*. If an engine fails to start, try again immediately. Successful engine start may not be possible until airspeed and altitude are within the air-start envelope. Monitor EGT carefully. If a hung start occurs, the EGT will increase rapidly. If the engine is just slow in accelerating, the EGT will increase slowly. Engines are very slow to accelerate to idle at high altitude, especially in volcanic ash — this may be interpreted as a failure to start or as a failure of the engine to accelerate to idle or as an engine malfunction;

viii) *monitor airspeed and pitch attitude*. If unreliable airspeed is suspected, or if a complete loss of airspeed indication occurs (volcanic ash may block the pitot system), establish the appropriate pitch attitude dictated by the operations manual for "flight with unreliable airspeed." If airspeed indicators are unreliable, or if loss of airspeed indication occurs simultaneously with an all-engine thrust loss, shutdown or flame-out, use the attitude indicator to establish an appropriate ~~minus-one degree~~ pitch attitude. Inertial ground speed may be used for reference if the indicated airspeed is unreliable or lost. Ground speed may also be available from approach control during landing;

ix) *land at the nearest suitable airport* if volcanic ash has been encountered and aircraft damage is expected ~~A precautionary landing should be made at the nearest suitable airport if aircraft damage~~ or abnormal engine operation occurs due to volcanic ash penetration; ~~and~~

x) upon landing use reversers as lightly as feasible. If it appears that maximum reverse thrust will be needed, apply reverse thrust when the main landing gear touches down. Limit the use of reverse thrust as much as possible, because reverse flow may throw up ash, sand, dust and impair visibility.

xi) because of the abrasive effects of volcanic ash on windshields and landing lights, visibility for approach and landing may be markedly reduced. Forward visibility may be limited to that which is available through the side windows. Should this condition occur, and if the autopilot system is operating satisfactorily, a diversion to an airport where an autolanding can be accomplished should be considered. After landing, if forward visibility is restricted, consider having the aircraft towed to the parking gate.

xii) exposure to volcanic ash can create physical (sulphur, dust, deprivation of oxygen) and mental health (anxiety, stress) problems. If deemed necessary consult a medical specialist.

4.4.2 ~~The foregoing general procedures should be supplemented by~~ As mentioned in the previous paragraph, pilots should always follow the specific procedures in the aircraft operations manual — developed by aircraft operators for each aircraft type in their fleet — dealing with the particular aircraft engine combination concerned. Guidance on this is provided in the ICAO document Preparation of an Operations Manual (Doc 9376), Chapter 8 and Attachment K, and in aircraft manufacturers' flight manual procedures for each of their aircraft types. Guidance should also be included in aircraft maintenance manuals regarding the necessary maintenance and/or inspections to be undertaken on an aircraft following an encounter with volcanic ash. Mention has already been made in Chapter 2 that for those airlines which operate aircraft regularly through regions of the world subject to frequent volcanic eruptions, the long-term consequences of frequent flights through even very low concentrations of volcanic ash may be increased maintenance costs. Certainly a number of airlines have found that cockpit and passenger windows needed to be re-polished or replaced rather more frequently than expected for the flight hours involved. At this stage it is not clear, however, if this is due more to newer types of plastic window materials used for passenger outer windows or if low concentrations of volcanic ash/acid droplets in the atmosphere are contributing to the problem.

4.4.3 ~~Given that the most serious threat to an aircraft from volcanic ash is the risk of multiple-engine flame-out, it is extremely important to consider the ways and means of improving the success of engine restarts in air contaminated by volcanic ash. In the United States in 1991, the Aerospace Industries Association of America (AIA) ad hoc Propulsion Committee was formed comprising AIA members and representatives from international aircraft and engine manufacturers and the U.S. Geological Survey (USGS). The mandate of the Committee was to evaluate the threat of multiple-engine flame-out due to volcanic ash and to make appropriate recommendations to the aviation industry and responsible government agencies. The Committee made a number of recommendations5 but, in particular, the following bear directly on the problem of engine restart, after flame-out:~~

~~"Aircraft manufacturers, with assistance from the engine manufacturers, should define maximum engine power levels (expressed in engine pressure ratio (EPR), fan speed (N1), and (or) exhaust-gas temperature (EGT) levels) that will minimize buildup of melted and resolidified ash on HPT nozzle guide vanes. These values should be added to flight-manual procedures and should be used only when the recommended flight idle power will not assure adequate terrain clearance.~~

~~Aircraft manufacturers, with assistance from engine manufacturers, should consider addition of a time-delay circuit to allow an air-started engine to reach stabilized idle speed before the electrical or generator load is applied. This would facilitate engine restarts under less-than-ideal conditions.~~

~~FAA and other equivalent government agencies should require that air crews practice engine air-restart procedures in a simulator on recurring basis. Normal and deteriorated engine start characteristics should be simulated."~~

~~The prime importance of the last recommendation cannot be overestimated. Engine shut-downs or flameouts in flight are rare events which many pilots will never be called upon to deal with in their whole careers. This is further complicated by the different procedures used for air-start as compared to normal ground-start. The only solution is for pilots to be provided with a set of air-start procedures which also cover procedures in volcanic ash contaminated air and for simulator air-starts to be part of basic and recurrent pilot training.~~ Given that the most serious threat to an aircraft from volcanic ash is the risk of multiple-engine flame-out, it is extremely important to consider the ways and means of avoiding engine shut-down and improving the success of in-flight engine restarts contaminated by volcanic ash. Engine shut-downs or flameouts in flight are rare events which many pilots will never be called upon to deal with in their whole careers except during simulator based training. This is further complicated by the different procedures that are used for in-flight engine starts as compared to normal on ground-starts. The best solution is for pilots to be provided with a set of air-start procedures which also cover procedures in volcanic ash contaminated air and for simulator air-starts to be part of basic and recurrent pilot training.

3A.2 ICAO Doc 9691

Chapter 6.3.2.2: In this chapter, incorrect reference is made to Chapter 4.3, this should be changed to Chapter 4.4.

3A.3 ICAO DOC 4444

It is proposed to add the following Note to the special air-report of volcanic activity (model VAR) from Appendix 1 of the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444).

> *"Note.— Keep observation as descriptive as possible and do not give any judgment on the kind or severity of the eruption unless trained and qualified to do so."*

This will make flight crew aware that a subjective judgement could render their report less useful.

3A.4 ICAO EUR DOC 019 / NAT DOC 006 PART II

At the end of paragraph 2, the following text is proposed to be added:

> "For more in depth information on anticipated pilot issues and actions when encountering volcanic ash please refer to ICAO *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds* (Doc 9691), Chapter 4.4."

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APPENDIX 3B

REPORT AND RECOMMENDATIONS FROM THE IVATF AIRWORTHINESS SUB-GROUP AIR04 TEAM REGARDING THE MANAGEMENT OF FLIGHT OPERATIONS WITH KNOWN OR FORECAST VOLCANIC CLOUD CONTAMINATION

SUMMARY

The ICAO International Volcanic Ash Task Force Airworthiness Sub-Group AIR04 task team has developed this proposal to States for a globally applicable process to facilitate the management of flight operations into, or avoiding, 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 a safety management system including a risk assessment process for use by an operator wishing to conduct such an operation and a methodology for use by that operator's State in evaluating the robustness of the process and the competence of the operator in using the process.

It is intended that the State of the Operator or State of Registry, as appropriate, would make this determination which would be subject to acceptance by other States through whose airspace the resultant flight operations are planned to be conducted.

- *Draft Version 7.0* -

14 JULY 2011

TABLE OF CONTENTS

1. DEFINITIONS

The terminology and acronyms used in this document are set out in Appendix H.

2. INTRODUCTION

There are areas of volcanic activity worldwide that are hazardous to aviation. Volcanic clouds can also be transported long distances into non-volcanic areas. This document sets out guidelines which States may cause aircraft operators and Civil Aviation Authorities to adopt in order to minimize the safety risk of flight operations in areas known or forecast to be affected by volcanic cloud. Although health issues exist, they are not considered in this document.

2.1 The hazard

Volcanic ash[1] 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. Volcanic ash contains particles whose melting point is below engine burner temperature; these then fuse in the turbine section reducing the throat area and efficiency leading to engine surge and possibly flame-out;
- 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;
- erosion of external aircraft components;
- reduced electronic cooling efficiency and, as ash readily absorbs water, potential short circuits leading to a wide range of aircraft system failures and anomalous behaviour;
- the aeroplane ventilation and pressurization systems to become heavily contaminated. In particular, cleaning or replacement may be required in response to air cycle machine contamination and abrasion to rotating components, ozone converter contamination and air filter congestion.
- aircraft to be manoeuvred for volcanic cloud avoidance in a manner that conflicts with other aircraft;

[1] 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 and cause additional hazards

- deposits of volcanic ash on a runway degrading braking performance, especially if ash is wet; in extreme cases, this can lead to runway closure.

This list is not intended to be exhaustive.

2.2 Managing the risk

States that are required by Annexes 1, 6 (Parts I or III), 11 or 14 to implement a State Safety Programme, are required to set an acceptable level of safety for the relevant activities and to require all aviation service providers to implement a Safety Management System.

It is proposed that the approach set out in this document be applied also by States to those engaged in international general aviation as governed by Annex 6, Part II. The definition of an (aircraft) operator, set out in Appendix H, reflects this.

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 general guidance on the establishment of an SMS and on the conduct of safety risk assessments.

One of many issues requiring such an SMS approach relates to operations into or avoiding airspace with known or forecast volcanic cloud contamination or at aerodromes contaminated by volcanic ash. The operator is accountable for assessing the risk of such operations and for determining and implementing appropriate mitigation measures. This document describes an approach to formulate and evaluate the safety risk assessment, within an SMS, that is 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 safety risk assessment and that the assessment process itself is robust. This present document sets out a process that States may advise CAAs to use in evaluating an operator's safety risk assessment.

It is further expected that States will cause the CAA to maintain adequate ongoing surveillance of the operator so that it can identify those operators who fail to maintain adequate competence, capability and robust procedures to continue to operate safely into or avoiding volcanic cloud contamination; in such cases, it is expected that the State would ensure that the CAA could take such action as may be necessary to control the risk associated with the operator's lack of competence, capability or necessary procedures.

The safety control measures set out in this document are intended to be sufficiently robust that they facilitate acceptance by a State whose airspace is known or forecast to be affected by volcanic clouds without further investigation, confident in the ability of operators from other States to undertake operations safely in their airspace.

Until such time as this approach has been widely accepted and implemented, however, it is recognized that a State may wish to seek from the State of the Operator of a foreign operator, positive confirmation of the satisfactory consideration of a safety risk assessment.

2.3 Coordinating the response to a volcanic event

There are many other contributors to the overall volcanic risk mitigation system such as, Air Navigation Service Providers including Aeronautical Information Services and Air Traffic Flow Management Units, Meteorological Service providers including Meteorological Watch Offices, Volcanic Ash Advisory Centres and Volcano Observatories and aircraft and engine TCHs, STC holders and PMA holders. Their cooperation in supplying States, operators and CAAs with the information necessary to support the pre-flight process and the in-flight and post-flight decision making process is essential to continuing safe operations.

Information on the procedures of these contributors in respect of operations with known and forecast volcanic ash cloud contaminated areas is available in other ICAO documents such as:

- ICAO Procedures for Air Navigation Services (PANS) – Air Traffic Management (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),
- ICAO Meteorological Services for International Air Navigation (Annex 3), and
- Regional contingency plans such as the EUR/NAT Contingency Plan (EUR Doc 019).

This present document, in providing advice to States on addressing the role of the aircraft operator and of the operator's CAA, is complementary to the documents listed above. Relevant parts of these documents are under review by other sub-groups of IVATF and amendment proposals are to be expected. In time, it is anticipated that ICAO will wish the guidance material to be consolidated.

To ensure good coordination between all concerned, it is recommended that States encourage operators and their CAAs to participate in such annual volcanic risk exercises as are organized by ICAO (VOLCEX). In the EUR and NAT region, for example, information on these exercises is available on the ICAO Paris website http://www.paris.icao.int/.

3. THE AIRCRAFT OPERATOR

ICAO's generic safety risk assessment process is described in ICAO Doc 9859[2]. Alternative approaches, aligned with an organization's approved SMS, would be equally appropriate. The material in this document is designed to provide States with information to support operators in developing the safety risk assessment, within their SMS, covering the volcanic cloud hazard.

3.1 Responsibilities

a) The operator is responsible for the safety of its operations.

b) In order to decide whether or not to operate into, or avoid, airspace or aerodromes with known or forecast volcanic cloud contamination, the operator should have in place an identifiable safety risk assessment within its SMS.

> **NOTE:** Guidance on the production of a safety risk assessment is provided in Appendices A (guidelines on conducting a safety risk assessment), B (procedures to be included in a safety risk assessment) and C (risks to be considered). Each operator should develop its own list of procedures and hazards since these have to be relevant to the specific equipment, experience and knowledge of the operator, and to the routes to be flown.

c) The operator should have this safety risk assessment as part of the SMS before initiating operations into or avoiding airspace or aerodromes, which may be contaminated by volcanic clouds or ash. During its normal oversight of its operators, a CAA should normally accept[3] this safety risk assessment as an identifiable part of the operator's SMS.

> **NOTE:** Subject to the provisions set out below regarding the updating of safety risk assessments, it is intended that the operator should present the CAA with a safety risk assessment covering its overall operations in which volcanic clouds are a hazard rather than a safety risk assessment for each flight.

[2] ICAO *Safety Management Manual* (Section 9, Issue 2, 2009).

[3] "Accept" has here the meaning "not objected to by the CAA as suitable for the purpose intended" as opposed to "approved" which, had it been used, would mean "documented by the CAA as suitable for the purpose intended". The former has been adopted to remain consistent with the key principle of prime responsibility for safe operations resting with the operator. This distinction is not novel as evidenced by European Commission Regulation (EC) 859/2008 (EU OPS) OPS1.003.

d) An operator will need to have satisfied its CAA regarding the likely accuracy and quality of the information sources it uses in its SMS and its own competence and capability to interpret such data correctly in order to reliably and correctly resolve any conflicts among data sources that may arise.

> **NOTE**: The operator is not prevented from operating through, under or over, airspace affected by a VAA, VAG or SIGMET provided it has demonstrated in its SMS the capability to do so safely.

e) The operator should revise its safety risk assessment when changes that are material to the integrity of the safety risk assessment occur; it will need to inform its CAA of such updates in a timely manner.

f) The operator's safety risk assessment should take into account data published by the relevant TCHs regarding the susceptibility to volcanic cloud-related airworthiness effects of the aircraft they operate, the nature of these effects and the related pre-flight, in-flight and post-flight precautions to be observed by the operator.

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

g) The operator should ensure that those of its personnel needing to be familiar with the details of the safety risk assessments receive all relevant information (both pre-flight and in-flight) in order to be in a position to apply appropriate mitigation measures as specified by the safety risk assessments, especially when the situation deviates from any scenario contemplated in the safety risk assessments.

h) The operator should ensure that any incidents related to volcanic clouds are reported immediately to the nearest ATS unit using the VAR/AIREP procedures followed up by a more detailed VAR on landing together with, as applicable, an ASR and AML entry.

3.2 Procedures

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

> **NOTE:** Procedures should include crew action in the event that they encounter a volcanic cloud (the related material is being developed by the IVATF AIR 05 team).

> **NOTE:** Procedures should include collaboration with ATM and aerodrome operators.

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

c) Maintenance and engineering personnel should be provided with procedures allowing them to correctly assess the need for, and execute, relevant maintenance or other engineering interventions.

d) The operator will need to retain sufficient qualified and competent staff to generate well supported operational risk management decisions, and ensure that its staff is appropriately trained and current.

> **NOTE:** It is not intended that the operator be precluded from securing necessary resources from other competent parties.

e) The operator should encourage its flight operations staff to take up opportunities to be involved in volcanic ash exercises conducted in their area of operations.

3.3 Information

Before and during eruptions, information valuable to the operator is generated by various volcanological agencies worldwide. The operator's risk assessment and mitigating actions need to take account of, and respond appropriately to, the information likely to be available during each phase of the eruptive sequence from pre-eruption through to end of eruptive activity. Further material is provided in Appendix E.

4. THE TYPE CERTIFICATE HOLDER

In fulfilling its primary responsibility for the safety of operations, the operator is dependent on the Type Certificate Holders of the equipment it operates for some information necessary to inform its safety risk assessment when volcanic clouds are a hazard.

States are, therefore, advised to request TCHs to establish, update and make available to operators a range of information important to the operator's safety risk assessment when volcanic clouds are a hazard.

> **NOTE:** An indication of the range of information that an operator might require is provided in Section 3 and in Appendix B.

5. THE CIVIL AVIATION AUTHORITY

ICAO's safety risk assessment process is described in the ICAO *Safety Management Manual (SMM)* (Doc 9859, Section 9, Issue 2, 2009). Alternative approaches, aligned with an organisation's approved SMS, would be equally appropriate.

The operator-orientated responsibilities of the CAA of the State of Operator/Registry, and of States with known or forecast volcanic contamination, are indicated in Section 2.2 above.

The State is advised that the CAA exercising oversight of an operator that intends to undertake operations into, or avoid, areas of known or forecast volcanic contamination should establish a methodology for evaluating the SMS including a safety risk assessment on volcanic ash of such an operator and, if satisfied, accept the SMS. The guidance set out in Appendix F indicates a process that the CAA can use to achieve this outcome.

APPENDIX A

GUIDELINES FOR COMPLETING A SAFETY RISK ASSESSMENT

A1 Introduction

ICAO's safety risk assessment process is described in the ICAO *Safety Management Manual* (Doc 9859 Section 9, Issue 2, 2009). Alternative approaches, aligned with an organisation's approved SMS, would be equally appropriate.

Implementation of an SMS, in accordance with State Regulation, is a key capability for an operator. The operator should develop any safety risk assessment in accordance with its authorised SMS risk management processes. For an operator in the process of implementing an SMS, or where the regulatory framework has yet to be promulgated by the State, then it should be possible for the State to accept a safety risk assessment provided the operator has implemented an SMS that, as a minimum:

a) identifies safety hazards;

b) ensures the implementation of remedial action necessary to maintain agreed safety performance;

c) provides for continuous monitoring and regular assessment of the safety performance; and

d) aims at a continuous improvement of the overall performance of the safety management system.

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.

A2 The Process Steps

When made specific to the issue of intended flight into, or avoiding, known or forecast volcanic ash cloud contaminated airspace or aerodromes, then the process involves:

- Identifying the hazard (i.e. arising from the generic hazard of airspace or aerodromes with known or forecast contamination by volcanic ash clouds with characteristics harmful to the airworthiness and operation of the aircraft);

- 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 cloud);
- Evaluating the likelihood of encountering volcanic ash clouds with characteristics harmful to the safe operation of the aircraft;
- Determining whether the consequent risk is acceptable and within the organisation's risk performance criteria;
- Taking action to reduce the safety risk to a level that is acceptable to the operator's Accountable Executive or equivalent.

A2.1 Hazard Identification

The generic 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.

Within this generic hazard is the specific hazard of an operator not having secured the information necessary to properly characterise that hazard and develop a robust assessment of the risk and likely success of any chosen mitigating actions. To assist operators in relation to this specific hazard, guidance on the list of procedures to be considered is given in Appendix B.

A list of suggested hazards and their associated risks is provided in Appendix C.

Neither of these lists is exhaustive; the operator should develop its own taking into account its specific equipment, experience, knowledge and type of operation.

A2.2 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.

A2.3 Risk Probability

For each hazard, the likelihood of adverse consequences should be assessed, either qualitatively or quantitatively, using a suitably calibrated likelihood scale. When assessing likelihood, 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 TCHs, regulators, other operators, Air Navigation Service Providers, internal reports etc;
- The expert judgement of relevant stakeholders notably from TCHs.
- Operational environment in which flight operations are performed.

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

A2.4 Risk Tolerability

At this stage of the process, the safety risks should be classified acceptable or unacceptable.

It is recognised that the assessment of tolerability will be subjective based on qualitative data and expert judgement until specific quantitative data is available in respect of a range of parameters such as uncertainty in volcanic cloud forecast accuracy, the likely range of engine tolerability to ingestion of ash and other volcanic cloud elements with time and engine condition etc.

Appropriate mitigations for each unacceptable risk identified should then be considered, recorded on the risk register and implemented in order to reduce the risks to a level acceptable to the operator’s Accountable Executive or equivalent.

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. An effective SMS will incorporate procedures for continuous monitoring of hazards and risk, with qualified personnel establishing the mitigating actions or halting affected operations.

Given the potential introduction of new risks, or a change of circumstances on which the original assessment was predicated changing, it is critical that an operator ensures that the safety risk assessment is repeated as necessary following any mitigation process and at regular intervals as part of its SMS activities.

A3 Records

The results of the safety risk assessment should be documented and submitted to the operator's CAA. 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 and as necessary, to ensure that the assumptions and decisions remain valid.

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

NOTE: The SMS material of ICAO Doc 9859 continues to be developed within the ICAO ISM section and this team's expert assessment of this Appendix and associated material will be sought as part of the process of considering the Guidance Material for formal ICAO adoption.

APPENDIX B

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

Considerations	Actions
Preparation	
Type Certificate Holder	The operator will need to obtain advice from the TCHs of the aircraft and engines it operates concerning operations in potentially contaminated airspace and/or to/from aerodromes contaminated by volcanic ash cloud. This advice should set out: – the features of the aircraft or engine that are susceptible to airworthiness effects related to volcanic ash clouds; – the nature and severity of these effects; – the effect of volcanic ash clouds on operations to/from contaminated aerodromes; – the related pre-flight, in-flight and post-flight precautions to be observed by the operator including any necessary amendments to Aircraft Operating Manuals, Aircraft Maintenance Manuals Master Minimum Equipment List/Despatch Deviation or equivalents required to support the operator (cf “Operator Procedures” later in this Appendix); – the recommended continuing airworthiness inspections associated with operations in volcanic cloud contaminated airspace and to/from volcanic ash contaminated aerodromes; this may take the form of Instructions for Continuing Airworthiness or other advice.
Operator Personnel or their Service Providers	The operator should publish procedures for flight planning, operations, engineering and maintenance ensuring that: – personnel responsible for flight planning are equipped to evaluate correctly the risk of flight into volcanic ash cloud-contaminated airspace, or aerodromes, and can plan accordingly; – flight planning and operational procedures enable crews to avoid areas and aerodromes with unacceptable volcanic ash contamination levels; – flight crew are aware of the possible signs of entry into a volcanic cloud and execute the associated procedures; – engineering and maintenance personnel are able to assess the need for, and to execute, any necessary maintenance or other required interventions.

Considerations	Actions
Operator procedures	
Provision of Enhanced Flight Watch	The operator will need to: – 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 its Operations Unit, or equivalent, and its crews, have access to plots of the affected area from SIGMETs and NOTAMs; – ensure that the latest information is communicated to its crews and planners in a timely fashion.
Flight Planning	The operator will need to plan flights to remain clear of areas with a volcanic ash cloud contamination level beyond that for which it has developed a safety risk assessment accepted by its CAA. The operator's process should be sufficiently flexible to allow re-planning at short notice should conditions change.
Departure, Destination and Alternates	For the airspace to be traversed, or the aerodromes in use, the operator should determine, and take account of: – 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	The operator should determine, and take account of,: – 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	The operator should determine, and take account of: – 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	The operator should consider additional restrictions for dispatching aircraft with unserviceabilities which might affect: – air conditioning packs; – engine bleeds; – pressurisation system; – electrical power distribution system; – air data computers; – standby instruments; – 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. (This list is not exhaustive)

Considerations	**Actions**
Flight Crew Procedures	
Standard Operating Procedures	The operator should ensure that crews are familiar with normal and abnormal operating procedures and particularly any changes regarding: – 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 cloud contamination; – recognition and detection of volcanic ash clouds: – in-flight indications of a volcanic cloud encounter; – procedures to be followed if a volcanic cloud is encountered; – unreliable or erroneous airspeed; – non-normal procedures for engines and systems potentially affected by volcanic ash cloud contamination; – engine-out and engine relight; – escape routes; and – operations to/from aerodromes contaminated with volcanic ash. (This list is not exhaustive)
AML	The operator should ensure that crews: – make an AML entry related to any actual or suspected volcanic ash encounter whether in-flight or at an aerodrome; – confirm, prior to flight, completion of maintenance actions related to an AML entry for a volcanic ash cloud encounter on a previous flight.
Incident Reporting	The operator should specify crew requirements for: – reporting an airborne volcanic cloud encounter (VAR); – post-flight volcanic cloud reporting (VAR); – filing a mandatory occurrence report as required by the State.

Considerations	Actions
Maintenance Procedures	
Maintenance Procedures	An operator operating in, or near, areas of volcanic ash cloud contamination should: – 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 cloud 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 TCHs and the relevant authorities their observations and experiences from operations in areas of volcanic ash cloud contamination; – comply with any additional maintenance recommended by the TCH.

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

APPENDIX C

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

Activity or Issue	Hazard	Risk
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 with adverse safety consequences
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 with adverse safety consequences
Lack of awareness, or incorrect interpretation, of volcanic ash concentration information provided to crews at pre-flight briefing	Crews unaware of correct extent, concentration and position of volcanic clouds	Inadvertent volcanic ash encounter with adverse safety consequences
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
	Aircraft in unsafe condition for flight	Serious incident or accident
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, crew mishandle aircraft or inadvertent ash encounter with adverse safety consequences
Ground equipment in temporary storage state	Equipment not operating as designed or intended following temporary storage	Adverse safety consequences 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 with adverse safety consequences
Change in location of volcanic ash-affected area that incorporates an area in which an aircraft is flying	Crews unaware of the change of position or extent of the volcanic ash-contaminated area	Inadvertent volcanic cloud encounter with adverse safety consequences
Provision of graphical data to crews	Crews unaware of the position or extent of the volcanic ash-contaminated area	Inadvertent volcanic cloud encounter with adverse safety consequences
etc		
In-flight (inadvertent volcanic cloud encounter)		
Pitot and probe blockage	– Unreliable, or erroneous, airspeed – Aircraft control problems – Thrust control reduced	Loss of control
Window abrasion	– Restricted external vision – Loss of visual reference	Loss of control / runway excursion
Turbine and compressor damage	– Anomalous engine behaviour – Loss of thrust: single engine – Loss of thrust: all engines	– Increased crew workload – Diversion – Forced landing
Fuel Contamination	Loss of thrust: all engines	Forced landing
Air-conditioning Pack volcanic cloud ingestion	– Loss of cabin pressurisation – Noxious fumes in cabin	Emergency descent / Diversion / Loss of control
Equipment Cooling Failure due to volcanic cloud ingestion	Anomalous behaviour of aircraft systems	– Increased crew workload – Diversion – Forced landing – Loss of control
Volcanic cloud static charge	Prolonged loss of communications	– Increased crew workload – Increased ATC workload
Escape Manoeuvre	Conflict with another aircraft	Mid air collision

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

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

APPENDIX D

EXAMPLE OF A RISK REGISTER

				Outcome (Pre-Mitigation)				Outcome (Post-Mitigation)				
No	Hazard Description	Hazard Consequence Description	Existing Controls	Severity	Likelihood	Risk Tolerability	Further Actions to Reduce Risk	Severity	Likelihood	Risk Tolerability	Risk Owners	Monitoring and Review Actions
1	Flying into area of volcanic ash cloud	Loss of thrust – all engines	Avoidance, existing crew procedures	High	Remote	Un-acceptable	Monitoring of NOTAMs, Flight planning to avoid flying into Danger Area, QRH drills for volcanic ash procedures, Notice to crew on in-flight volcanic ash encounters	High	Extremely Remote	Review	Flight Operations	Ensure latest information available to crew. Monitoring of pilot reports and review of revised flight planning and operating procedures
2	Flying into area of volcanic ash cloud	Damage to windscreen obscuring vision	Avoidance, existing crew procedures	Medium	Remote	Un-acceptable	Monitoring of NOTAMs, Flight planning to avoid flying danger Area, QRH drill for volcanic ash procedures, Notice to crew on in-flight volcanic ash encounters	Medium	Extremely Remote	Acceptable	Flight Operations	Ensure latest information available to crew. Monitoring of pilot reports and review of revised flight planning and operating procedures
3	Flying into or close to area of volcanic ash cloud	Undetected engine and airframe damage leading to system or component failure	Pre-flight checks and walk-around checks, Scheduled maintenance	Medium	Possible	Un-acceptable	Enhanced reporting and flight tracking for flights into or close to Danger Area. Additional inspections of ash cloud contamination iaw TCH Instructions	Medium	Extremely Remote	Acceptable	Operations, Engineering	Monitoring of enhanced reporting system and engineering inspections
4	…	…	…	…	…	…	…	…	…	…	…	…
5	…	…	…	…	…	…	…	…	…	…	…	…

APPENDIX E

GUIDELINES ON VOLCANIC ACTIVITY INFORMATION AND OPERATOR RESPONSE

E.1 Overview

The material set out in this Appendix is intended to inform the operator about the range of volcanic activity information that may be available during an eruptive cycle and to indicate the operator's potential response. It is noted that eruptions rarely follow a deterministic pattern of behaviour.

E.2 Pre-Eruption

a) The operator should have in place a robust mechanism for ensuring that it is constantly vigilant for any alerts of pre-eruption volcanic activity relevant to its operations. The staff involved need to understand the threat to safe operations that such alerts represent; some operators include this expertise within their "Operations Unit".

b) An operator whose routes traverse large, active volcanic areas for which immediate IAVW alerts may not be available, should define its strategy for capturing information about increased volcanic activity before pre-eruption alerts are generated.[4] Such an operator should also ensure that its crews are aware that they may be the first to observe an eruption and so need to be vigilant and ready to ensure that this information is made available for wider dissemination as quickly as possible.

E.3 Start of an Eruption

a) Given the likely uncertainty regarding the status of the eruption during the early stages of an event and regarding 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) It is expected that following initial actions will be taken:

- Determine if any aircraft in flight could be affected, alert the crew and provide advice re-routing as required;
- Alert management;

[4] For example, an operator may combine elevated activity information with information concerning the profile and history of the volcano to determine an operating policy, which could include re-routing or restrictions at night. This would be useful when dealing with the 60% of volcanoes which are unmonitored.

- Brief flight crew and revise flight and fuel planning in accordance with the safety risk assessment;
- 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 safety risk assessment process.

E.4 Ongoing Eruption

a) As the eruptive event develops, the operator can expect the responsible VAAC to provide VAA/VAGs defining, as accurately as possible, the vertical and horizontal extent of areas and layers of volcanic clouds. As a minimum, the operator should monitor, and take account of, this VAAC information as well as of relevant SIGMETs and NOTAMs.

b) 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[5]. The operator should plan its operations in accordance with its safety risk assessment taking into account also those of these additional sources of information that it considers accurate and relevant.

c) The operator will have to 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 should, as soon as possible, report such discrepancies to the appropriate authorities.

d) Given the dynamic nature of the volcanic hazards, the operator should ensure that the situation is monitored closely and operations adjusted to suit.

e) The operator should be aware that, depending on the State concerned:

   i. Affected Areas or 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;

[5] In the US, operators holding Enhanced Weather Information System (EWINS) approval are authorized to produce flight movement forecasts, adverse weather phenomena forecasts and other meteorological advisories, including those related to ash contamination, based on meteorological observations provided by the State.

ii. Affected Areas or 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, unless the operator's safety risk assessment allows it to do otherwise safely.

f) The operator should require 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 authorities.

g) 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, modified in accordance with their safety risk assessment. The operator will need to take account of the risk of cabin depressurisation or engine failure resulting in the inability to maintain level flight above a volcanic cloud, especially when conducting ETOPS operations. Additional MEL restrictions should be considered in consultation with the TCHs.

h) When the airspace is no longer contaminated by volcanic ash clouds, a NOTAMC cancelling the active NOTAM is likely to be promulgated. A new NOTAM/ASHTAM would then be promulgated to update the situation.

APPENDIX F

GUIDELINES FOR CAAs ON EVALUATING AN OPERATOR'S CAPABILITY TO CONDUCT FLIGHTS SAFELY IN RELATION TO VOLCANIC CLOUD

F.1 Procedures

a) The aim of these guidelines is to assist the CAA of the State of Registry/Operator in its oversight of an operator intending to undertake operations into, or avoid, areas with known or forecast volcanic cloud contamination where the CAA requires the use of SMS.

b) Prior to the planned operation, the CAA will need to be satisfied that the operator has completed a safety risk assessment relevant to its type of operation and acceptable to the CAA.

> **NOTE:** The significance of the CAA accepting, rather than approving, a safety risk assessmentis that the operator clearly retains responsibility for managing the risks and mitigating measures.

c) The objective of the SMS is to provide a formal, robust and transparent method by which the operator can demonstrate to the CAA that it has the capability and competence to achieve a safe outcome from flight operations into, or avoiding, areas with known or forecast volcanic cloud contamination.

d) The CAA's acceptance of the safety risk assessment should be dependent on a satisfactory confirmation by the operator of its competence and capability to:

- understand the hazards associated with volcanic ash clouds and the effect on the equipment being operated;
- be clear on where these hazards may exceed acceptable safety risk limits;

> **NOTE**: 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 its intended destination or a planned alternate.

- identify and implement mitigations including suspension of operations where mitigation cannot reduce the risk to within safety risk limits;

> **NOTE:** This assessment is generally recorded in a formal Risk Register (example at Appendix D).

- develop, and execute effectively, robust procedures for planning and operating flights through, or avoiding, potentially contaminated airspace safely;

- choose correctly information sources to use, to interpret the information correctly and to resolve correctly any conflicts among such sources;
- take account of detailed information from its TCHs concerning volcanic ash-related airworthiness aspects of the aircraft it operates, and the related pre-flight, in-flight and post-flight precautions to be observed;
- assess the competence and currency of its staff in relation to the duties necessary to operate safely in, or avoid, areas of known or forecast volcanic ash cloud contamination and implement any necessary training;
- retain sufficient numbers of qualified and competent staff for such duties

> **NOTE:** It is not intended that the operator be precluded from securing necessary resources from other competent parties.

e) The CAA should consider:

- those of the operator's recorded mitigations of most significance to a safe outcome are in place;
- those of the operational procedures specified by the operator with the most significance to safety appear to be robust;
- that the staff on which the operator depends in respect of those duties necessary to operate safely in, or avoid, areas of known or forecast volcanic ash cloud contamination are trained and assessed as competent in the relevant procedures.

f) Analysis of the operator's SMS allows the CAA to review its Hazard Analysis competency and Safety Culture in a coherent way, and provides the CAA with a degree of confidence. An example of one approach to a Safety and Risk Assessment Matrix is given at Appendix G to guide CAAs through the process of evaluating operator safety risk assessments. It is acknowledged that each CAA may modify this document to fit their SMS approach. 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.

g) As part of its regular oversight of the operator, the CAA should remain satisfied as to the continuing validity of a safety risk assessment accepted for operations into or avoiding volcanic cloud contamination;

> **NOTE:** Should an operator fail to maintain an acceptable safety risk assessment, and associated resources, knowledge and procedures, the CAA should prohibit operations into or avoiding volcanic cloud contamination.

F.2 Capabilities

a) The CAA will need to have a thorough understanding of SMS principles and methodology.

b) The CAA will need to have the means to impose such restrictions on its operators as are necessary to minimise the volcanic ash cloud safety risk.

c) The CAA should ensure those of its staff involved in evaluating operator’s SMS are appropriately trained and current and strongly encourage them to take up any opportunity to be involved in such VOLCEX exercises as are conducted in their area of operations.

d) Where a CAA considers that it lacks the capability to assess an operator’s SMS and the related safety risk assessment on volcanic ash, it should enlist the assistance of a CAA with this capability.

APPENDIX G

EXAMPLE OF A SAFETY AND RISK ASSESSMENT MATRIX

THE OPERATION

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

AUTHORISATION

Any "NO" rating should cause the CAA to with-hold and withdraw acceptance of the safety risk assessment

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**
Authorisation	Has the safety risk assessment been accepted thus signifying that the CAA 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

Any "unacceptable" elements in should result in operational restrictions up to and including prohibition or suspension of operations. Any "acceptable" elements could indicate an increased likelihood of failing to sustain acceptable standards and should result in the CAA enhancing its operator surveillance accordingly.

	Evaluated As			
Factor	**Unacceptable**	**Acceptable**	**Best Practice**	**Notes**
Safety Policy[6]	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	

[6] The Safety Policy is one component of the operator's SMS and the subject of a mandatory ICAO Annex 6 requirement. Without an acceptable or best practice safety policy, it would be expected that the AOC of the operator would be suspended.

	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 <u>and</u> 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 <u>and</u> 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 and occurrence experience is factored into picture of risks/hazards faced	Leaders in understanding of relevant risks, based on own knowledge and evidence from elsewhere	

APPENDIX H

TERMINOLOGY

H.1 Acronyms

AIREP	Special Air Report - a message from an in-flight aircraft to a ground station describing significant in-flight conditions
AML	Aircraft Maintenance Log or equivalent, e.g. Aircraft Technical Log
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
CAA	Civil Aviation Authority
CDM	Collaborative Decision Making
ETOPS	Extended Range Twin-engined Operations
FIR	Flight Information Region
IAVW	International Airways Volcano Watch - international arrangements for monitoring and providing warnings to aircraft of volcanic ash cloud in the atmosphere
IVATF	ICAO Volcanic Ash Task Force
LIDAR	Light Detection and Ranging: an optical remote sensing technology counting among its capabilities that of detecting and measuring volcanic ash particle size and density
MEL	Minimum Equipment List
MET	Meteorological Service
MWO	Meteorological Watch Office
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
PMA	Parts Manufacturer Approval

SIGMET	Significant Meteorological Information message - information concerning en-route weather phenomena which may affect the safety of aircraft operations
SMM	Safety Management Manual ICAO Doc 9859
SMS	Safety Management System
STC	Supplemental Type Certificate
TCH	Type Certificate Holder
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.

H.2 Definitions

Accountable Executive: The individual within a CAA-approved organisation who is accountable to that CAA for ensuring that the safety standards required by regulation, and any additional standards specified by the organisation, are met on an ongoing basis by the organisation.

Affected Area*:* A volume of airspace, an aerodrome or another area on the ground, identified by VAA/VAG and/or SIGMET as being affected by known or forecast volcanic cloud contamination.

(Aircraft) Operator**:** In the context of this document, references to the (aircraft) operator refer to those operators subject to ICAO Annex 6 Parts I, II and III being operators of aeroplanes or helicopters authorised to conduct International commercial air transport operations or involved in international general aviation.

Danger Area: In the context of volcanic cloud contamination, a volume of airspace identified by NOTAM as being affected by levels of known or forecast volcanic cloud contamination which States judge merit publication to operators.

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, aerodromes, MWOs and VAACs.

State of the Operator: The State in which the operator’s principal place of business is located or, if there is no such place of business, the operator’s permanent residence.

State of Registry**:** The State on whose register the aircraft is entered.

Visible Ash: [Needs formal definition from IVATF SCI Subgroup].

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 chemicals[7] (refer section 2.1 of ICAO Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds - Doc 9691).

Volcanic Ash: is comprised of minerals unique to the volcanic eruption. Minerals common to most volcanic ash are silica together with smaller amounts of the oxides of aluminium, iron, calcium and sodium. The glassy silicate material is very hard and extremely abrasive. Its melting point is below jet engine burner temperature which introduces additional hazards. (refer section 2.1 of ICAO Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds - Doc 9691).

Volcanic Ash Contamination Level: An ash concentration level used to delineate airspace in which ash density is considered to have significance in safety terms.

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

APPENDIX 3C

AIR04 TASK TEAM FINDINGS

Note — Tasks pending review by the AIR SG

Task Number (origin)	Sub-group responsibility	Task	Deliverable	Milestones Progress report	Expected Completion	Inter-dependencies
TF-AIR04		To specify to the VAACs a level of ash that constitutes an unsafe level in which exists a significant risk of a substantive adverse safety outcome (being an encounter with ash likely to render the aircraft unable to continue to, and land safely at, its intended destination or planned alternate).				
TF-AIR04		To define the term "visible and discernible ash", as used by many Type Certificate Holders (TCH) in advice to operators, more closely and express it in a manner that is meaningful in safety terms and in a manner that is operationally useful to States, operators and those, such as Volcanic Ash Advisory Centres and Air Navigation Service Providers, who facilitate safe operations.				
TF-AIR04		To provide operators with VAAC information that is globally consistent by focussing on reducing differences among VAACs in relation to their skill level and				

Task Number (origin)	Sub-group responsibility	Task	Deliverable	Milestones Progress report	Expected Completion	Inter-dependencies
		resources available, and in the processes applied, to detect and forecast ash in the atmosphere and to delineate airspace in which ash at a level of interest is likely to exist.				
TF-AIR04		To provide information to the aviation community that clarifies the roles and responsibilities of the Meteorological Services and Air Traffic Services and of the processes used by each.				
TF-AIR04		To develop an optimal approach to the production of SIGMETs and NOTAMs be defined which would lead to the most accurate possible depiction of the location of the ash hazard. Two options have emerged: • The first is for the VAAC products to be advisory in nature and be one of many inputs (together with other satellites, AIREPs, LIDAR, reconnaissance flights etc) used by each Meteorological Services and Air Traffic Services in generating the SIGMET and/ NOTAM. • the second is a collaborative decision making process involving detailed interactions between the Meteorological Services, the Air				

Task Number (origin)	Sub-group responsibility	Task	Deliverable	Milestones Progress report	Expected Completion	Inter-dependencies
		Traffic Services and the VAAC which allows the VAAC to produce a product so well developed from the debate that the Meteorological Services and Air Traffic Services can adopt it without amendment to create the SIGMET and NOTAM.				
TF-AIR04		To develop a collaborative decision making process in relation to the production of optimized SIGMET and NOTAM involving not only the VAACs and Meteorological Services and Air Traffic Services but also aircraft operators and other stakeholders leading to greater clarity and accuracy in the depiction of the areas of ash concentration of interest to the aviation community and to consider, in this context, the formal assessment and authorization of information sources; such an initiative might include an assessment of the value of wider adoption of the "Enhanced Weather Information Network System" approach currently in use in the United States.				
TF-AIR04		To establish procedures to ensure the rapid transmission of Special AIREPs to VAACs.				
TF-AIR04		To respond to the need to provide guidance for use by operators of classes				

Task Number (origin)	Sub-group responsibility	Task	Deliverable	Milestones Progress report	Expected Completion	Inter-dependencies
		of aircraft other than commercial operators and international general aviation.				
TF-AIR04		To ensure that the IVATF guidance on the use of SMS to manage flight operations where ash is a threat be made fully effective by encouraging all participants in the airspace system act in way that complements and supports that methodology. Specifically that: • rather than close ash cloud contaminated airspace, States should prefer to keep airspace open, focus on providing information to operators and allow operators to discern where hazardous cloud lies and to constrain their operations in accordance with any limitations set out in their accepted safety risk assessments; • with airspace open, States should encourage air navigation service providers, working through a CDM process to agree on the tactical/strategic operations, to alert aircrews to the position of significantly contaminated airspace. A crew electing to proceed into such airspace should continue to benefit				

Task Number (origin)	**Sub-group responsibility**	**Task**	**Deliverable**	**Milestones Progress report**	**Expected Completion**	**Inter-dependencies**
		from an air navigation service; • States may wish to establish appropriate mechanisms to monitor the flight operations within their airspace that result from the application of the SMS approach and to liaise with fellow States and such other stakeholders as necessary to drive improved safety performance and improved efficiency and effectiveness in application of the overall methodology; and • States, and the aviation industry, should offer every assistance to the VAACs in the acquisition of such capability or information as is best suited to enhancing the operational value of their forecast products. This might include improving the opportunities for the VAACs to collaborate with each other in developing ash dispersion and trajectory models or in gaining better access to additional information sources such as satellites, role-equipped surveillance aircraft, ground observation networks (radar, LIDAR) or AIREPs.				

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APPENDIX 3D

PROPOSED TEXT FOR INCLUSION IN ICAO DOC 9691

GENERAL ADVICE FOR AIRCRAFT MAINTAINANCE INSPECTION WHEN OPERATING IN AIRSPACE WITH A LOW CONTAMINATION OF VOLCANIC ASH
(for all turbine and piston powered aircraft, including rotorcraft)

The following is provided as advice to States for aircraft and engine TC Holders:

(1) Accomplish inspections when operating in an area of low volcanic ash airspace contamination, to detect any erosion, accumulation of volcanic ash, or any aircraft and/or engine damage or system degradation. Turbine engines as well as piston engines operation can be adversely affected by volcanic ash on the ground or in the air.

The inspections should as a minimum include the following:

- 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 (turbine), induction air filter (piston)
- engine cooling system components
- engine compressor and turbines
- engine oil systems
- fuel tank venting system
- rotor blades
- airplane ventilation and pressurization systems (e.g., the air cycle machines, ozone converter, recirculation fans, HEPA filters, etc.)
- smoke detectors (e.g., detectors located in the cargo compartment, lavatory, electrical equipment bay, remote crew rest areas, etc.)

Based on the findings of the above inspections, more detailed inspections (such as boroscope inspections of the engine, oil analysis, inspection of filters, cleaning of parts) may be necessary.

(2) Report any encounter of volcanic ash, and any relevant findings, to the aircraft and engine TC holders, the State of Registry and VAACs through the Service Difficulty Reporting System.

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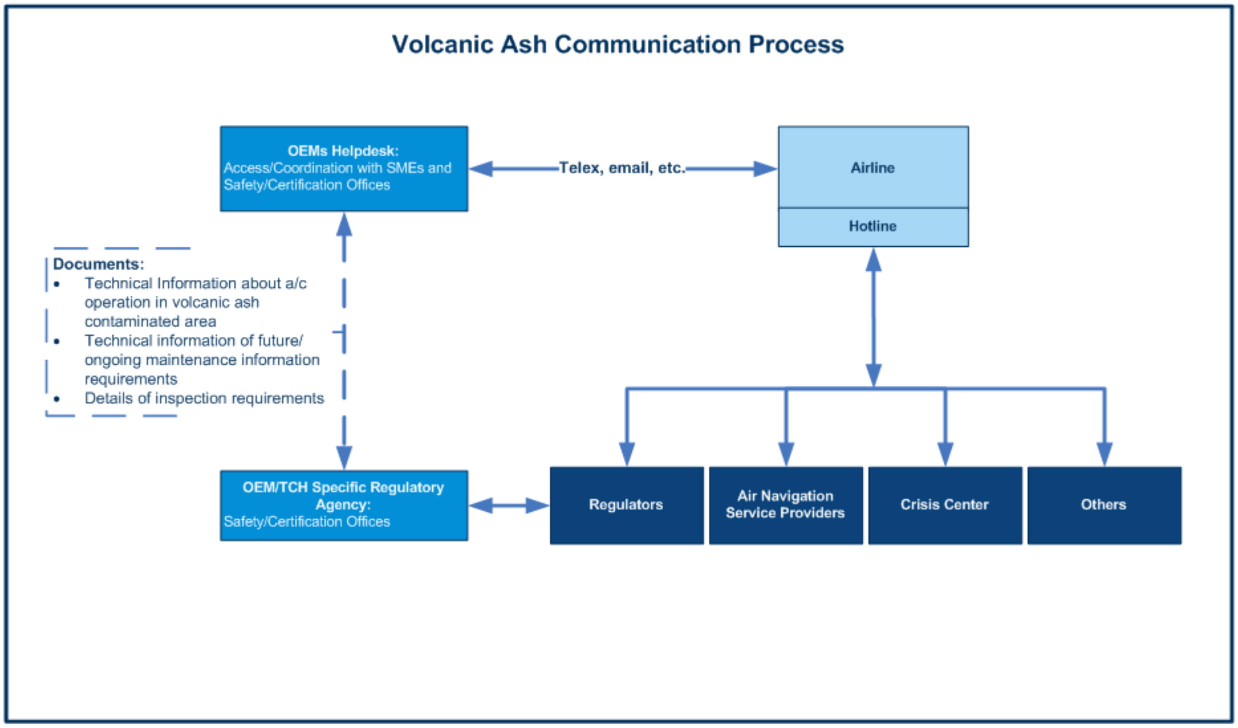
APPENDIX 3E

VOLCANIC ASH COMMUNICATION PROCESS WITH ORIGINAL EQUIPMENT MANUFACTURERS

The attached flow diagram has been produced to accompany the ICAO guidance material to indicate the processes to be followed in order to obtain Original Equipment Manufacturers (OEM) expert advice during times of volcanic eruption and the consequent potential disruption to aviation.



In the event of a volcanic eruption where the resulting volcanic ash affects any adjacent airspace, airways or airfields, accessibility to accurate information from the (appropriate) OEM(s) or TCH is a vital part of any regulatory accepted safety assessment process for the operator(s) in determining whether operations may or may not be continued. This information should be proactively sought out by the operator before any such event to minimize air service disruptions.

It is recognized, that equally important is the information flow to the State regulators, ANSPs and Crisis Centres amongst others. Regulating agencies which manage certification should contact their respective TCH certification or safety offices for information related to operating recommendations, inspections, and airworthiness. Other regulating agencies, ANSPs, and crisis centres should contact the appropriate regulating agency for a give TCH for this type information.

In the meantime, during periods of volcanic activity, each airline should set up its own hotline to deal directly with any incoming calls for information from its associated regulator, ANSPs or nearby crisis centre to either respond directly to the questions. The subsequent response may then come from the airline. Every situation being different and unpredictable, this does not preclude direct communication between the regulator and the OEM.

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APPENDIX 4A

AIR TRAFFIC MANAGEMENT CONTINGENCY PLAN FOR VOLCANIC ASH

(DRAFT TEMPLATE, 10 JUNE 2011)

TABLE OF CONTENTS

APPENDIX D	**Procedures for the production of modelled ash concentration charts**
APPENDIX E	**Recommended actions by States of the operator/registry with regards to aircraft operations in the event of a volcanic eruption**
APPENDIX F	**Example safety risk assessment process**
APPENDIX G	**Example table of considerations for planned operations in airspace to/from aerodromes which may be contaminated by volcanic ash**
APPENDIX H	**Example of a hazard log (risk register)**
APPENDIX I	**Example SIGMET, NOTAM and ASHTAM**

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1. FOREWORD

1.1 This plan sets out standardised guidelines for the alerting of aircraft when eruptions occur, and procedures to be followed. Volcanic ash may be a hazard for flight operations; the issue cannot be resolved in isolation but through collaborative decision making (CDM) involving all entities concerned. Encounters with volcanic ash may result in one or more of the following and other problems:

- 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.

1.2 Regulatory authorities of State of the Operator, or State of Registry as appropriate, should therefore prescribe appropriate operational procedures for flight crew to be followed in case of operation in or near airspaces that are contaminated by volcanic ash. Operators are required by ICAO Annex 6 – *Operation of Aircraft* to assess the risk of operation in volcanic ash and to implement appropriate mitigation measures in accordance with their safety management system (SMS) as approved by the State of the Operator/Registry, as appropriate.

1.3 It should be noted that this document is a contingency plan including its interfaces with supporting services such as Aeronautical Information Service (AIS) and Meteorological (MET) and that the plan therefore primarily addresses the provider States. Where distinct actions by the Meteorological Watch Offices (MWOs) are described, these are additional procedures to be considered by MWOs. Where actions by Volcanic Ash Advisory Centres (VAACs) and operators are described, these are for clarification only.

1.4 Volcanic ash can also affect the operation of aircraft on aerodromes. In extreme cases, aerodromes might no longer be available for operation at all, resulting in repercussions on the air traffic management (ATM) system; e.g. diversions, revised traffic flows, etc.

1.5 These suggested procedures are not intended to establish or confirm a safe level of ash concentration. Operation through any area where volcanic ash is forecast is at the discretion of the operator. Considering that a commercial aircraft will travel about 150 km (80 NM) in 10 minutes and that volcanic ash can rise to flight levels commonly used by turbine-engine aeroplanes in half that time, a timely response to reports of volcanic ash is essential.

1.6 It is imperative that information on the volcanic activity is disseminated as soon as possible. In order to assist staff in expediting the process of originating and issuing relevant messages (SIGMET, NOTAM, and ASHTAM), a series of templates should be available for different stages of the volcanic activity. **[**Examples of SIGMET, NOTAM and ASHTAM announcing operational measures and volcanic activities in the different stages and are contained in Appendix X.**]** A list of ICAO registered volcanoes should be available at the international NOTAM office with volcano name, number and nominal position. In order to ensure the smooth implementation of the contingency plan in case of an actual volcanic eruption, annual VOLCEX exercises should be conducted.

2. TERMINOLOGY

2.1 *AREAS OF CONTAMINATION*

Area of low contamination: An airspace of defined dimensions where volcanic ash may be encountered at concentrations equal to or less than X x 10^{-3} g/m^3.

Area of medium contamination: An airspace of defined dimensions where volcanic ash may be encountered at concentrations greater than X x 10^{-3} g/m^3, but less than X x 10^{-3} g/m^3.

Area of high contamination: An airspace of defined dimensions where volcanic ash may be encountered at concentrations equal to or greater than X x 10^{-3} g/m^3, or areas of contaminated airspace where no ash concentration guidance is available.

Note.– The term "defined dimensions" refers to horizontal and vertical limits.

2.2 *PHASES OF AN EVENT*

2.2.1 The response to a volcanic event that affects air traffic has been divided into three distinct phases as described briefly below. Volcanic activity at many locations is continuously monitored by the scientific community. Furthermore, flight crew are required to report observations of significant volcanic activity by means of a Special Air Report (AIREP). Arrangements should be put in place to ensure that such information is transferred without delay to the appropriate aeronautical institutions responsible for subsequent action.

> **ALERTING PHASE:** The initial response, "raising the alert", commences when a volcanic eruption is expected. Alerting information will be provided by SIGMET, NOTAM or ASHTAM as appropriate and disseminated to affected aircraft in flight by the most expeditious means. In addition to the normal distribution list, the NOTAM/ASHTAM will be addressed to meteorological/volcanological agencies.

2.2.2 If it is considered that the event could pose a hazard to aviation, a danger area[1] will be declared by NOTAM around the volcanic source. Normally, clearances will not be issued through the danger area.

> **OUTBREAK PHASE:** The outbreak phase commences at the outbreak of the volcanic eruption and entrance of volcanic ash into the atmosphere and mainly pertains to aircraft in flight. A "Start of Eruption SIGMET" will be issued and a danger area will be declared by NOTAM. Normally, clearances will not be issued through the danger area.

> **ONGOING ERUPTION PHASE:** The ongoing eruption phase commences with the issuance of the first VAA after completion of reactive responses. The T+0 hours and T+6 hours forecasts of the contaminated area are to be issued as SIGMET. The T+12 hours and T+18 hours (and further into the future) forecasts of contaminated areas are to be issued as NOTAM/ASHTAM. Significant changes may result in a reversion to a temporary outbreak phase situation and unscheduled issuance of VAA, SIGMET and NOTAM/ASHTAM. As appropriate, danger areas will be notified via NOTAM.

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[1] Wherever this document discusses the possible establishment of danger areas, States are not prevented from establishing restricted or prohibited areas over the sovereign territory of the State if considered necessary by the State concerned.

3. ALERTING PHASE

3.1 *GENERAL*

3.1.1 Where flight operations are planned in areas that are susceptible to volcanic eruptions, a system of monitoring volcanoes should be established. As the lack of resources results in a large number of volcanoes unmonitored locally, pilots of aircraft passing by are frequently the first source of information on an eruption. Therefore, pilots operating in areas with unmonitored volcanoes should always be vigilant for signs of an eruption and should fully understand their importance as information providers. Operators should provide them with the ICAO Volcanic Activity Report form (Doc 4444, Appendix 1, page A 1-6), preferably in an easily useable electronic format, as part of the pre-flight briefing.

3.1.2 The focus of this phase is to gain early recognition of volcanic events. This phase is characterised by a limited availability of information on the extent and severity of the volcanic event. The purpose of this phase is to ensure the safety of aircraft in flight and to promulgate information as a matter of urgency. Regardless of the extent of information available the alerting phase actions should be carried out for every event.

3.1.3 The initial response, "raising the alert", commences when a volcanic eruption is expected or occurring unexpectedly. The source of this information can be pilots (AIREP/Volcanic Activity Report) and/or meteorological or volcanological agencies. Arrangements in each State between designated volcano observatories, meteorological and air traffic management agencies shall ensure that alerting information is provided by SIGMET, NOTAM or ASHTAM or re-transmitted AIREPs, as appropriate to affected aircraft in flight by the most expeditious means, and disseminated according to established procedures.

3.1.4 The focus of this phase is to raise awareness concerning the (potential) hazard and to protect aircraft in flight from the hazards of the eruption. The actions are based on well-prepared contingency plans and standard operating procedures. Aircraft are expected to clear or avoid the affected area based on standard operating procedures. The alerting will trigger action, such as the collection of additional data and the preparation of specific safety risk assessments (SRAs).

3.2 *ORIGINATING ACC ACTIONS (eruption in its own flight information region)*

3.2.1 In the event of significant pre-eruption volcanic activity, a volcanic eruption occurring, or a volcanic ash cloud being reported which could pose a hazard to aviation, an area control centre (ACC), on receiving information of such an occurrence, should carry out the following:

a) define an initial danger area in accordance with established procedures. The size of the danger area should encompass a reasonable volume of airspace in accordance with the limited information available, aiming to avoid undue disruption of flight operations;

   i) if no such procedures have been established, the danger area should be defined as a circle with a radius of xxx km (xx NM). If the eruption has not commenced or if no information on upper winds is available, the circle should be centred on the estimated location of the volcanic activity;

ii) should a precautionary danger area be established, its size should encompass a reasonable volume of airspace in accordance with the limited information available aiming to avoid undue disruption of flight operations;

Note.– An area with a radius of 5 to 10 minutes flying time would result in only 2 – 3 minutes additional flying time.

iii) If the eruption has started and predicted upper wind information is available, the circle should be centred xxx km (xx NM) downwind from the volcano whilst enclosing it. The purpose of this initial danger area is to ensure safety of flight in the absence of any prediction from a competent authority of the extent of contamination;

iv) although ATC would not normally initiate a clearance through a danger area, it is the responsibility of the pilot-in-command to determine the safest course of action.

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b) advise the associated Meteorological Watch Office (MWO) and the appropriate VAAC (unless the initial notification originated from either of these entities). The VAAC will then inform the appropriate air traffic flow management (ATFM) units.

c) alert flights already within the danger area and offer assistance to enable aircraft to exit the area in the most expeditious and appropriate manner. Aircraft that are close to the danger area should be offered assistance to keep clear of the area. Tactically re-clear flights which would penetrate the danger area onto routes that will keep them clear. The ACC should immediately notify other affected ACCs of the event and the location and dimensions of the danger area. It should also negotiate any re-routings necessary for flights already coordinated but still within adjacent flight information regions (FIRs). It is also expected that adjacent ACCs will be asked to reroute flights not yet coordinated to keep them clear of the danger area.

d) ensure that a NOTAM/ASHTAM is originated. This must provide as precise information as is available regarding the activity of the volcano. The name (where applicable), reference number and position of the volcano should be included along with the date and time of the start of the eruption (if appropriate). It is imperative that this information is issued by the international NOTAM office and disseminated as soon as possible.

e) in order to assist staff in expediting the process of composing the NOTAM/ASHTAM, a series of templates should be available for this stage of the volcanic activity. **[**Example NOTAM and ASHTAM are provided in Appendix xxx.**]**

3.2.2 In addition to sending the NOTAM/ASHTAM and any subsequent NOTAM/ASHTAM to the normal distribution list, it will be sent to the relevant meteorological agencies after adding the appropriate World Meteorological Organisation (WMO) header. **[**Example NOTAM and ASHTAM are provided in Appendix xxx.**]**

3.3 *ADJACENT ACC ACTIONS*

3.3.1 During the alerting phase ATC will not normally initiate clearances through the danger area; instead, aircraft should be tactically rerouted to avoid the area. Any ash contamination should be contained within a limited area and disruption to traffic should not be excessive. Adjacent ACCs should take the following action to assist:

a) when advised, re-clear flights to which services are being provided and which will be affected by the danger area.

b) unless otherwise instructed, continue normal operations except:

i) if one or more routes are affected by the danger area, stop clearing aircraft on these routes and take steps to reroute onto routes clear of the danger area; and

ii) initiate a running plot of the affected area.

3.4 *ATFM UNIT ACTIONS*

3.4.1 The ATFM unit and the VAAC will determine how their initial communications will take place on the basis of bilateral agreements. Upon reception of preliminary information on volcanic activity from the VAAC, the ATFM unit should initiate actions in accordance with its procedures to ensure exchange of information in order to support CDM between air navigation service providers (ANSP), MWOs, VAACs and aircraft operators concerned.

4. OUTBREAK PHASE

4.1 *GENERAL*

4.1.1 This phase commences at the outbreak of volcanic eruption. The focus of the processes in this phase is to protect aircraft in flight and on aerodromes from the hazards of the eruption; to collect relevant information; and to combine the information available into reliable information about the volcanic cloud (horizontal and vertical extent; composition; ash concentration levels; etc.).

4.1.2 In addition to relevant actions described under the alerting phase, major activities of the outbreak phase are: Issuance of an eruption commenced SIGMET; eruption commenced NOTAM/ASHTAM; and rerouting of airborne traffic. As appropriate, danger areas will be notified via NOTAM. This phase will last until such time as the ongoing eruption phase can be activated.

4.2 *ORIGINATING ACC ACTIONS (eruption in its own FIR)*

4.2.1 The ACC providing services in the FIR within which the volcanic eruption takes place should inform flights about the existence, extent and forecast movement of volcanic ash and provide information useful for the safe conduct of flights.

4.2.2 Rerouting of traffic commences immediately or may be in progress if the alerting time has been sufficient to facilitate activation of the alerting phase. The ACC should assist in rerouting aircraft around the danger area as expeditiously as possible. Adjacent ACCs should also take the danger area into account and give similar assistance to aircraft as early as possible.

4.2.3 During this phase the ACC should:

a) maintain close liaison with its associated MWO. The MWO should issue a "start of eruption" SIGMET message by the most expeditious means. It may simply contain information that an ash cloud has been reported and the date/time and location. A "start of eruption" message may also be promulgated by a VAA. During this phase information on the extent and severity of the volcanic event may be limited; however, when possible, the message should contain information on the extent and forecast movement of the ash cloud based on appropriate sources of information.

b) based on these forecasts and in cooperation (CDM) with aircraft operators and the adjacent ACCs, ATFM measures should be devised and updated when necessary to ensure safety of flight operations.

c) ensure a NOTAM is originated to define a danger area delineated cautiously so as to encompass a volume of airspace in accordance with the limited information available.

d) ensure that reported differences between published information and observations (pilot reports, airborne measurements, etc.) are forwarded as soon as possible to the appropriate authorities to ensure its dissemination to all concerned.

e) should significant reductions in intensity of volcanic activity take place during this phase and the airspace no longer is contaminated by volcanic ash, a NOTAMC cancelling the last active NOTAM shall be issued stating the cause for cancellation; new ASHTAM should be promulgated to update the situation. Otherwise, begin CDM planning for the ongoing eruption phase in conjunction with aircraft operators, the appropriate ATFM unit and the affected ACCs.

4.3 *ADJACENT ACC ACTIONS*

4.3.1 During the outbreak phase adjacent ACCs should take the following actions:

a) maintain close liaison with the appropriate ATFM unit and the originating ACC to design, implement and keep up to date ATFM measures which will enable aircraft to ensure safety of flight operations.

b) in the event that tactical measures additional to those issued by the appropriate ATFM unit are required, the adjacent ACC should, in cooperation with the originating ACC and aircraft operators, impose such measures.

c) maintain a running plot of the affected area.

d) begin planning for the ongoing eruption phase in conjunction with the aircraft operators, the appropriate ATFM unit and ACCs concerned.

4.4 *ATFM UNIT ACTIONS*

4.4.1 During the outbreak phase, depending on the impact of the volcanic ash, the appropriate ATFM unit should organise the exchange of latest information on the developments with the VAAC, ANSPs, and MWOs and operators concerned in order to support CDM.

5. ONGOING ERUPTION PHASE

5.1 The ongoing eruption phase commences with the issuance of the first VAA/VAG by the VAAC after completion of the reactive responses. The VAA/VAG will contain the current position of the volcanic cloud and forecasts of the expected vertical and horizontal extent of the volcanic ash cloud, and its expected movement, at six-hourly time-steps for the period T+0 to T+18 hours. In addition, the meteorological office co-located with the VAAC will, where feasible, issue ash concentration forecasts to supplement the VAA/VAG information, at six-hourly intervals with a nominal validity time of 0000Z, 0600Z, 1200Z and 1800Z which will define areas of low, medium and high contamination. When the volcanic ash cloud is expected to move considerably during a 6 hour period, SIGMETs for shorter periods should be produced.

5.2 The volcanic cloud forecasts for T+12 and T+18 hours and further into the future (if available) are used for the preparation of NOTAM/ASHTAM. Volcanic cloud forecasts and/or VAA/VAGs may include (if available) quality indicators (e.g. accuracy, variability, etc.) and risk levels that can more easily be used in SRAs.

5.3 Following the outbreak phase, the VAA/VAG and (where available) ash concentration forecasts should be used to define airspace volumes encompassing the furthest extent of contamination predicted for that period. These volumes should be used to:

a) publish NOTAM indicating the extent of danger areas, indicating which levels of contamination are forecasted therein;

b) issue SIGMET warning of potential hazard from areas of volcanic ash contamination;

c) publish NOTAM to separately indicate the extent of areas of medium contamination if not included in a danger area; and

d) apply appropriate ATFM measures.

5.4 Longer term forecasts (i.e. beyond T+6 hours) should be used to generate NOTAM in order to ensure that adequate information is available to support flight planning. These messages should differentiate between levels of contamination.

5.5 Operators should use the information published regarding areas of low, medium and high contamination to plan their flights in accordance with their regulatory requirements and the service that will be provided in the airspace concerned. Operators should be aware that, depending on the State concerned, danger areas may be established to contain an area of high contamination, areas of medium/high contamination, or areas of low/medium/high contamination. During this phase, operators should only operate in the affected area in accordance with their SRA.

5.6 The volcanic ash may affect any combination of airspace; therefore, it is impossible to prescribe measures to be taken for any particular situation. Nor is it possible to detail the actions to be taken by any particular ACC. The following guidance may prove useful during the ongoing eruption phase but should not be considered mandatory:

a) ACCs affected by the movement of the ash should ensure that NOTAM/ASHTAM continue to be originated at appropriate intervals. ACCs concerned and the appropriate ATFM unit should continue to publish details on measures taken to ensure dissemination to all concerned.

b) depending on the impact of the volcanic ash, the appropriate ATFM unit may take the initiative to organise teleconferences to exchange latest information on the developments, in order to support CDM, with the VAACs, ANSPs and MWOs and operators concerned.

c) during this phase the VAAC should endeavour to assess the vertical extent of the ash contamination and provide appropriate VAA/VAG to define the contaminated airspace as accurately as possible. For the purpose of flight planning, operators should treat the horizontal and vertical limits of the danger area to be over-flown as they would mountainous terrain. Operators are cautioned regarding the risk of cabin depressurisation or engine failure resulting in the inability to maintain level flight above the danger area, especially where extended range operations by turbine-engined airplanes (ETOPS) are involved.

d) any reported differences between published information and observations (pilot reports, airborne measurements, etc.) should be forwarded as soon as possible to the appropriate authorities; and

e) when the airspace is no longer contaminated by volcanic ash, a NOTAMC cancelling the active NOTAM shall be promulgated. New ASHTAM should be promulgated to update the situation.

6. ATFM PROCEDURES

6.1 Depending on the impact of the volcanic ash and in order to support CDM, the appropriate ATFM unit should organize the exchange of latest information on the developments with the VAACs, ANSPs and MWOs and operators concerned.

6.2 The ATFM unit will apply ATFM measures on request of the ANSPs concerned. The measures should be reviewed and updated in accordance with updated information. Operators should also be advised to maintain watch for NOTAM/ASHTAM and SIGMET for the area.

7. AIR TRAFFIC CONTROL PROCEDURES5

7.1 If volcanic ash is reported or forecast in the FIR for which the ACC is responsible, the following procedures should be followed:

a) relay all available information immediately to pilots whose aircraft could be affected to ensure that they are aware of the horizontal and vertical extent of the ash contamination;

b) if requested, suggest appropriate rerouting to assist flights to avoid areas of known or forecast ash contamination;

c) when appropriate, remind pilots that volcanic ash may not be detected by ATC radar systems;

d) if modelled ash concentration charts are available showing areas of low, medium and high contamination, the provider State may establish danger areas. Depending on the State concerned, the danger areas will be established to contain an area of high contamination, areas of medium/high contamination, or areas of low/medium/high contamination;

e) in the absence of ash concentration guidance, the entire area of forecast volcanic ash should be considered as an area of high contamination, for the purposes of applying ATC procedures, until ash concentration guidance is available;

f) normally, ATC should not provide a clearance for an aircraft to enter or operate within a danger area. Assistance to enable an aircraft to exit a danger area in the most expeditious and appropriate manner should be provided; and

g) if the ACC has been advised by an aircraft that it has entered an area of ash contamination and indicates that a distress situation exists:

   i) consider the aircraft to be in an emergency situation;

   ii) do not initiate any climb clearances to turbine-powered aircraft until the aircraft has exited the area of ash contamination; and

iii) do not attempt to provide vectors without pilot concurrence.

7.2 Experience has shown that the recommended escape manoeuvre for an aircraft which has encountered volcanic ash is to reverse its course and begin a descent (if terrain permits). However, the final responsibility for this decision rests with the pilot.

8. GENERAL GUIDANCE FOR THE DEVELOPMENT OF ATS CONTINGENCY PLANS FOR VOLCANIC ASH

(This information is adapted from the *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds* (Doc 9691). Refer to this document for full details.)

8.1 In a contingency plan relating to volcanic ash certain steps need to be taken to provide a coordinated and controlled response for dealing with an event of this nature. Responsibilities should be clearly defined for the manager in charge, supervisors and air traffic controllers (ATCOs). The plan should also identify the officials who need to be contacted, the type of messages that are to be created, the proper distribution of the messages and how to conduct business.

8.2 ATCOs need to be trained and be made aware of the potential effects if aircraft encounter unsafe levels of volcanic ash.

8.3 Some particular points of guidance are as follows:

a) volcanic ash contamination may extend for hundreds of miles horizontally and reach the stratosphere vertically;

b) volcanic ash may block the pitot-static system of an aircraft, resulting in unreliable airspeed indications;

c) braking conditions at airports where volcanic ash has recently been deposited on the runway will affect the braking ability of the aircraft. This is more pronounced on runways contaminated with wet ash. Pilots and ATCOs should be aware of the consequences of volcanic ash being ingested into the engines during landing and taxiing. For departure it is recommended that pilots avoid operating in visible airborne ash; instead they should allow sufficient time for the particles to settle before initiating a take-off roll, in order to avoid ingestion of ash particles into the engine. In addition, the movement area to be used should be carefully swept before any engine is started;

d) volcanic ash may result in the failure or power loss of one or all engines of an aeroplane; and

e) airports might have to be declared unsafe for flight operations. This might have consequences for the ATM system.

8.4 The ACC in conjunction with ATFM units serves as the critical communication link between the pilot, dispatcher and meteorologists during a volcanic eruption. During episodes of volcanic ash contamination within the FIR, the ACC has two major communication roles. First and of greatest importance is its ability to communicate directly with aircraft en route which may encounter the ash. Based on the information provided in the volcanic ash SIGMET and VAAs and working with MWO, the ATCOs should be able to advise the pilot of which flight levels are affected by the ash and the projected trajectory and drift of the contamination. Through the use of radio communication, ACCs have the capability to coordinate with the pilot alternative routes which would keep the aircraft away from the volcanic ash.

8.5 Similarly, through the origination of a NOTAM/ASHTAM for volcanic activity the ACC can disseminate information on the status and activity of a volcano even for pre-eruption increases in volcanic activity. NOTAM/ASHTAM and SIGMET together with AIREPs are critical to dispatchers for flight planning purposes. Operators need as much advance notification as possible on the status of a volcano for strategic planning of flights and the safety of the flying public. Dispatchers need to be in communication with pilots en route so that a coordinated decision can be made between the pilot, the dispatcher and ATC regarding alternative routes that are available. The ACC should advise the ATFM unit concerning the availability of alternative routes. It cannot be presumed, however, that an aircraft which is projected to encounter ash will be provided with the most desirable route to avoid the contamination. Other considerations have to be taken into account such as existing traffic levels on other routes and the amount of fuel reserve available for flights which may have to be diverted to other routes to allow for the affected aircraft to divert.

8.6 The NOTAM/ASHTAM for volcanic activity provide information on the status of activity of a volcano when a change in its activity is, or is expected to be, of operational significance. They are originated by the ACC and issued through the respective international NOTAM office based on the information received from any one of the observing sources and/or advisory information provided by the associated VAAC. In addition to providing the status of activity of a volcano, the NOTAM/ASHTAM also provides information on the location, extent and movement of the ash contamination and the air routes and flight levels affected. NOTAM can also be used to limit access to the airspace affected by the volcanic ash. Complete guidance on the issuance of NOTAM and ASHTAM is provided in Annex 15 — *Aeronautical Information Services*. Included in Annex 15 is a volcano level of activity colour code chart. The colour code chart alert may be used to provide information on the status of the volcano, with “red” being the most severe, i.e. volcanic eruption in progress with an ash column/cloud reported above flight level 250, and “green” at the other extreme being volcanic activity considered to have ceased and volcano reverted to its normal pre-eruption state. It is very important that NOTAM for volcanic ash be cancelled and ASHTAM be updated as soon as the volcano has reverted to its normal pre-eruption status, no further eruptions are expected by vulcanologists and no ash is detectable or reported from the FIR concerned.

8.7 It is essential that the procedures to be followed by ACC personnel, including supporting services such as MET, AIS and ATFM should follow during a volcanic eruption/ash cloud event described in the foregoing paragraphs are translated into local staff instructions (adjusted as necessary to take account of local circumstances). It is also essential that these procedures/instructions form part of the basic training for all ATS, AIS, ATFM and MET personnel whose jobs would require them to take action in accordance with the procedures. Background information to assist the ACC or flight information centre (FIC) in maintaining an awareness of the status of activity of volcanoes in their FIR(s) is provided in the monthly

Scientific Event Alert Network Bulletin published by the United States Smithsonian Institution and sent free of charge to ACCs/FICs requesting it.

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APPENDIX A

ANTICIPATED PILOT ISSUES WHEN ENCOUNTERING VOLCANIC ASH

1. ATCOs should be aware that flight crews will be immediately dealing with some or all of the following issues when they encounter volcanic ash:

a) smoke or dust appearing in the cockpit which may prompt the flight crew to don oxygen masks (could interfere with the clarity of voice communications);

b) acrid odour similar to electrical smoke;

c) multiple engine malfunctions, such as stalls, increasing exhaust gas temperature (EGT), torching, flameout, and thrust loss causing an immediate departure from assigned altitude;

d) on engine restart attempts, engines may accelerate to idle very slowly, especially at high altitudes (could result in inability to maintain altitude or Mach number);

e) at night, St. Elmo's fire/static discharges may be observed around the windshield, accompanied by a bright orange glow in the engine inlet(s);

f) possible loss of visibility due to cockpit windows becoming cracked or discoloured, due to the sandblast effect of the ash;

g) cockpit windows could be rendered completely opaque; and/or

h) sharp distinct shadows cast by landing lights as compared to the diffused shadows observed in clouds (this affects visual perception of objects outside the aircraft).

2. Simultaneously, ATC can expect pilots to be executing contingency procedures. This may include a possible course reversal and/or an emergency descent.

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APPENDIX 4B

DETAILED RESULTS OF AN INVESTIGATION INTO FLIGHT PLANNING INFORMATION DISSEMINATION

(Extracted from IVATF/2 WP/28)

1. EXISTING ICAO PROVISIONS

1.1 Annexes and Docs

1.1.1 SARPs for volcanic ash information are contained in Annex 3 – *Meteorological Service for International Air Navigation* and Annex 15 – *Aeronautical Information Services*. Procedures for Air Navigation Services (PANS) and guidance are contained in PANS-ATM (Doc 4444), the Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds (Doc 9691), the Handbook on the International Airways Volcano Watch (Doc 9766), the Aeronautical Information Services Manual (Doc 8126) and others.

1.1.2 SARPs for volcanic contaminants other than ash that could also constitute a hazard for aircraft operations and aircraft occupants are missing from the ICAO SARPs. Only a few references are contained in guidance material, such as the pilot actions in case of SO_2 encounter contained in Doc 9766.

1.1.3 Some overlaps and inconsistencies exist. For details and proposals, see also the reports and recommendations from various IAVW Coordination Group tasks and section 3 of this working paper.

1.1.4 The ‘Level of Alert Colour Code’ described in Annex 15 is not fully aligned with the operational needs of the airspace users.

1.1.5 There are vast differences in the interpretation of ICAO SARPs, PANS and guidance. One particular issue of importance is the status that providers and users assign to the various products, which determines how the information is applied. A commonly agreed end-to-end information process would be desirable to enable all users a common and consistent application.

1.1.5.1 ICAO defines SIGMET as “Information issued by a meteorological watch office concerning the occurrence or expected occurrence of specified en-route weather phenomena which may affect the safety of aircraft operations”. It seems that, despite this being clearly spelt out in the Annexes, many users have interpreted it (probably because of "may affect the safety of aircraft operations") as a warning. Others have obviously not done so and the (partial) overlap with NOTAMs for VA and ASHTAMs, as well as the advent of VAAs/VAGs/MACC have increased the confusion.

1.1.5.2 Due to technical limitations, SIGMETs and NOTAMs are transmitted in a format that is not considered, by some, to be user-friendly (CAPTIAL LETTERS, MISSING STRUCTURE, etc). When the transmitted information includes long lists of coordinates defining the affected area it becomes a nightmare for aircrews to gain situational awareness on the position of the hazard.

1.1.5.3 There appears to be no widespread usage of ASHTAMs. NOTAMs are the preferred format for aeronautical information dissemination related to volcanic ash. It seems that the ASHTAM template is too limited in its content for some needs of the information providers or State authorities. The AIS-AIM Study Group of ICAO is understood to have commissioned a survey of users' views on the use of ASHTAM versus NOTAM for volcanic contamination.

1.1.5.4 The altitude bands provided in VAAs, VAGs, NOTAMs/ASHTAMs and SIGMETs do not appear to fully address operational requirements of the airspace users.

1.1.5.5 One State's representative in the EUR/NAT Volcanic Ash Task Force in 2010 had reported an uncertainty on how to address a SIGMET when a volcanic cloud would pass his State in the time between the VAA forecasts, but no volcanic ash would be present at these times; e.g the volcanic cloud is not yet in the respective FIR at T+6 hours and has exited the FIR already at T+12 hours, but would clearly affect the FIR in between these times.

1.1.5.6 One European operator has advised its pilots to ignore SIGMETs unless the presence of visible volcanic ash is confirmed by a pilot report.

1.1.6 For a number of issues no consensus could be achieved within the IVATF Sub-Groups. These are highlighted for further work or decision by the task force, either in this working paper or in the appropriate papers from other IVATF Sub-Groups. A number of issues also depend on the outcome of work of other ICAO groups, such as those mentioned in paragraph 4.

1.1.7 Several solutions for the issues identified need technical solutions that need to be developed by the appropriate ICAO groups. Appropriate recommendations, where they were identifiable, are included in section 3 of WP/28 of IVATF/2.

1.2 (Regional) Guidance Material

1.2.1 Regional volcanic ash contingency plans exist several ICAO Regions and some States. Their review was undertaken as Task TF-ATM01. See the relevant working paper(s) under agenda item 4.1 of IVATF/2 for details.

2. CONSISTENCY OF VARIOUS (OVERLAPPING) INFORMATION PRODUCTS

2.1 There are ICAO Standards requiring both SIGMETs and NOTAMs for volcanic hazards to be produced, which largely contain the same information, but also some different aspects. For example, airspace measures (establishment of a Danger Area etc) are to be notified by NOTAM.

2.2 Volcanic ash advisory information provided by the VAACs should be the basis for SIGMETs (as per Annex 3 Chapter 7 paragraph 7.1.4), but variations exist. Some are based on the fact that national MWOs apply – in accordance with this recommended practice – additional information (e.g. the results of validation flights) to amend VAAs. This has created discrepancies in the eruption of the Grimsvötn volcano in Iceland in May 2011. Ideally all information should be consistent. When a MWO has better local information than a VAAC, then this information should be fed back to the VAAC, which should then – in agreement with the MWO concerned – adapt the VAA/VAG, so that consistency is established.

3. NATIONAL AND REGIONAL IMPLEMENTATION: VARIANCES AND DEFICIENCIES

3.1 SIGMET and AIRMET have different meanings in the United States; there are however SIGMETs in graphical format (commonly with a validity period of only two hours) available that are highly appreciated by the airspace users.

3.2 As reported to the third meeting of the Meteorological Warnings Study Group (METWSG/3 held 15 to 18 November 2010), problems with either the issuance, dissemination and/or formatting of SIGMET exist in most regions which are a major concern to the aviation industry. For example, the AFI and ASIA/PAC Regions have been identified as areas where multiple deficiencies exist with respect to the issuance of SIGMET. In some States, no Meteorological Watch Office (MWO) has been implemented, resulting in no SIGMET being issued for the corresponding Flight Information Region (FIR).

3.3 It is believed that some States in the EUR Region have reported that their air traffic controllers are frequently unable to relay SIGMETs to all aircraft in peak traffic times. This might also be the case in other regions.

3.4 The METWSG has tried to overcome some of the deficiencies by investigating regional SIGMET advisories (provided by regional SIGMET advisory centres) and by investigating the possibility to provide regional SIGMETs for large complex volcanic ash events. The intent of a regional SIGMET advisory would be to provide advice for States on what conditions exist for which a SIGMET should be issued. These advisories are not intended to be used by the airspace users, but might be the only source of information if a State still would not issue a SIGMET.

3.5 Regional SIGMET advisory trials have been set-up with the help of IATA both in the AFI and ASIA Regions of ICAO for three months each in mid-2011. The findings of the trial will be reported to the next meeting of the METWSG in 2012.

4. ICAO GROUPS

4.1 METWSG (status provided in IP/11 of IVATF/2)

4.2 AIS/AIM SG (status provided in IP/11 of IVATF/2)

4.3 The IAVWOPSG is more or less congruent with IVATF's IAVW Coordination Group and will hold its next meeting (IAVWOPSG/6) from 15 to 23 September 2011 in Dakar, Senegal. A number of IVATF issues will be taken up and further developed by the IAVWOPSG.

5. TECHNOLOGY

5.1 SIGMETs, NOTAMs and ASHTAMs are traditionally transmitted via alpha-numeric communication means which do not allow user-friendly presentation. The Task Team recognized that these systems will have to be maintained for years to allow information flow to the low-end users, including aircraft in flight that do not have reception capability for graphical information.

5.2 It can be assumed that graphical products (e.g. VAGs) can be received nowadays or in a near future at most ground stations, even those in remote areas of the world with relatively little technical investment necessary. So, at least for pre-flight planning, a better product could be made globally available.

5.3 Advanced airspace users (e.g. large airlines) require the information in data formats that can be used in automated systems.

5.4 It was noted that the modelled ash concentration charts, outlined above and produced during the eruptive events in the EUR/NAT Region in 2010 and 2011, differed “due to the automation process” from VAGs produced for the same times. This difference is so far not sufficiently explained, although may be considered to relate to the fact that the Annex 3 required volcanic ash advisories (text based and graphical forms) are prepared by forecasters taking into consideration all available sources of information (satellite observations, aircraft reports, dispersion model output, etc) whilst the modelled ash concentration charts have little or no human intervention.

6. APPLICATION BY THE END USERS (FUNCTIONAL AND REGIONAL VARIATIONS)

6.1 As the operational concepts of different aviation service providers (e.g. Air Traffic Services and Airspace Users) and their application of volcanic ash information are not harmonized in many regions, there is inconsistency in the application of this information across the users.

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APPENDIX 5A

OPTIONS FOR THE DEPICTION OF SIGMET FOR VOLCANIC ASH IN GRAPHICAL FORMAT

(Extracted from IVATF/2 WP/23)

1.1 **Graphical SIGMET Option 1**

1.1.1 Annex 3 — *Meteorological Service for International Air Navigation*, Chapter 7 and Appendix 6 provide the Standards and Recommended Practices for the criteria and format of SIGMETs. Amendment 75 to Annex 3 updated the Model SVA in Appendix 1 of volcanic ash cloud SIGMET. This is the basic of SIGMETs, and for this working paper is referred to as Option 1 and is shown in Figure 1 to the Appendix of this paper. The task for the ad-hoc group was to propose a new Model SVA for Annex 3 that would depict a complex volcanic ash cloud.

1.2 **Graphical SIGMET Option 2**

1.2.1 During the course of reviewing proposals, it became obvious that this task is much more involved and complicated than what was originally thought by the IAVW Coordination Group. The first proposal considered for a replacement to Option 1 is shown in Appendix Figure 2, and is known as Option 2. Option 2 is a simple set of polygons which depict an initial ash cloud and two separate forecast polygons, which represent the ash cloud moving in different directions due to the difference in wind flow at the mid and upper troposphere. Several VAACs are already producing VAAs in this manner, and subsequently, MWOs are following the lead and producing simple polygons for the ease of use by the customers. The case can be made that this option meets both the in-flight, direct voice transmission of the text described in option 3, and the flight planning and ATC decision maker's needs. The primary concern with the depiction in Option 2 was that it did not represent a real-world example of an ash cloud. In other words it was too simple.

1.3 **Graphical SIGMET Option 3**

1.3.1 Based on the comments received on Option 2, a new proposal was considered, Option 3 (Appendix Figure 3a), which attempts to show a more realistic volcanic ash cloud. Option 3 shows a two-panel graphical SIGMET. This example contains 3 polygons. The polygon drawn with a solid line is the position of the volcanic ash cloud valid for the beginning of the SIGMET validity time. The two polygons drawn with dashed lines represent the positions of the ash cloud, at two distinct altitudes and areas, both valid at the end of the SIGMET validity time. Movement vectors were omitted in this proposal since the user could determine the movement by comparing the two images.

1.3.2 However, there is an inherent need to include movement information in the text SIGMET. For complex SIGMETs, there is a need for multiple movements. An example of the associated text SIGMET for Option 3 is shown in Appendix Figure 3b.

1.3.3 Option 3 received mixed reviews. Some thought the graphical depiction was much more realistic and would provide decision makers with more precise information. But others were concerned with the very lengthy text version of the SIGMET (Appendix Figure 3b).

1.3.4 These concerns with the long text SIGMET were related to the VOLMET broadcast. For the most part, a SIGMET is sent to an aircraft in flight via an ATC unit (usually by direct voice), or via VOLMET or Datalink. In the case of D-VOLMET a long text SIGMET could be sent, but very few pilots would be able to do anything with it. They would receive a message with a number of points to plot. But what would they plot the SIGMET information on? Increasingly, flight decks are becoming paperless with most information (MET included) now being displayed on an array of liquid crystal display (LCD) screens and electronic flight bags (EFB). Also, pilots generally don't carry blank maps with them to plot SIGMETs or other items.

1.3.5 For HF-VOLMET, a long text SIGMET wouldn't make the broadcast. This is because these broadcasts are restricted to 5 minute broadcast slots, and have to include TAF, METAR/SPECI, TREND and SIGMET. So a long SIGMET wouldn't fit within the broadcast slot.

1.3.6 Further discussions related to the number of coordinates allowed in the SIGMET. Study Note 6 presented at METWSG/2 discussed the issue of SIGMET coordinates. The resultant recommendation resulted in the proposal for 7 points by Amendment 76. Clearly, a complex graphic outline of an ash cloud, as shown in Figure 3 (Option 3) will easily exceed 5 coordinates, and in most cases exceed 7 coordinates.

1.4 Graphical SIGMET Option 4

1.4.1 The concern for keeping the number of SIGMET coordinates to a minimum, and the need for a complex graphical depiction resulted in Option 4 which is shown in Appendix Figure 4. This proposal is a detailed complex graphic VA SIGMET surrounded by a simple sided polygon. The five points of the simple polygon would become the "Text VA SIGMET", while the complex graphic is the "Graphic VA SIGMET". The simple polygon would be intended for the aircrew and since it surrounds the complex graphic, it covers more airspace and is thus more conservative and would not be a safety risk issue. Flight planners and ATC traffic management decision makers would benefit from the detailed graphic depiction of the ash cloud.

1.4.2 Option 4 presents a case where the text SIGMET does not exactly equate to the graphic SIGMET. Annex 3 does not state that the text and graphic are to be identical. One just assumes they should be, but in trying to provide a complex graphic and comply with a minimum set of coordinates, it becomes obvious that it can’t be done. Thus, if the text version of a complex graphical SIGMET was translated into a few coordinates, all users of the SIGMET information would benefit for the strengths of each product.

1.4.3 Operational impacts of this option vary, and it is essential to consider how users are currently working with the text version of SIGMETs. Some flight decks and Area Control Centres (ACC) have internal networks and proprietary software which cannot easily display outside graphics. More importantly, these graphics that MWOs produce might not have the tactical or strategic information required by certain decision makers, such as air routes, sectors, and current traffic. Some ACCs use proprietary software to translate the text SIGMET into a graphical form which can be overlaid onto the information they regularly use. This software decodes the text version, a process much more simple than using a graphic from an outside source. Therefore, consideration needs to be given to how a users process a text and graphic SIGMET for their operations.

1.5 Graphical SIGMET Option 5

1.5.1 Perhaps it is time to consider whether a Volcanic Ash Advisory and Graphic (VAA/VAG) should be upgraded to warning status and replace VA SIGMET. Several airline operators have confirmed that there is an increasing trend for the use of the VAA/VAG for pre-flight planning in preference to VA SIGMET. The reason is fairly straightforward. The VAA/VAG covers a number of Flight Information Regions (FIR), is produced by skilled personnel who have access to tools and information not necessarily available at some MWOs, and includes forecast information out to 18 hours. In other words a more complete product, and in some areas of the globe, a more reliable product. Some MWOs struggle to issue any SIGMET, let alone a VA SIGMET, thus considering an upgrade of the VAA/VAG to replace the VA SIGMET has merit. Appendix Figure 5 is an example of a VAG and is our Option 5.

1.5.2 This option has wide ranging changes at almost every level and user. Impacts include, but are not limited to, eruption SIGMETs, VOLMETs of all kinds, and in-flight use of VAAs. Additionally, detailed VAAs have the same issues as option 3 of this paper where in-flight use and broadcasts to aircrew are difficult to impossible.

1.6 Measure of Uncertainty and/or Levels of Ash Concentration

1.6.1 No consideration was given by the group for adding measure of uncertainty and/or levels of ash concentration because validity studies have not been done with respect to a detectable ash concentration level contoured by the VAACs.

1.6.2 These additions would clearly add more complexity to the SIGMET, both in text and graphic forms. Before these new measures are added to the SIGMET, it is important to agree on the provision of a complex graphic SIGMET.

SUMMARY OF FINDINGS

Options for Volcanic Ash Cloud SIGMETs	Figure in Appendix	Pro	Con
1. Simple Graphic and Short Text	Fig. 1	• No change to Annex 3. • Simple to produce by MWO. • Easy to convey to pilots.	• Does not provide a detailed depiction of the ash cloud. • Does not address events where ash moves in different directions at different altitudes.
2. Multiple simple polygons that depict layers. Text with multiple forecast elements	Fig. 2	• Addresses ash complex ash events. • Graphic and text identical.	• Not a realistic depiction of an ash cloud.
3. Detailed Graphic and Long Text	Figs 3a and 3b.	• Addresses ash complex ash events. • Graphic and text identical.	• Text too long for in-flight broadcast to aircrew.
4. Detailed Graphic, Short Text.	Fig 4	• Addresses ash complex ash events. • Provides all users with SIGMET information tailored to their needs	• Varied capabilities by MWOs to develop software to produce a graphical SIGMET and associated simple text. • Some decoders currently generate graphic SIGMETs from the text. • Text not equal to graphic.
5. VAA/VAG be upgraded to a warning product	Fig 5	• Valid more than 6 hours. • Covers multiple FIRs. • Ensures warnings for areas deficient in SIGMETs.	• Impact on MWOs. • Text too long for in-flight broadcast to aircrew.

OPTION 1

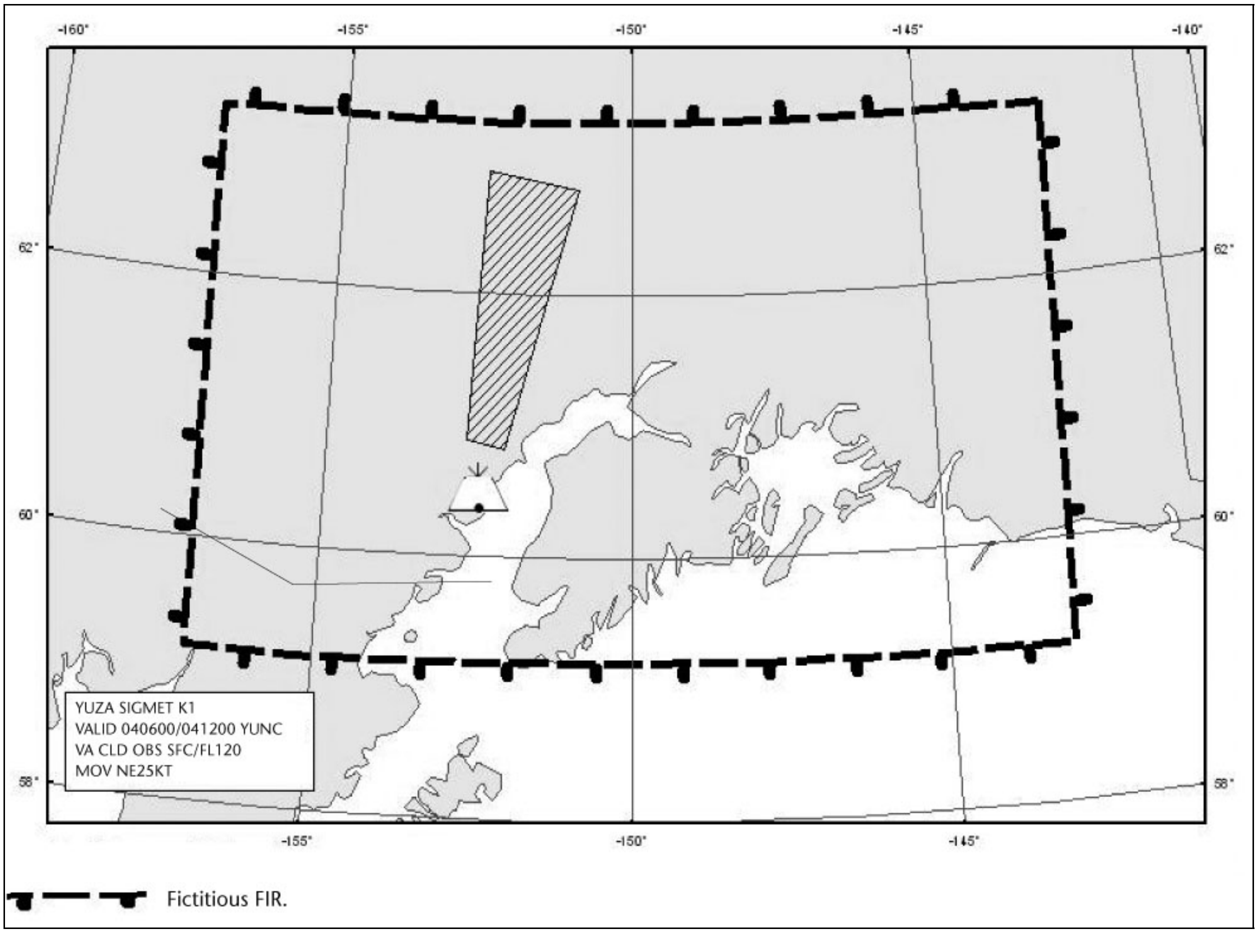


Figure 1a.

YUDD SIGMET 2 VALID 211100/211700 YUSO – YUDD SHANLON FIR/UIR VA ERUPTION MT ASHVAL PSN S1500 E07348 VA CLD OBS AT 1100Z FL310/450 APRX 220KM BY 35KM S1500 E07348 – S1530 E07642 MOV SE 65KMH FCST 1700Z VA CLD APRX S1506 E07500 – S1518 E08112 – S1712 E08330 – S1824 E07836

Figure 1b. Text SIGMET example in Annex 3.

OPTION 2

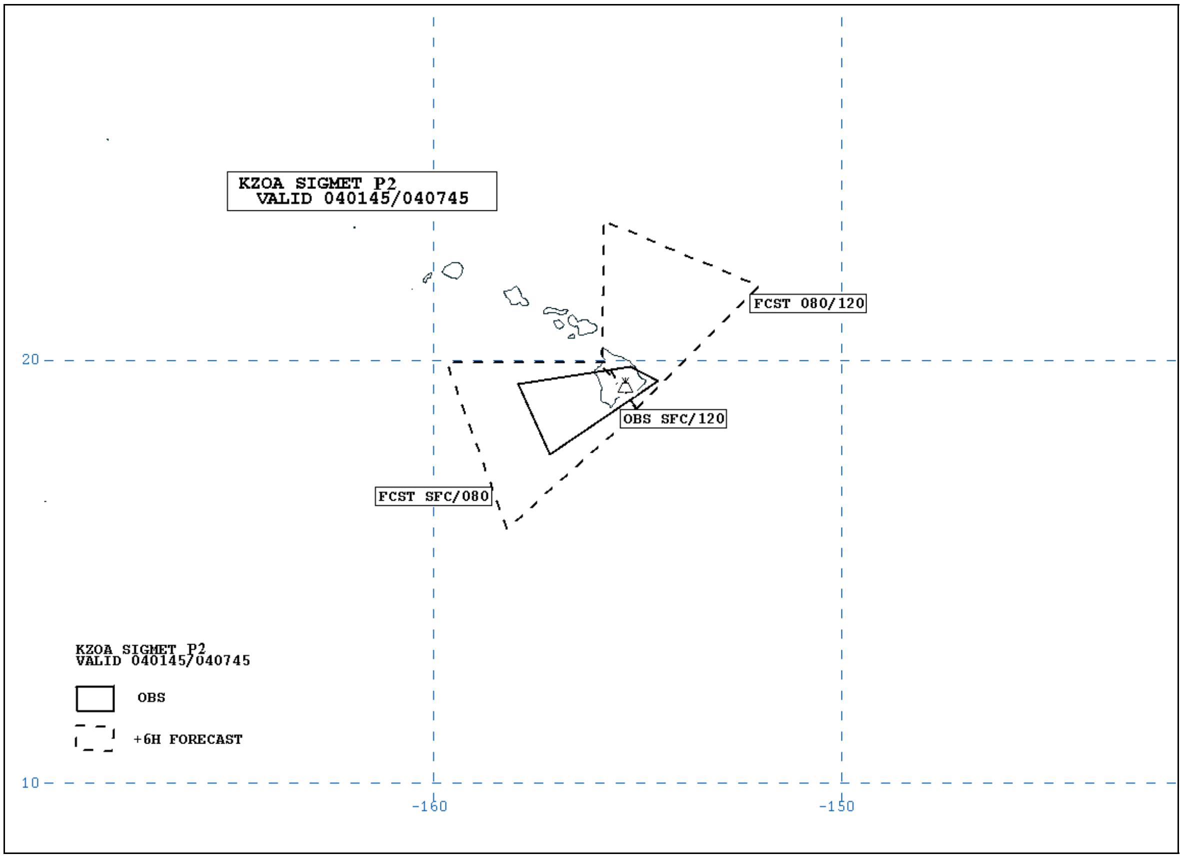
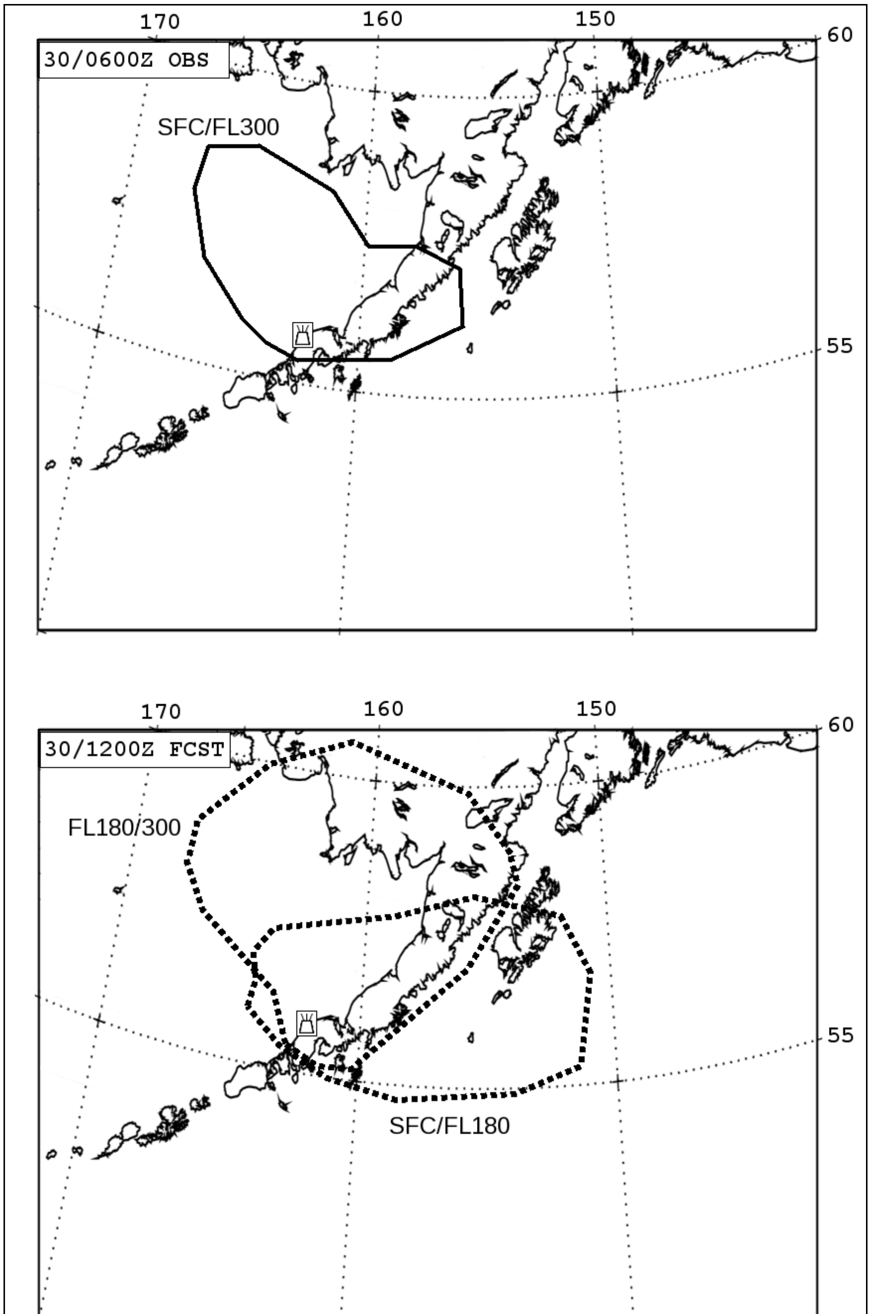


Figure 2.

OPTION 3



VOLCANIC ASH SIGMET
WVAK01 PAWU 300600
PAZA SIGMET I1 VALID 300600/301200 PAWU
PAZA ANCHORAGE FIR VA ERUPTION MT PAVLOF PSN N5542 W16189

Figure 3a.

WVAK01 PAWU 300600
PAZA SIGMET I1 VALID 300600/301200 PAWU-
PAZA ANCHORAGE FIR VA ERUPTION MT PAVLOF PSN N5542 W16189 VA CLD OBS AT 0600Z WI N5600 W16528 - N5617 W16623 - N5707 W16806 - N5812 W16907 - N5858 W16908 - N5916 W16730 - N5851
W16437 - N5804 W16303 - N5814 W16128 - N5760 W15957 - N5701 W15932 - N5614 W16132 - N5551 W16422 - N5600 W16528 SFC/FL300 NC FCST 1200Z VA CLD APRX N5552 W16615 - N5618 W16733 - N5648 W16733 - N5718 W16757 - N5746 W16728 - N5804 W16602 - N5834 W16341 - N5910 W16117 - N5906 W15813 - N5810 W15700 - N5633 W15656 - N5556 W15852 - N5524 W16224 - N5531 W16436 - N5552 W16615 SFC/FL180 MOV E 5KT AND APRX N5540 W16459 - N5556 W16604 - N5644 W16653 - N5742 W16954 - N5857 W17155 - N5938 W17207 - N6101 W17028 - N6152 W16748 - N6131 W16306 - N6029 W16046 - N5930 W15952 - N5753 W16104 - N5636 W16255 - N5546 W16359 - N5540 W16459 - N5540 W16459 FL180/300 MOV N 10KT

Figure 3b. Text version of Option 3 (shown in Figure 3a).

OPTION 4

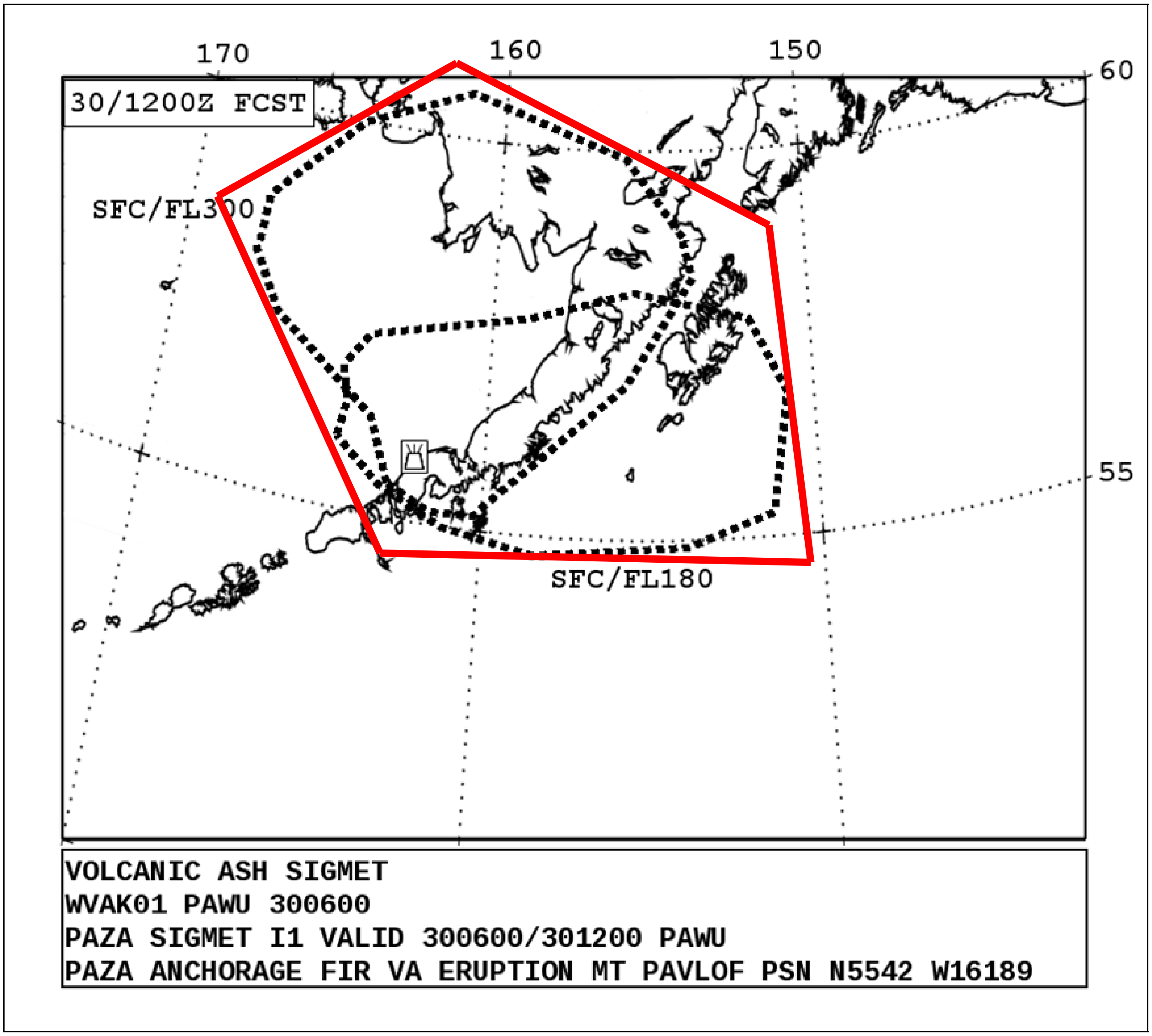
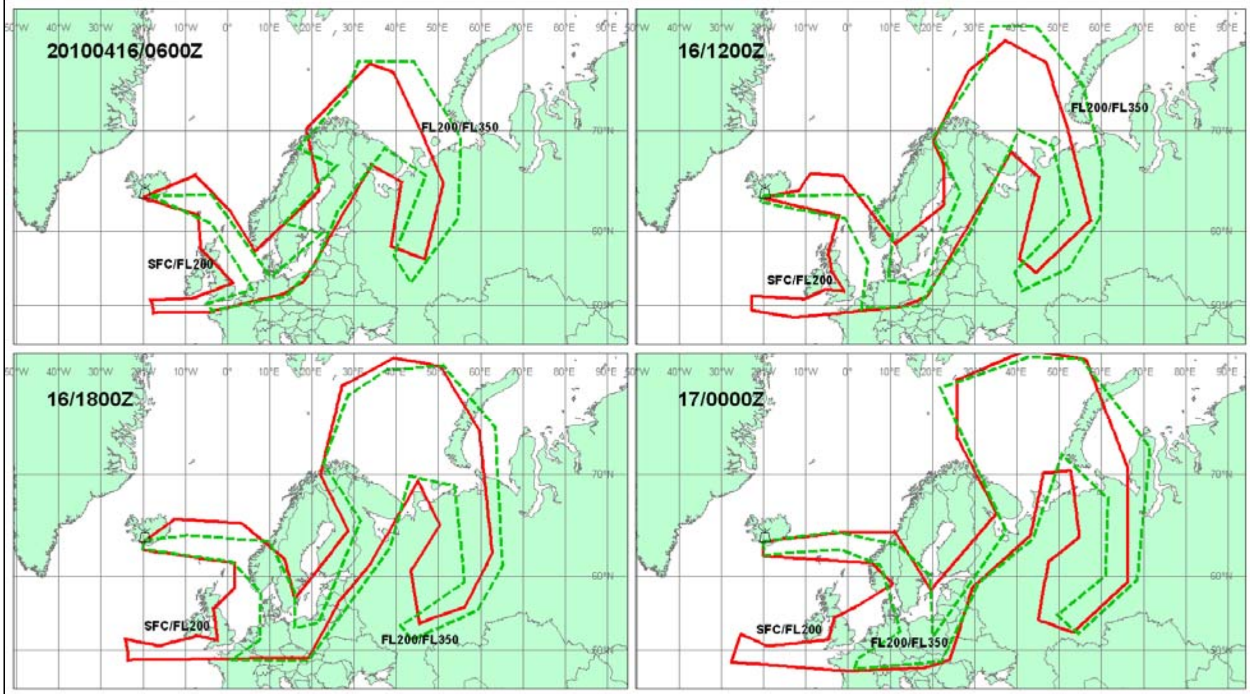


Figure 4. The red polygon represents the forecast portion of the text SIGMET, such that the text SIGMET would have 5 sets of coordinates while the associated SIGMET graphic would be the detailed polygon represented by the dashed lines.

OPTION 5



VA ADVISORY
DTG: 20100416/0600Z
VAAC: LONDON
VOLCANO: EYJAFJALLAJOKULL
PSN: N6338 W01937
AREA: ICELAND

SUMMIT ELEV: 1666M
ADVISORY NR: 2010/009
INFO SOURCE: ICELAND MET OFFICE
AVIATION COLOUR CODE: RED
ERUPTION DETAILS: SIGNIFICANT ERUPTION CONTINUING, REACHING FL180.

RMK: ASH CONCENTRATIONS WITHIN INDICATED AREAS ARE UNKNOWN. NO SIGNIFICANT ASH RISK ABOVE FL350.
NXT ADVISORY: 20100416/1200Z

Figure 5.

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APPENDIX 5B

VOLCANO OBSERVATORY SUPPORT FOR DECISION MAKING

(Extracted from IVATF/2 WP/32)

1.1 Some guidance on the role of observatories in the IAVW exists in the provisions of Annex 3, in the Handbook to the International Airways Volcano Watch (Doc 9766), and in the recently developed Guidance for Volcano Observatories on the IAVW. Fundamental to these documents is the principle that a well-functioning system will capture cooperation requirements for aviation safety in a structural manner. In this regard, the IAVW Coordination Group task leaders considered that it was likely that all of the required arrangements could be captured in updates to these documents, as discussed below.

1.2 However, it is evident that the current arrangements, as documented in Annex 3 and the Handbook on the IAVW, both of which have been in existence for some time, have not been implemented except in isolated cases. The uptake of revised arrangements can be reasonably forecast to be inadequate without targeted intervention. An inadequate uptake would be unacceptable from the viewpoint of the IVATF, which is powerfully motivated towards demonstrating improved, universal, and sustainable outcomes. As the 2010 Eyjafjallajökull and 2011 Grimsvötn eruptions were both from relatively well-monitored volcanoes in a developed State, there is a risk of this aspect being overlooked in IVATF considerations. Numerous examples exist of sudden eruptions from less well monitored volcanoes or where strong communication does not exist, and this issue is considered one of the most pressing issues for the International Airways Volcano Watch.

1.3 A special problem relating to volcanic activity is the potentially long period of repose between major eruptions at any one volcano or within any one State. To complicate matters, not all eruptions will give major precursory signals that are detectable to low technology monitoring. This will result in a need to emphasise long term monitoring strategies that capture the onset of a volcanic crisis, as well as methods of quick escalation of monitoring should the volcanic activity allow it.

1.4 This long-term emphasis would suggest that an essential measure for the IAVW will be regular assessment of the readiness of States for volcanic eruptions. It would also be appropriate in this context to explicitly state the requirement for an appropriate quality management system (ISO 9001) to be implemented in State Volcano Observatories[1], as well as in other IAVW principal nodes. An audit process, incorporated into the ICAO Universal Safety Oversight Audit Programme (USOAP) that assesses all services required of States under all of the Annexes to the Convention, would also be highly useful. In addition, it is possible that some legislative or other formal underpinning is required to better cement the role of some State Volcano Observatories. Improved guidance to States on these matters is required.

1.5 As volcanic monitoring techniques constantly improve, any IAVW guidance in relation to these matters should in general be principle-based rather than prescriptive in regards to technology. For example, a widely-held understanding in the volcanological community is that a modest amount of appropriate seismological monitoring can make a very significant difference to an emergency response[2].

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[1] Note – outside of aviation requirements, it may also be appropriate for State Volcano Observatories to capture and update broader themes, such as best practice eruption forecasting, under the same process. A Volcano Observatory Best Practice Workshop is planned September 2011 that could potentially explore these themes on the suggestion of the IVATF.

[2] http://www.scidev.net/en/news/modest-volcano-monitoring-can-still-save-lives-.html

From the viewpoint of the IVATF, this is an issue to be dealt with by States, so long as aviation requirements are clear and the appropriate processes are in place to ensure best practice.

1.6 Consistent with the Hyogo Framework for Action 2005-2015, part of the International Strategy for Disaster Risk Reduction, the principles and examples of volcanic monitoring for the IAVW should reflect a holistic approach. A technology or a staffing resource deployed for IAVW purposes would ideally form part of a monitoring network that assists ground-based populations (for example, a seismometer), and even assist in monitoring multiple hazards (as in the case of a dual purpose meteorological radar). The cost sharing benefits of this principle are most-likely self-evident, but may still need to be articulated in an aviation-focused environment. The wording of IVATF task TF-VAA08 reflects this point, and the wording of ICAO guidance should continue to reflect these principles.

1.7 In addition to technological strategies, appropriate institutional strategies are also very important. For example, aviation needs are sufficiently different from 'traditional' volcanic monitoring that a dedicated liaison officer, with clear organisational authority, may be required to ensure that aviation receives appropriate services. In addition, many States have relatively little interaction between volcanological and meteorological agencies; the maintenance of good relations is essential prior to the onset of, during and after a volcanic crisis.

1.8 At the WMO international volcanic ash workshop in Santiago, Chile, in March 2010, a number of possible areas of cooperation between meteorological and volcanological agencies were articulated. The text of this discussion has been included in **Attachment 1** (Appendix A to IVATF/2 WP/32). The second meeting of the newly created WMO-IUGG Volcanic Ash Scientific Advisory Group (VASAG) in Vienna in April 2011 further explored the observed and potential future role of third parties (particularly research scientists) during volcanic crises in providing additional information and interpretation[3]. In reflecting on these matters, the VASAG recalled a key guidance document produced by the International Association of Chemistry and Volcanology of the Earth's Interior, which articulates protocols to be followed during a volcanic crisis[4]. The concepts developed in that document are useful in themselves and in general translatable to the IAVW context.

1.9 In consideration of all of the above, a proposed revision to the wording of the Handbook on the IAVW is given in **Attachment 2** (Appendix B to IVATF/2 WP/32) for consideration by the IVATF. It is proposed that this revision also form the basis for developing any required complementary amendments to the recently developed guidance on the IAVW for State Volcano Observatories, and any other related guidance.

1.10 An issue with the wording of Annex 3, paragraph 3.6, has been noted. This states, in part '[…] *Contracting States that maintain volcano observatories monitoring active volcanoes shall arrange that selected State volcano observatories, as designated by regional air navigation agreement, observing significant pre-eruption volcanic activity […]*'. This appears to leave the options for States to not monitor their active volcanoes. The task force may wish to agree that it is *necessary* and reasonable for Annex 3 to require that active volcanoes are monitored for the purposes of the International Airways Volcano Watch, whether or not the State chooses to monitor for other purposes. A suggested draft recommendation is given on this below. It is noted that for States that currently choose to not monitor some volcanoes, this will be a significant change in practice.

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[3] Some State Volcano Observatories are already well advanced in these matters.

[4] IAVCEI Subcommittee for Crisis Protocols, Professional conduct of scientists during volcanic crises. Bull Volcanol (1999) 60:323–334. Available from http://www.iavcei.org/documents/newhall1.pdf

1.11 In relation to task TF-VAA09 (the international office of volcanologists), the IAVW Coordination Group has concluded that the idea possibly has merit. However, there are various practical issues. If a new United Nations treaty organisation is proposed, it would presumably be focused on the entirety of volcanology rather than aviation only. Hence while aviation can give support and encouragement to such a development, it would be both inappropriate and difficult from an aviation perspective to be the main driver of such a creation. If a new office under an existing treaty organisation is proposed, the effort required would be less, but the terms of reference and overall credibility and representativeness of the office may be relatively diminished. Therefore, other options should be explored.

1.12 The IAVW Coordination Group recalled the strong support of the Executive Council of the World Meteorological Organization (WMO) in 2010 for the creation of the WMO-IUGG Volcanic Ash Scientific Advisory Group, the science and natural hazard focus of the WMO, and WMO's extensive experience in encouraging voluntary cooperation in natural hazard mitigation. The IAVW Coordination Group considered that an appropriate first step in seriously exploring the idea of an office of volcanologists or other alternatives would be to request the WMO whether they are able to, in providing Secretariat support to that Group, also provide support to promote improvements in volcano observatory products for aviation, improvements in communications between volcano observatories and the aviation community, and function as a bridge to ICAO.

1.13 Should quality management for volcano observatory support to aviation be introduced, an appropriate role for WMO would be to facilitate the joint ISO-WMO certification of aviation services from observatories. This would provide a process for achieving the desired rigour in observatory operations and also considerably aid an ICAO Special Implementation Project.

1.14 Should such a request to WMO not be fully successful or should the revised guidance for the role of volcano observatories not be fully implemented through ICAO's direct liaison with States, a more far-reaching proposal, such as the creation of a separate treaty organisation, may become necessary.

1.15 In relation to task TF-SCI02, the task members feel that the above discussion and suggested recommendations, including revised guidance, recommendations on instrumental monitoring, recommendations on liaison, consideration of the role of third parties, request to WMO, and foreshadowed quality management and audit process with States, will considerably enhance situational awareness of impending volcanic eruptions.

1.16 The team concerned with task TF-SCI02 also noted the comprehensive guidance in the Handbook on the IAVW in respect of NOTAM for pre-eruptive activity:

> Excerpt from the Handbook on the International Airways Volcano Watch (Doc 9766) chapter 4.2 (Action to be taken by the ACC in the event of a volcanic eruption):
>
> In the event of significant pre-eruption volcanic activity, a volcanic eruption occurring or a volcanic ash cloud being reported in areas which could affect routes used by international flights, the ACC/FIC responsible for the FIR concerned, on receiving information of the occurrence, should take the following actions:
>
> a) Pass this information **immediately** to aircraft in flight which could be affected by the volcanic ash cloud and advise ACCs in relevant adjacent FIRs. Issue an ASHTAM or a NOTAM through the State International Notam Office (NOF), in accordance

with Annex 15, Chapter 5, giving details of the pre-eruption activity, volcanic eruption and ash cloud, including the name and geographical coordinates of the volcano, the date and time of the eruption, the flight levels and routes or portions of routes which could be affected and, as necessary, routes temporarily closed to air traffic. Include in the address list for ASHTAMs or NOTAMs concerning volcanic activity the associated MWO (see Part 2 of this document), all VAACs, the World Area Forecast Centre (WAFC) London at EGZZVANW and the WAFC Washington at KWBCYMYX.

Note 1.— In issuing an ASHTAM or a NOTAM concerning significant pre-eruption volcanic activity, or for volcanic eruptions not producing ash plumes, it is recommended that the ASHTAM or NOTAM text include the following actual wording, as appropriate:

"INCREASED VOLCANIC ACTIVITY REPORTED FOR VOLCANO (NAME AND LAT/LONG) AIRCRAFT ADVISED TO EXERCISE CAUTION UNTIL FURTHER NOTICE AND MAINTAIN WATCH FOR ASHTAM/NOTAM/ SIGMET FOR AREA".

or

"VOLCANO (NAME AND LAT/LONG) ERUPTED (DATE/TIME UTC) BUT NO ASH PLUME REPORTED, AIRCRAFT ADVISED TO AVOID FLYING WITHIN ... KM OF THE VOLCANO UNTIL FURTHER NOTICE, MAINTAIN WATCH FOR ASHTAM/NOTAM/SIGMET FOR AREA".

Use of such language in an ASHTAM or a NOTAM ensures that large volumes of airspace are not rendered unavailable to aircraft unnecessarily until such time as a volcanic ash plume/cloud is actually reported, or observed from satellite data.

[…]

1.17 The task members considered that, in terms of NOTAM wording, very little improvement of the suggested approach would be possible, so long as the approach was implemented and information was forthcoming for monitored volcanoes. However, the task members also recalled other discussion in the IVATF and/or IAVWOPSG on other forms of communication to the aviation industry, including the potential direct use of the Volcano Observatory Notice to Aviation (VONA), volcano colour codes, and also on a situational awareness product (a daily volcanic activity summary). The task members felt that it would be appropriate for the IVATF to, *inter alia*, urge the IAVWOPSG to strongly consider development in these areas.

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ATTACHMENT 1 TO APPENDIX 5B

RECENT WMO DISCUSSION ON DATA-SHARING ARRANGEMENTS

Extract from *WMO Science Workshop Report – 5th WMO International Workshop On Volcanic Ash (Santiago, Chile, March 2010).*

Data-sharing for the International Airways Volcano Watch

Given the good representation of volcano observatories at the Workshop, the opportunity was taken to have discussions on scientific data-sharing needs and related issues required for the purposes of the IAVW. The group considered that:

- the scientific data that should be shared should be that which helps each agency reach a professional and consistent analysis of the situation,
- data analysis should be performed by the agency with the appropriate expertise (for example, seismic station data by the Volcano Observatory (VO), and
- documented data-sharing arrangements between VOs, National Meteorological and Hydrological Services (NMHSs) , and Volcanic Ash Advisory Centres (VAACs) should ideally be agreed in advance of a volcanic crisis.

Observatories have been requested to use the Volcano Observatory Notice for Aviation (VONA) format for their analysis of volcanic activity for aviation purposes, including for the critical role of eruption prediction. In general the data contained in this or equivalent communications should suffice for operational purposes, although there may be occasions where other information might be usefully added by mutual agreement or individual initiative. An example of this last point might be for information about possible ‘remobilised ash’, where dry ash can be blown off a deposit for many decades after an event. These clouds can be seen in remote sensing and pose an aviation hazard, but the events also bear much in common with sandstorms despite the lower melting point of ash and the associated explicit aviation hazard.

In order to produce the analysis contained in a VONA, the data needs of the Volcano Observatories from other IAVW participants will vary according to local arrangements, but may include:

- Pilot, ship, and ground-based meteorological observer observations of volcanic activity, including cloud height
- Radar observations of a volcanic plume
- Lightning data indicating the possibility of eruptions at a volcano
- Satellite-based analysis of volcanic plumes
- Satellite-derived ‘hot spot’ observations (noting that many NMHSs and all VAACs are in receipt of meteorological satellite data including ‘hot spot’ channels in real-time)
- Archived VAAs for post analysis
- Post event analysis results, including that information sent to the Smithsonian Institution.

Where a volcanic eruption has no ground-based monitoring in place, the above observations tend to take on particular importance, but even with instrumental monitoring, multiple sources of information are often required to establish volcanic plume height, which can significantly affect volcanological assessment of the scale of an eruption as well as the scale of plume dispersion.

Data-sharing for general disaster risk reduction

The Handbook on the International Airways Volcano Watch, ICAO Doc 9766-AN/968, which sets out communications between Selected State Observatories and other parties for the purposes of aviation safety, suggests that, consistent with the Hyogo Framework for Action 2005-2015, “in order to enhance stronger linkages, coherence and integration with States' disaster risk reduction units, Contracting States are encouraged to send back to States' volcano observatories any relevant information regarding volcanic ash to the extent and in a form agreed between the VAAC and the VO concerned”. Further to this, the group noted informally that a number of volcanic hazards are closely related to atmospheric processes, and that close cooperation between VO, VAACs and NMHSs would indeed be useful in providing a comprehensive and consistent natural hazards warning system in the States concerned. Areas of interest include:

1) Ashfall modelling and dispersion modelling. Volcano observatories are becoming increasingly interested and proficient in modelling ashfall using real-time numerical model data and combined dispersion models such as Fall3d & VOL-CALPUFF. Ashfall is an important volcanic hazard because of the immediate risk to life and property close to the source, as well as a disruption to life and to industries such as agriculture further away from the source. Ashfall on airports has caused considerable disruption during many eruptions, and this can have the further effect of inhibiting airborne relief efforts. Ashfall modelling and long-term dispersion modelling for airborne volcanic cloud warnings are typically conducted on different scales and at different model resolutions (with terrain a particular consideration for mesoscale ashfall patterns), but it would nevertheless be useful to ensure consistent input meteorology to the extent possible, and that, regardless of which agency takes formal responsibility for ashfall, NMHSs, VOs, and VAACs closely coordinate for efficiency of effort, ensure the best possible meteorological and volcanological input, and possibly seek assistance from a WMO Regional Specialised Meteorological Centre in obtaining suitable numerical weather prediction data.

The group also noted that quantitative estimates of ash depth are an important factor in ashfall prediction. Currently, ash concentration is more qualitative for VAAC dispersion modelling, since there is no defined ‘safe’ concentration, but this may change in the future.

The group also noted the potential importance of an ensemble approach in future work.

2) Rainfall-triggered volcanic hazards. Lahars (volcanic mudflows) are a common, highly destructive, and frequently fatal volcanic hazard and are generally rainfall triggered. Rainfall is also known to trigger lava dome collapses in some situations4, causing highly dangerous pyroclastic flows. Rainfall intensity and duration forecasting by NMHSs can be highly useful for assisting VOs and disaster mitigation agencies in mitigating these hazards.

3) Volcanic landslides, ashfall, submarine eruptions and pyroclastic flows, into the sea pose shipping hazards. Landslides and volcanic eruptions may cause localised tsunami, and major volcanic eruptions or collapses may cause basin or ocean-wide tsunami. Incorporation of warnings and eruption analysis from VOs will be important in the further development of global tsunami warning systems.

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ATTACHMENT 2 TO APPENDIX 5B

IAVW COORDINATION GROUP PROPOSED CHANGES TO THE HANDBOOK ON THE INTERNATIONAL AIRWAYS VOLCANO WATCH (DOC 9766)

Extracts from current text:	**Suggested replacement to current text:**
4.1.1 In order to permit efficient application of the measures noted in 4.2, 4.3, 4.4 and 4.5, States responsible for flight information regions (FIRs) in which there are active or potentially active volcanoes in proximity to routes used by international flights should make arrangements to ensure that: a) information on increasing volcanic activity, volcanic eruption or cessation thereof, or volcanic ash cloud in areas which could affect routes used by international flights, available from one or more observing sources, such as vulcanological, seismological, geological, meteorological, or the police/military networks and domestic aviation, is passed **immediately** to the area control centre/flight information centre (ACC/FIC) and the meteorological watch office (MWO) concerned; b) appropriate channels of communication are established between such sources of observation (especially vulcanological observing stations) and the nearest ACC/FIC and MWO to ensure that, in the event of an eruption, the information reaches the ACC/FIC/MWO as speedily as possible; c) access to information from available geostationary and polar-orbiting weather satellites and other sources, such as volcanic ash advisory centres (VAACs), is arranged through the national meteorological authority concerned in order to obtain, as far as practicable, information regarding the extent and trajectory of volcanic ash clouds (see 4.4.1 a)); d) access to vulcanological advice is made available to the ACC/FIC and MWO and, in the Provider States concerned, to the VAAC,	4.1.1 In order to permit efficient application of the measures noted in 4.2, 4.3, 4.4 and 4.5, States responsible for flight information regions (FIRs) in which there are active or potentially active volcanoes in proximity to routes used by international flights should make arrangements to ensure that: a) active or potentially active volcanoes are instrumentally and visually monitored, for example by seismological means supplemented by other information available, by designated volcano observatories supported by appropriate authorities, resourcing, and quality management systems (ISO 9001); b) systems are in place to make available appropriate meteorological data on volcanic plume height or resuspended ash (in particular radar data, but also lidar, satellite remote sensing, and visual observations by trained meteorological observers); c) 24 hour contact numbers are made available for the area control centre/flight information centre (ACC/FIC), meteorological watch office (MWO), volcano observatories and relevant VAAC, d) information on increasing volcanic activity, volcanic eruption or cessation thereof, or volcanic ash cloud available from the above or supplementary sources, such as police/military networks and domestic aviation, or the research community, is passed **immediately** to the ACC/FIC, the MWO concerned, the VAAC concerned, and the volcano observatory concerned; *Note: Where information comes from supplementary sources such as the research community, Contracting States are strongly encouraged to make arrangements consistent with*

Extracts from current text:	**Suggested replacement to current text:**
including 24-hour telephone contact numbers at which a vulcanologist can be contacted in an emergency; *Note.— A convenient forum to explore ways and means to implement the foregoing measures is the National Disaster Committee or any similar consultative body.* e) the State international NOTAM office personnel are familiar with the issuance of ASHTAMs1 (or NOTAMs for volcanic ash); f) information, preferably supplemented by charts, concerning volcanoes in the FIRs for which the State is responsible should be included in the State aeronautical information publication in accordance with Annex 15, Appendix 1, Section ENR 5.3.1; and g) ATM contingency arrangements in respect of volcanic ash are made and promulgated, as necessary, for air routes crossing FIRs for which the State is responsible, in coordination with adjacent FIRs. *(paragraph 4.1.2 deals with pilot reports)* 4.1.3 It is essential that the foregoing arrangements be made in every State concerned and their efficacy continually maintained. In the case of volcanic ash, the hazard to jet transport aircraft is greatest within the first few hours following an eruption; hence speed of notification between all links in the chain of communication is critical. States may wish to consider drawing up letters of agreement between the parties involved, in particular, the civil aviation and meteorological authorities and the vulcanological agency, to record the agreed responsibilities of each party. 4.1.4 In order to assist States in enhancing the coordination between the different States' authorities/agencies involved in the IAVW, at Appendix A is a sample letter of agreement covering the coordination and responsibilities between meteorological authorities, ATS	*the appropriate scientific protocols as advised by the IUGG.* e) the State international NOTAM office personnel are familiar with the issuance of ASHTAMs1 (or NOTAMs for volcanic ash); f) information, preferably supplemented by charts, concerning volcanoes in the FIRs for which the State is responsible should be included in the State aeronautical information publication in accordance with Annex 15, Appendix 1, Section ENR 5.3.1; and g) ATM contingency arrangements in respect of volcanic ash are made and promulgated, as necessary, for air routes crossing FIRs for which the State is responsible, in coordination with adjacent FIRs. *(paragraph 4.1.2 deals with pilot reports)* 4.1.3 It is essential that the foregoing arrangements be made in every State concerned and their efficacy continually maintained. In the case of volcanic ash, the hazard to jet transport aircraft is greatest within the first few hours following an eruption; hence speed of notification between all links in the chain of communication is critical. States may wish to consider drawing up letters of agreement between the parties involved, in particular, the civil aviation and meteorological authorities and the vulcanological agency, to record the agreed responsibilities of each party. 4.1.4 In order to assist States in enhancing the coordination between the different States' authorities/agencies involved in the IAVW, at Appendix A is a sample letter of agreement covering the coordination and responsibilities between meteorological authorities, ATS authorities and vulcanological authorities for the provision and exchange of information relevant to volcanic ash. *Note 1. — Consistent with the Hyogo Framework for Disaster Risk Reduction 2005-2015,*

Extracts from current text:	**Suggested replacement to current text:**
authorities and vulcanological authorities for the provision and exchange of information relevant to volcanic ash. *Note. — In order to enhance stronger linkages, coherence and integration with States' disaster risk reduction units, Contracting States are encouraged to send back to States' volcano observatories any relevant information regarding volcanic ash to the extent and in a form agreed between the VAAC and the volcano observatory concerned. The sample letter of agreement could be used to document such agreements.* ……… Note 3 of Section 4.2a: *… A volcano level of alert colour code has been developed for aviation which may be used by some vulcanological agencies to report volcanic activity information to aviation. In those States where the colour code has been introduced by the vulcanological agency, it is useful to include the reported colour code in ASHTAMs or NOTAMs issued for volcanic activity. The aviation volcano level of alert colour code is….* *….. The colour code for the level of alert indicating the status of activity of the volcano and any change from a previous status of activity should be provided to the area control centre by the responsible vulcanological agency in the State concerned, e.g. "RED ALERT FOLLOWING YELLOW" OR "GREEN ALERT FOLLOWING ORANGE"…..*	*Contracting States may wish to consider the above as part of an integrated suite of arrangements for other related volcanic hazards, such as ashfall on airports, populated areas and agricultural zones, shipping hazards, volcanic tsunami, and rainfall that may induce dome collapse, lahar activity or slope failure.* *Note 2. — Given the variation between States in capacity and the cross-border nature of the volcanic ash hazard, all Contracting States are encouraged to take note of relevant arrangements in the surrounding regions, and where appropriate and invited, to assist in any reasonable manner* ……… Note 3 of Section 4.2a: *… A volcano level of alert colour code has been developed for aviation which should be used by vulcanological agencies to report volcanic activity information to aviation. In those States where the colour code has been introduced by the vulcanological agency, it is highly desirable to include the reported colour code in ASHTAMs or NOTAMs issued for volcanic activity. The aviation volcano level of alert colour code is….* *….. The colour code for the level of alert indicating the status of activity of the volcano and any change from a previous status of activity should be provided to the area control centre by the responsible vulcanological agency in the State concerned, e.g. "RED ALERT FOLLOWING YELLOW" OR "GREEN ALERT FOLLOWING ORANGE"…..*

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APPENDIX 6A

MODUS OPERANDI AND TERMS OF REFERENCE OF THE INTERNATIONAL VOLCANIC ASH TASK FORCE (IVATF)

(as updated by IVATF/2)

1. MODUS OPERANDI

1.1 The International Volcanic Ash Task Force (IVATF) is a multi-disciplinary global group and a focal point and coordinating body of all work related to volcanic ash being carried out by ICAO at the global and regional levels. It will address issues related to air traffic management (ATM), airworthiness, aeronautical meteorology (MET) and atmospheric sciences and is tasked to identify work that needs to be undertaken, together with plans on how to progress them relying, to the extent possible, on existing bodies, such as the International Airways Volcano Watch Operations Group (IAVWOPSG). Any need for amendments to ICAO provisions, which are identified will be forwarded to the appropriate ICAO body for further action.

1.2 The IVATF works, to the extent possible, through correspondence, thus limiting the need for meetings to preferably not more than one per year. Between the meetings, the work will be progressed by the IVATF sub-groups with the following areas of expertise (the name of the group in brackets):

a) air traffic management (ATM sub-group);

b) airworthiness (AIR sub-group);

c) science (SCI sub-group); and

d) international airways volcano watch (IAVW coordination group).

1.3 After each meeting, quarterly teleconferences of the sub-groups will be held (in October, January and April) to monitor progress, i.e. at the teleconferences, the project managers of each sub-group will provide progress reports and identify any issues which need to be brought to the attention of the IVATF as a whole. Project managers of the sub-groups may, if considered necessary, convene additional teleconferences within their respective sub-groups.

1.4 The Secretary of the task force is Mr. Greg Brock, C/MET, ICAO Air Navigation Bureau (ANB) assisted by Mr. Raúl Romero, Secretary of the IAVWOPSG, ICAO ANB. Additional Secretariat support is provided in particular by the Flight Operations, the Air Traffic Management, and the Future Aviation Systems and Technology Sections of the ICAO ANB.

2. TERMS OF REFERENCE

2.1 The IVATF is tasked to undertake, in close coordination with the IAVWOPSG and other appropriate ICAO groups, the following tasks:

a) evaluation of the eruption of the Eyjafjallajökull volcano in Iceland in April/May 2010, plus other significant eruptions or regional volcanic ash exercises of relevance;

b) propose revision of guidance on volcanic ash contingency plans;

c) review of operational response to volcanic ash encounter;

d) development of ash concentration thresholds, if deemed appropriate;

e) improvement of ash detection systems;

f) review of notification and warning for volcanic ash;

g) improvement and harmonization of dispersion models; and

h) improvement of volcanic ash advisory centre (VAAC) products, including volcanic ash advisories in graphical format.

2.2 The details of the tasks, together with the expected deliverables, completion dates and coordination plans, are to be determined at each meeting of the IVATF.

2.3 The IVATF is expected to complete its work by July 2012. Any tasks and associated deliverables outstanding by July 2012 will be transferred to the IAVWOPSG or other appropriate ICAO bodies. The composition of such ICAO bodies should be reviewed in light of those tasks transferred.

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APPENDIX 6B

WORK PROGRAMME OF THE IVATF (2011 TO 2012)

Note.— The quarterly teleconferences are expected to be held on 19 October 2011 (IVATF/T4), 18 January 2012 (IVATF/T5) and 18 April 2012 (IVATF/T6). IVATF/3 and IVATF/4 meetings tentatively scheduled for February and June 2012.

6B.1 TASKS ALLOCATED TO THE ATM SUB-GROUP

Task number (origin)	Sub-group/ responsibility	Task	Deliverable	Milestones (progress reports)	Expected completion	Inter-dependencies
TF-ATM01 (IVATF/1 updated at IVATF/2)	Cay Boquist	Review IVATF/2 WP/25, WP/26 and IP/21 and propose a common terminology for the Response Phases. (Alert/Reactive/Proactive versus Monitoring and Preparation/Alerting/Initial Reaction/Proactive/Review). Check ATM contingency plan draft template. Finalize ATM contingency plan draft template (clarify the intended reference to Danger Area, concentration levels).	Integrate the proposals into one. Ensure wording matches in IVATF/2 WP/25 Appendix A and WP/18 Appendix B. Concentration levels – add indicating text as determined by the appropriate ICAO group.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	IAVW CG; AIR SG; SCI SG

Task number (origin)	**Sub-group/ responsibility**	**Task**	**Deliverable**	**Milestones (progress reports)**	**Expected completion**	**Inter-dependencies**
TF-ATM02 (IVATF/1 updated at IVATF/2)	ICAO TO/ATM	Investigate other ICAO groups work related to volcanic activities and report on their conclusions. (e.g. EUR/NAT VOLCEX SG, AIS-AIM SG)	Report on findings.	Teleconference: 19 October 2011	October 2011	
TF-ATM03 (IVATF/1 updated at IVATF/2)	Dragica Stankovic	Review the communication chain regarding the collection and dissemination of pilot reports of volcanic activity (IVATF/2 WP29 refers) and include in contingency plan. VAR form and taxonomy review (i.e. VAR → Pilot VAR).	Provide guidance or suggestion to improve the collection, exchange and dissemination of volcanic activity reports (VAR) by pilots. Monitor the progress within task TF-VAA12	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	IAVW CG [Link to task TF-VAA12] IAVW CG; AIR SG; Secretariat
TF-ATM04 (IVATF/2)	Sigurleifur Kristjánsson (EUR/NAT contingency) ICAO TO/ATM (intent of "Danger Area" use)	Recommend that EUR/NAT volcanic ash contingency plan should be clarified on the issuance of clearances through Danger Areas. Pilots wishing to fly through will be informed about the danger area and if the pilot still wished to proceed, clearance will be issued.	WP for NAT ATMG/38 (12-16 September 2011, Paris)	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	NAT ATMG
TF-ATM05 (IVATF/2)	Andy Wells	Investigate the terminology Danger Area and its relevance in today's operating environment.	Propose a way forward regarding the Danger Area naming convention (e.g. Alert Area).	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	

Task number (origin)	**Sub-group/ responsibility**	**Task**	**Deliverable**	**Milestones (progress reports)**	**Expected completion**	**Inter-dependencies**
TF-ATM06 (IVATF/2)	Heinz Frühwirth	Review the current processes regarding the issuance of NOTAM, ASHTAM, VAA/VAG, SIGMET and its affect in light of IVATF/2 (i.e. information overload)	Propose a way forward.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	AIR OPS; IAVW CG

6B.2 TASKS ALLOCATED TO THE AIR SUB-GROUP

Task number (origin)	**Sub-group/ responsibility**	**Task**	**Deliverable**	**Milestones (progress reports)**	**Expected completion**	**Inter-dependencies**
TF-AIR01 (IVATF/1 updated at IVATF/2)	AIR SG	To develop, in close coordination with the SCI SG and IAVW CG, a volcanic ash operationally applicable characteristic(s) that can be used as a threshold value for the concept of "visible ash".	Report addressing an initial quantified value for defining observations and value for forecasts of volcanic ash. Recommendation for further work by the SCI SG and/or IAVW CG.	Detailed work plan by 1 September 2011 Teleconference: 19 October 2011 Draft report by 15 November 2011 Teleconference: 18 January 2012 Final report by 1 February 2012	February 2012	SCI SG (IVATF/2 WP/08)
TF-AIR02 (IVATF/1)	Complete at IVATF/2					
TF-AIR03 (IVATF/1)	Complete at IVATF/2					
TF-AIR04 (IVATF/1 updated at IVATF/2)	AIR SG	That the AIR04 task team findings (IVATF/2 Report Appendix 3C) be given careful consideration and such further action, as required, so as to provide resolutions to the issues raised.	Action plan.	Teleconference: 19 October 2011	February 2012	To be confirmed once action plan developed.
TF-AIR05 (IVATF/1	AIR SG	Determine, in coordination with the SCI SG, how best	Additional guidance material.	Teleconferences: 19 October 2011	July 2012	SCI SG

Task number (origin)	**Sub-group/ responsibility**	**Task**	**Deliverable**	**Milestones (progress reports)**	**Expected completion**	**Inter-dependencies**
updated at IVATF/2)		to relocate and revise guidance for flight into SO_2 clouds within Chapter 4.7 of Doc 9766.		18 January 2012 18 April 2012		
TF-AIR06 (IVATF/1 updated at IVATF/2)	AIR SG	Develop maintenance and operations considerations for international General Aviation.	Inventory of international General Aviation segment that requires additional guidance material.	Teleconference: 19 October 2011	February 2012	
TF-AIR07 (IVATF/1 updated at IVATF/2)	AIR SG	To monitor, report and make recommendation on emerging technologies that measure volcanic cloud characteristics of concern to aircraft airworthiness.	IP or WP depending on state of technology.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	SCI SG
TF-AIR08 (IVATF/1)	Complete at IVATF/2					

6B.3 TASKS ALLOCATED TO THE SCI SUB-GROUP

Task number (origin)	**Sub-group/ responsibility**	**Task**	**Deliverable**	**Milestones (progress reports)**	**Expected completion**	**Inter-dependencies**
TF-SCI01.1 (IVATF/1 updated by IVATF/2)	SCI SG in collaboration with WMO/IUGG VASAG	Structure IVATF/2 WP/05 report into a table of capabilities and accuracies of ground-based detection methods.	Guidance material.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	Ongoing as WMO/IUGG VASAG task. To be completed as an IVATF task by July 2012.	WMO/IUGG VASAG
TF-SCI01.2 (IVATF/1 updated by IVATF/2)	SCI SG in collaboration with WMO/IUGG VASAG	Prepare training material on satellite remote-sensing techniques.	Training material.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	Ongoing as WMO/IUGG VASAG task. To be completed as an IVATF task by July 2012.	WMO/IUGG VASAG
TF-SCI01.3 (IVATF/1 updated by IVATF/2)	SCI SG in collaboration with WMO/IUGG VASAG	Finalize guidance table concerning airborne sampling in IVATF/2 WP/19 for Doc 9766.	Guidance material.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	Ongoing as WMO/IUGG VASAG task. To be completed as an IVATF task by July 2012.	WMO/IUGG VASAG
TF-SCI02.1 (IVATF/1 updated by IVATF/2)	IAVWOPSG and WOVO	Evaluate volcano monitoring gaps worldwide.	Produce a list of volcanoes that threaten aviation and are inadequately monitored	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	Ongoing as IAVWOPSG and WOVO task.	IAVWOPSG; WOVO

Task number (origin)	Sub-group/ responsibility	Task	Deliverable	Milestones (progress reports)	Expected completion	Inter-dependencies
					To be completed as an IVATF task by July 2012.	
TF-SCI02.2 (IVATF/1 updated by IVATF/2)	IAVWOPSG and WOVO	Encourage increased use of aviation colour code among Volcano Observatories	Guidance material for WOVO use.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	Ongoing as IAVWOPSG and WOVO task. To be completed as an IVATF task by July 2012.	IAVWOPSG; WOVO
TF-SCI03.1 (IVATF/2)	SCI SG in collaboration with WMO/IUGG VASAG and global scientific community	Quantify the detectability of "visible ash", utilizing proposals/ recommendations in IVATF/2 WP/08 and WP/17.	Additional scientific guidance material to support operational application of the IAVW.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	Ongoing as task of WMO/IUGG VASAG To be completed as an IVATF task by July 2012.	WMO/IUGG VASAG; AIR SG
TF-SCI03.2 (IVATF/1)	Complete at IVATF/2.					
TF-SCI04.1 (IVATF/1)	Complete at IVATF/2.					
TF-SCI04.2 (IVATF/1)	SCI SG in collaboration with WMO/IUGG VASAG	Coordinate with WMO on MET data gathered during a volcanic event.	Contact with WMO with a view to increased data sharing.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	Ongoing as WMO/IUGG VASAG and WMO task. To be completed as an IVATF task by July	WMO/IUGG VASAG

Task number (origin)	**Sub-group/ responsibility**	**Task**	**Deliverable**	**Milestones (progress reports)**	**Expected completion**	**Inter-dependencies**
					2012.	
TF-SCI05 (IVATF/1)	Complete at IVATF/2.					
TF-SCI06 (IVATF/1)	Complete in view of updated task TF-AIR05 at IVATF/2.					

6B.4 TASKS ALLOCATED TO THE IAVW COORDINATION GROUP

Task number (origin)	**Sub-group/ responsibility**	**Task**	**Deliverable**	**Milestones (progress reports)**	**Expected completion**	**Inter-dependencies**
TF-VAA01 (IVATF/1)	Complete at IVATF/2.					
TF-VAA02 (IVATF/1 updated by IVATF/2)	Dov Bensimon, Nigel Gait, Philippe Husson, Steve Albersheim, Mike Patnoe, Graham Rennie, Heinz Frühwirth	Enhancement of VAAC products	Proposed enhancements to VAA/VAGs (including consideration of concentration, etc).	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	AIR SG; ATM SG; SCI SG
TF-VAA03 (IVATF/1 updated by IVATF/2)	Steve Albersheim, Dov Bensimon, Jeff Osiensky, Graham Rennie, Philippe Husson, Heinz Frühwirth, Peter Webley	Improved integration of Collaborative Decision Making (CDM) within the IAVW.	Outline of CDM procedures for IAVW.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	ATM SG
TF-VAA04 (IVATF/1)	Complete at IVATF/2.					
TF-VAA05 (IVATF/1 updated by IVATF/2)	Mike Patnoe, Nigel Gait, Philippe Husson, Steve Albersheim, Graham Rennie, Heinz	Volcanic ash data files	Develop volcanic ash data file procedures for use by VAACs	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	ATM SG; AIS-AIM SG

Task number (origin)	**Sub-group/ responsibility**	**Task**	**Deliverable**	**Milestones (progress reports)**	**Expected completion**	**Inter-dependencies**
	Frühwirth, Patrick Simon, Herbert Puempel					
TF-VAA06 (IVATF/1 updated by IVATF/2)	Steve Albersheim, Philippe Husson	Consideration of incorporating uncertainty in SIGMETs	Recommendations on how to incorporate uncertainty in SIGMET	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	METWSG
TF-VAA07 (IVATF/1 updated by IVATF/2)	Andrew Tupper, Chris Newhall, Jun Ryuzaki, Peter Lechner, Herbert Puempel	Improvement to Volcano Observatory provisions	Proposal of additional measures necessary for improving eruption prediction and notification for the IAVW.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	SCI SG
TF-VAA08 (IVATF/1)	Complete at IVATF/2					
TF-VAA09 (IVATF/1)	Complete at IVATF/2					
TF-VAA10 (IVATF/2)	Steve Albersheim, Mike Patnoe, Nigel Gait, Philippe Husson, Graham Rennie	Further development of a Concept of Operations for the IAVW.	Concept of Operations	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	ATM SG; SCI SG; AIR SG
TF-VAA11 (IVATF/2)	Nigel Gait, Heinz Frühwirth,	Development of volcanic ash exercise guidance to support regional volcanic	Guidance material.	Teleconferences: 19 October 2011 18 January 2012	July 2012	ATM SG

Task number (origin)	Sub-group/ responsibility	Task	Deliverable	Milestones (progress reports)	Expected completion	Inter-dependencies
	Patrick Simon, Grace Swanson, Dov Bensimon, Jun Ryuzaki	exercises.		18 April 2012		
TF-VAA12 (IVATF/2)	Heinz Frühwirth, Miriam Andrioli, John Vincent	Improvements to Volcanic Activity Report (VAR) form, including taxonomy and transmission, in support of the IAVW.	Recommendations for improvements to the VAR format and receipt.	Teleconferences: 19 October 2011 18 January 2012 18 April 2012	July 2012	ATM SG [Link to task TF-ATM03]

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APPENDIX 6C

CRITICAL ISSUES IDENTIFIED AT IVATF/2

(1 = highest perceived priority)

IVATF Sub-Groups:
ATM SG =- Air Traffic Management Sub-Group
AIR SG = Airworthiness Sub-Group
SCI SC = Science Sub-Group
IAVW CG = International Airways Volcano Watch Coordination Group

6C.1 ATM SG

Priority	Critical issue identified	Reason
1	Danger Area	The term Danger Area requires review as it appears to be inappropriate for air traffic management with respect to volcanic ash. Some States consider a Danger Area as *closed airspace* and will not clear aircraft through the area. Operators require a safety management system (SMS) and believe they should have the option to *proceed* through such airspace based on available volcanic ash information and their SMS requirements.
2	NOTAM, ASHTAM, VAA/VAG, SIGMET	Information overload with these products especially when multiple FIRs are affected. These products are not harmonized in their use. Note: AIR OPS is looking into the issue as a bottom up approach to resolve the issues.

6C.2 AIR SG

Priority	Critical issue identified	Reason
1	There are times when pressures (e.g. economic and political) will be brought during prolonged and large eruptions in which the transported volcanic ash spreads into areas of dense air traffic. Would it be necessary to identify additional thresholds under these circumstances?	The AIR SG have differing opinions on whether taking this issue forward is necessary, beneficial, or technically feasible.
2	Difficulty to gain consensus on numerical value(s)/threshold(s), such as 2 mg/m^3, of volcanic ash concentration which may form guidance for volcanic ash advisory	Consensus needs to be gained from *all* stakeholders, and additionally to confirm the capabilities and willingness of the volcanic ash advisory centres to meet the criteria to produce consistent products.

Priority	Critical issue identified	Reason
	centres to globally assist in harmonizing their forecast products.	

6C.3 SCI SG

Priority	Critical issue identified	Reason
1	Absence of credible (consensus) criteria regarding acceptable volcanic ash contamination levels.	Hampers ability to provide scientific guidance.
2	Progress reliant on unfunded voluntary work by scientists in multiple agencies and States.	Limits timely progress.
3	There are many unmonitored high risk volcanoes that can take aviation by surprise.	A major threat to aviation is not being dealt with.

6C.4 IAVW CG

Priority	Critical issue identified	Reason
1	Need for integrated communications and collaborative decision making between volcano observatories, aeronautical meteorology services providers (including volcanic ash advisory centres and meteorological watch offices), Operators and air traffic management for tactical operations and strategic flight planning.	Difficult for stakeholders to interact on a real-time basis to get an integrated picture of the volcanic ash hazard and coordinate in order to support operations.
2	Issues with special reports from aircraft in flight (special AIREP_ and distribution to aeronautical meteorological service providers (including volcanic ash advisory centres and meteorological watch offices).	Non-receipt of special AIREP can compromise the issuance and quality of the volcanic ash advisories and SIGMET.
3	Lack of monitoring, by States, of many potentially active volcanoes.	Eruptions may go unnoticed and have a direct impact on aviation safety.

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APPENDIX 7A

IATA POSITION ON SPECIFIC POINTS CONSIDERED UNDER AGENDA ITEMS 2, 3 AND 4 OF THE IVATF/2 MEETING

Agenda Item 2: Report of the Science Sub-Group (SCI SG)
2.1: Volcanic ash cloud detection/avoidance systems and associated guidance

IATA Position: That, areas of discernible SO2 separate from ash should not be included in the VAAC products at this time.

Agenda Item 2: Report of the Science Sub-Group (SCI SG)
2.3: Supporting requirements for airworthiness determination

IATA Position: That,

a) for VAAC en-route observed reporting procedures and for the preparation of the VAA/VAG, one lower threshold at the value of conceptual visible ash (currently proposed to be 2mg/m^3) should be used until the science can provide a refined definition; and

b) for the production of a METAR, clearly define visible ash observation procedures in ICAO and WMO documentation and exclude any reference to "residual ash".

Agenda Item 2: Report of the Science Sub-Group (SCI SG)
2.4: Technologies and systems to support improved eruption source parameterization for dispersion modelling

IATA Position: That, an agreed set of VAAC procedures should be drafted which will ensure consistency and performance measurements and support new standards for inclusion in Annex 3. Metrics will be created for compliance of the above mentioned standard.

Agenda Item 3: Report of the Airworthiness Sub-Group (AIR SG)
3.7: Other issues

IATA Position: With relation to operations in airspace contaminated by volcanic ash, that:

a) airspace should not be closed when contaminated by volcanic ash;

b) the decision to operate in areas affected by contaminated volcanic ash should be left to the airlines; and

c) IATA will augment their IOSA (IATA Operational Safety Audit) process to include risk assessment with relation to operations in airspace contaminated by volcanic ash.

Agenda Item 4: Report of the Air Traffic Management Sub-Group
4.1: Air traffic management contingency planning, procedures and guidance

IATA Position: That,

a) *the longer term goal is the production of accurate concentration charts with demonstrated accuracies acceptable to the industry. The IVATF noted a proposal from IATA to immediately change the current concentration levels to two levels;*

b) *until such time that a VAAC could demonstrate that it was capable of producing ash concentration charts to the accuracy level, or better, of the supplementary products provided by the meteorological offices co-located with the London and Toulouse VAACs, then other VAACs should not issue ash concentration charts on their public internet websites; and*

c) *that until best practice performance measurements are available, London and Toulouse VAACs should present their current benchmark level of accuracy.*

IATA Position: That, the (temporary) danger area should be eliminated with respect to operations in volcanic ash.

Agenda Item 4: Report of the Air Traffic Management Sub-Group
4.2: Flight planning information dissemination

IATA Position: That, NOTAMs should not be used to close airspace when contaminated by volcanic ash. The ASHTAM/NOTAM is redundant with the VA SIGMET, therefore a review should be conducted with regard to the relevance of continued issuance of the ASHTAM/NOTAM.

Agenda Item 4: Report of the Air Traffic Management Sub-Group
4.3: Operational information exchange

IATA Position: That, a more efficient process needs to be put in place, and included within that process would be the ANSPs' automatic sending of AIREPs to operators or made available on-line.

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